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The High and Hidden Costs of Nuclear Power

By HENRY SOKOLSKI

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When security and arms control analysts list what has helped keep nuclear weapons technologies from spreading further than they already have, energy economics is rarely, if ever, mentioned. Yet large civilian nuclear energy programs can — and have — brought states quite a way towards developing nuclear weapons, and it has been market economics, more than any other force, that has kept most states from completing the original plans. Since the early 1950s, every major government in the Western Hemisphere, Asia, the Middle East, and Europe has been drawn to atomic power's allure only to have market realities prevent most of their nuclear investment plans from being fully realized.

Adam Smith's "invisible hand," then, could well determine just how far civilian nuclear energy expands, and how much attention its attendant secu-

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rity risks deserve. Certainly, if nuclear power's economics remain negative, diplomats and policy makers could leverage this point, working to limit legitimate nuclear commerce to what is economically competitive and so gain a powerful tool to help limit nuclear proliferation. If nuclear power finally breaks from its past and becomes the cheapest of clean technologies, though, it is unlikely that diplomats and policymakers will be anywhere near as able or willing to prevent insecure or hostile states from developing nuclear energy programs even if they help them to make atomic weapons.

Nuclear's past, present, and projected future

In the early 1950s, U.S. Atomic Energy Commission Chairman Lewis Strauss trumpeted the prospect of nuclear electricity "too cheap to meter." An international competition to develop commercial reactors, orchestrated under President Dwight D. Eisenhower's Atoms for Peace Program, ensued between the U.S., Russia, India, Japan, and much of Western Europe. Several reactors and nuclear fuel plants were designed and built, endless amounts of technology declassified and shared worldwide with thousands of technicians, and numerous research reactors exported in the 1950s. Yet, ultimately, the relative cheapness and abundance of oil and coal assured that only a handful of large nuclear power plants were actually built.

The next drive for nuclear power came in the late 1960s, just before the energy "crisis" of the early 1970s. President Richard Nixon, in announcing his Project Independence, insisted that expanding commercial nuclear energy was crucial to reducing U.S. and allied dependence on Middle Eastern oil. France, Japan, and Germany, meanwhile, expanded their nuclear power construction programs in a similar push to establish energy independence. The U.S., Russia, Germany, and France also promoted nuclear power exports at the same time. Four thousand nuclear power plants were to be brought on line worldwide by the year 2000.

But, market forces — coupled with adverse nuclear power plant operating experience — pushed back. As nuclear power plant operations went awry (e.g., fuel cladding failures, cracking pipes, fires, and ultimately Three Mile Island), spiraling nuclear construction costs and delays, as well as the disastrous accident at Chernobyl, killed the dream. More than half the nuclear plant orders in the U.S. and almost 90 percent of the projected plants globally were canceled — including a surprisingly large number of proposed projects in the Middle East.

Today, however, a third wave of nuclear power promotion is underway, buoyed by international interest in reducing greenhouse gas emissions and national concerns in enhancing energy security, at least as measured in terms of reliance on oil. The nuclear industry in the U.S. has been lobbying

Congress to finance the construction of more than $100 billion in reactors with federal loan guarantees. President Obama has responded by proposing $36 billion in new federal loan guarantees for nuclear power. Other governments have renewed their plans for reactor construction as well. Even Europe is reconsidering its post-Chernobyl ambivalence over nuclear power: Finland, France, Italy, and Eastern Europe are again either building or planning to build power reactor projects of their own. Germany and Sweden, meanwhile, are reconsidering their planned shutdown of existing reactors.

In all this, the hands of government are evident. Certainly, if nuclear power were ever truly too cheap to meter, could assure energy security, or eliminate greenhouse gas emissions economically, private investors would be clamoring to bid on nuclear power projects without governmental financial incentives. So far, though, private investors have shied from putting any of their own capital at risk. Why? They fear nuclear energy's future will rhyme with its past. In the 1970s and 1980s, new nuclear power projects ran so far behind schedule and over budget that most of the ordered plants had to be cancelled. Even those that reached completion were financial losers for their original utility and outside investors, and the banking sector became wary.

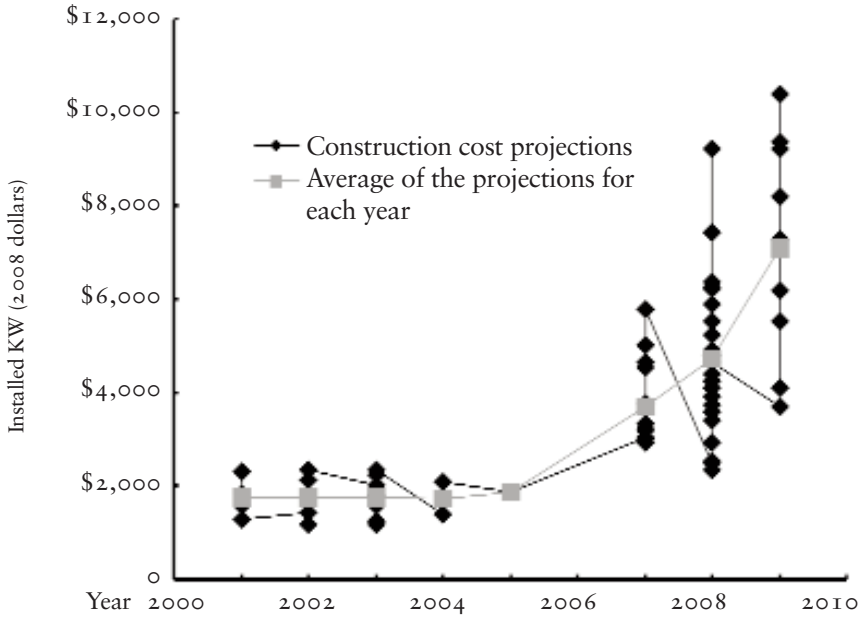
In the 1970s and 1980s, new nuclear power projects ran so far behind schedule and over budget that most had to be cancelled.

In this regard, little has changed. In Finland, a turnkey reactor project has been led by the French manufacturer AREVA, in part as a way to demonstrate just how inexpensively and quickly new nuclear plants can be built. The project is now more than three years behind schedule and at least 80 percent over budget. Finland says AREVA is to blame for the cost overruns and construction delays. AREVA blames Finland and has threatened to suspend construction entirely in hopes of securing a more favorable rate of return. In Canada, the government of Ontario chose to avoid this fate. It put its nuclear plans to build two large power plants on hold after receiving a $26 billion bid that was nearly four times higher than the $7 billion the government originally set aside for the project only two years before. Meanwhile, nuclear projects in the U.S. have seen their costs exclusive of financing rise more than fourfold in less than a decade. (See the range of rising estimates over the last decade in Figure 1.)

To address these concerns, the U.S. nuclear industry has succeeded in getting Congress to implement a growing number of subsidies, including nuclear energy production tax credits and very large federal loan guarantees. Industry estimates indicate that proposed loan guarantees alone would save an American utility at least $13 billion over 30 years in the financing a modern nuclear reactor. Granting these and additional government incentives, though, may not be sufficient. First, in 2003, the Congressional Budget Office (CBO) estimated that the nuclear industry would probably be

FIGURE 1

Capital costs projections for new power reactors — high and rising[1]



forced to default on nearly 50 percent of these loans. Second, most recently, Moody's warned that barring a dramatic positive change in utility-industry balance sheets, the ratings firm would downgrade any power provider that invested in new nuclear reactor construction on the basis that these projects were "bet the farm" gambles. The threat of Moody's to reduce credit ratings included utilities that might secure federal loan guarantees, which Moody's described as too "conditional" to be relied on.

Meanwhile, the president of America's largest fleet of nuclear power plants, who now serves as the World Nuclear Association's vice chairman, publicly cautioned that investing in new nuclear generating capacity would not make sense until both natural gas prices rise and stay above eight dollars per 1,000 cubic feet *and* carbon prices or taxes rise and stay above $25 a ton. Yet industry officials believe that neither condition, much less both, are likely to be met any time soon. Recent developments suggest their skepticism is warranted. After the latest international conference to control carbon emissions held in December 2009 in Copenhagen, carbon prices in the European carbon market hit a near all-time low. United States' natural gas prices,

1. This graph reflects some of the most recent nuclear cost projections and is based on a chart originally generated by Mark Cooper and spotlighted by Sharon Squassoni. See Mark Cooper, "The Economics of Nuclear Reactors: Renaissance or Relapse?" (Institute for Energy and the Environment, June 2009), available at http://www.vermontlaw.edu/Documents/Cooper%20Report%200n%20Nuclear%20Economics%20FINAL%5B1%5D.pdf (this and all subsequent web links accessed July 6, 2010), and Sharon Squassoni, "The U.S. Nuclear Industry: Current Status and Prospects under the Obama Administration" (Centre for International Governance Innovation, November 2009), available at http://www.carnegieendowment.org/files/Nuclear_Energy_7_0.pdf.

meanwhile, driven by reduced demand and massive increases in supplies and newly discovered reserves, have also dropped precipitously. There is good reason to believe that they are unlikely to rise significantly any time soon.[2]

Energy security and global warming

Many decision makers in the energy sector understand this, which, in turn, has given rise to public focus on another, less measurable but possible nuclear power benefit: energy security. The case here, though, is also yet to be demonstrated. In most large industrial countries, oil is only rarely used to produce electricity; more commonly, it is being consumed at increasing rates to fuel growing fleets of cars and trucks. This makes the link between oil imports and nuclear power quite tenuous at present. Perhaps nuclear power could supply the electricity and hydrogen to power the world's transport fleets. But unfortunately, for both electric and hydrogen vehicles, much is unknown about the costs, rate of market penetration, and even whether nuclear will prove to be the most economical way to produce the fuel needed to power these vehicles.

Another assertion nuclear power supporters frequently make is that once carbon is no longer free, their zero carbon emission power plants will be the clear, clean-energy victor. Yet nuclear power may already have priced itself out of the running in any carbon abatement competition. Factoring in industry construction, operation, and decommissioning costs, the total cost of abating one ton of carbon by substituting a new nuclear power plant for a modern coal-fired generator has been pegged by nuclear power critics at $120 or more.[3] This figure, which includes the costs of public subsidies, assumes fairly low capital construction costs (roughly one half of the industry's latest high-end cost projections). If one uses high-end projections, the cost for each ton of carbon abated approaches $200. Certainly there are much cheaper and quicker ways to reduce carbon emissions (see Figure 2).

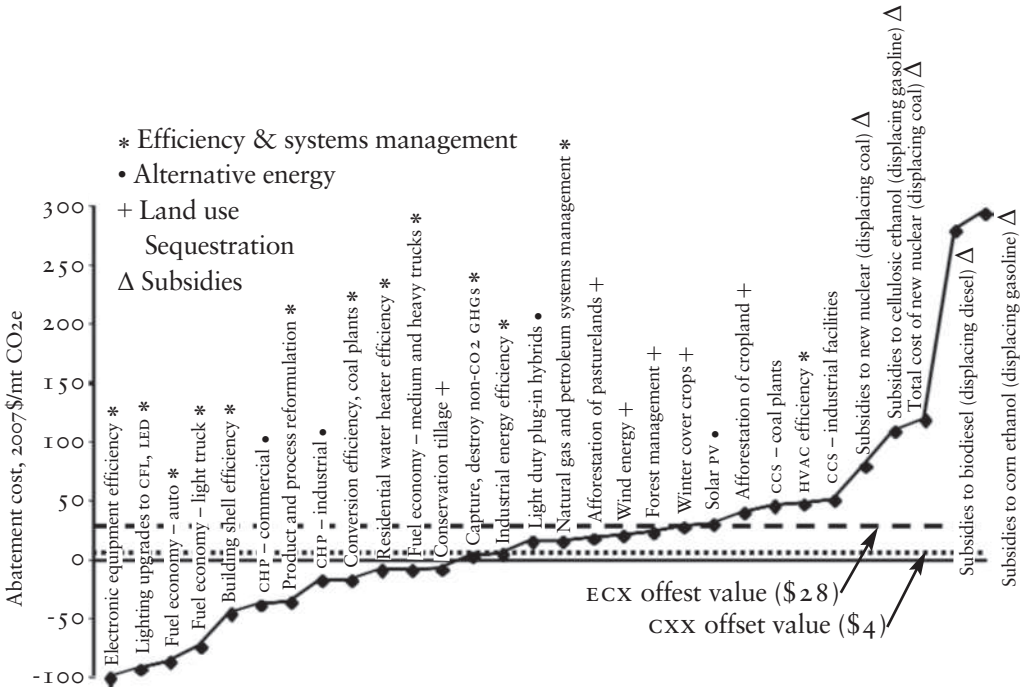
Just how rapidly nuclear power can abate carbon emissions is also a significant issue. Certainly, if one is interested in abating carbon in the quickest, least expensive fashion, building expensive nuclear plants that take up to a decade to bring on line will not be an appealing option. That's why in North

2. See Rebecca Smith and Ben Casselman, "Lower Natural-Gas Price Leaves Coal Out in Cold," *Wall Street Journal* (June 15, 2009), and Edward L. Morse, "Low and Behold: Making the Most of Cheap Oil," *Foreign Affairs* (September/October 2009).

3. See Doug Koplow, "Nuclear Power as Taxpayer Patronage: A Case Study of Subsidies to Calvert Cliffs Unit 3" (NPEC, July 2009), available at http://www.npecweb.org/files/Koplow%20-%20CalvertCliffs3_0.pdf. A recent study completed by one of America's largest nuclear reactor operators, Exelon, confirms Koplow's figures. Speaking before a group on May 12, 2010, John Rowe, chairman and CEO of Exelon, noted that carbon prices would have to rise to roughly $100 per ton of CO_2 before he would recommend Exelon invest in building new power reactors. This figure did not fully reflect the costs of public subsidies associated with nuclear power plant construction and operation. Had it, it would have been very close to Koplow's $120/ton of CO_2.

FIGURE 2

New nuclear power — an expensive way to abate carbon[4]



and South America and the Middle East, the building of natural gas burning generators is currently an attractive, near-term option. Advanced gas-fired power plants can halve carbon emissions as compared to coal-fired plants, can serve as base or peak power generators, and can be brought on line in 18 to 30 months rather than the years upon years needed to build large reactors. Advanced gas-fired generator construction costs, moreover, are a fraction of those projected for nuclear power.[5]

Where natural gas is plentiful, as it clearly already is in the Middle East and the U.S., these economic facts should matter. The benefits of gas become even more evident once one considers the nuclear-specific burdens for nations with no current capacity to create proper regulatory agencies and prepare the grid for a large-base load generator.

A future unlike our past?

THE COUNTERARGUMENT TO this, of course, is that fossil fuel resources are finite and, in time, will run out. This claim is irrefutable in principle, but in practice, when and how they run out

4. Chart generated by Doug Koplow, based on data provided by McKinsey & Company.

5. For a detailed description of natural gas fired electrical generating technologies, their cost, and their performance, see http://www.etsap.org/E-techDS/EB/EB_E02_Gas_fired%20power_gs-gct.pdf.

matters. Backers of renewables, for example, insist that renewables' costs are coming down significantly. Proponents of wind power argue that its costs have declined by more than 80 percent over the last 20 years. The costs of solar photovoltaic generated electricity has also been falling.

Many energy experts contend that significant changes would have to be made in how electricity is currently distributed and stored before intermittent generators like renewables could compete in addressing base load demand. Yet, as renewables' costs continue to decline, the incentives needed to prompt these changes are likely to increase.[6] Meanwhile, nuclear power's costs are high and rising. With new sources of oil and gas now projected to come on line, it is unclear when or how much fossil fuel prices might increase.

As noted, new electrical grid concepts could be employed incrementally to make the transmission of intermittent wind and solar much more practical; so, too, could the development of practical electrical storage and of viable distributed electrical systems. Economical sequestration of carbon from coal-fired plants also may emerge along with increased efficient use of electricity and smart metering that could change and reduce demand patterns. Bottom line: Although none of these developments are guaranteed, any one of them could have a dramatic impact on the long-term economic viability of investing now in nuclear systems that would come on line in 2020 and beyond and operate for 60 years or more.

Government nuclear power

Governments, on the other hand, view matters differently. The energy market uncertainties noted above have only encouraged governments to invest more in clean energy commercialization options. Thus, the current carbon and energy security challenges have been addressed by Japan, South Korea, India, Russia, France, and the U.S. not only by initiating investments in carbon sequestration and renewables, but by continuing, and sometimes significantly increasing, massive subsidies — e.g., loan guarantees, commercial export loans, energy production credits, accident liability caps and indemnification, and construction delay insurance programs — for the construction of new, large nuclear power plants.

In addition, two other factors fortify many governments' instinct to support nuclear commercialization. First, in several important cases — e.g., in France, Russia, India, South Korea, and Japan — the nuclear industry's payrolls have long been large and are essentially public: Commercial nuclear activities in these states are run through entities that are primarily government-owned. Exposing these industries to the full force of market realities

6. For an analysis showing that renewables are already more economical than nuclear or coal base load generations, though, see Amory Lovins's article "Mighty Mice," available at http://www.neimagazine.com/story.asp?storyCode=2033302.

could result in significant layoffs — dislocations large enough to produce negative political results. Continuing to subsidize them, on the other hand, is politically astute.

Second and less immediate, commercial nuclear power's historical links to national security make government support natural. Within the oldest and most significant nuclear states, government-run, dual-use reactors were long connected to electrical grids to produce both nuclear weapons fuels and electricity. In the U.S., this includes the Hanford dual-purpose reactor in Washington State (which no longer exists), and the Tennessee Valley Authority's tritium-producing light water reactors (whose operations are about to be expanded). It also includes Russia's RMBK reactors, which made plutonium for Russia's arsenal until the 1990s; France's gas-cooled natural uranium and breeder reactors, which did the same for France through the 1980s; India's heavy water reactors and planned breeder reactors, which currently provide tritium and plutonium for India's nuclear weapons program; and Britain's Magnox plants, which provided the bulk of the plutonium for the United Kingdom's nuclear arsenal. The most popular of nuclear power systems, pressurized light water reactors (versions of which Germany, France, Russia, Japan, and South Korea all now export and operate) were originally developed in the U.S. for nuclear submarine and naval propulsion.

Government-run, dual-use reactors were long connected to electrical grids to produce both nuclear weapons fuels and electricity.

This history of strong government involvement has made the new government financial incentives to promote the construction of additional nuclear power and fuel-making plants seem normal. Yet, pushing such government support of energy commercialization projects, both nuclear and nonnuclear, actually flies in the face of what market forces would otherwise recommend. More important, it hides the full costs and risks associated with each energy option. This, in turn, is undesirable for several reasons.

Commercial energy innovation. Conventional wisdom holds that government subsidies to commercialize technology optimize and catalyze commercial energy modernization. In reality, subsidy policies are politically challenging to implement. Not surprisingly, those that do make it into law most often support the more established and powerful players in the market independent of technical merit. As such, government imposition of energy commercialization subsidies makes it *more* difficult for winning ideas to emerge or prevail against large-scale losers, and this difficulty can increase over time. The reason is simple: Once government officials make a financial commitment to a commercially significant project, it becomes politically difficult for them to admit it might be losing money, or that it was ever a mistake to have supported it — even when such conclusions are economically clear. A "lock-in" effect begins to take hold: Not only won't governments terminate

funding to clear losers, but they may actually shore up such projects with additional funding or legal mandates to force the public to buy the project's commercial production even when cheaper alternatives clearly exist.[7] In France, Japan, Russia, South Korea, and India, where the power of the government in commercial matters is even stronger than in the U.S., this tendency is even more pronounced.

Nuclear safety and off-site damage. With nuclear-specific energy commercialization subsidies, such as low-priced nuclear accident liability insurance, private sector incentives that would otherwise improve operational and design safety also take a hit. Under U.S. law, U.S. commercial nuclear reactor operators (about 100 in number) must secure private insurance sufficient to cover roughly the first $300 million of damages any nuclear accident might inflict on third parties off-site. After any accident, the law provides that each nuclear utility should also pay up to approximately $96 million per reactor in annual installments of $15 million each (plus a bit more earmarked for legal fees) should the first tier policy be exceeded. These retrospective premiums are paid in a nondiscriminatory fashion: They are virtually identical for both the safest and worst-run utilities.

After any accident, the law provides that each nuclear utility should also pay up to some $96 million per reactor.

By most accounts, such pooling lessens the cost of nuclear insurance significantly to the nuclear industry as a whole.[8] A key argument for such pooling is that it is unreasonable to ask the nuclear industry to assume the full costs of insuring against nuclear accidents and nuclear terrorism; that these risks are simply too large. This certainly was the logic behind the passage of the U.S. Terrorism Risk Insurance Act of 2002 and its repeated extension. Yet, these acts are claimed by their backers to be only "temporary" — i.e., designed to allow private insurers the time to adjust to a new risk market.

Unfortunately, on this point, the U.S. nuclear industry has been increasingly schizophrenic. Originally, in 1957, when the nuclear industry first secured legislation capping its nuclear accident liability for damages suffered by third parties, it claimed that it needed the protection only until utilities had a chance to demonstrate nuclear power's safety record — i.e., until 1967. A half century later, though, industry officials pleaded with Congress that without another 20-year extension, commercial nuclear power would

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7. For a detailed case study of such effects in the case of bio-fuel commercialization programs, see David Victor, "The Politics of Fossil Fuel Subsidies" (Global Subsidies Initiative, October 2009), available at http://www.globalsubsidies.org/files/assets/politics_ffs.pdf.

8. Estimates of how much Price-Anderson nuclear accident liability limits on third party damages are worth range widely between 0.5 and 2.5 cents per kilowatt hour. For details see Anthony Heyes, "Determining the Price of Price Anderson," *Regulation* (Winter 2002–2003), available at http://www.cato.org/pubs/regulation/regv25n4/v25n4-8.pdf, and Doug Koplow, "Nuclear Power as Taxpayer Patronage," available at http://www.npec-web.org/Essays/Koplow%20-%20CalvertCliffs3.pdf.

die. They also insisted that they were still unwilling to export U.S. nuclear goods to foreign states that have not yet explicitly absolved nuclear vendors from liability for damages parties located off-site might suffer in case of an accident.

The future is supposed to be better. Industry backers of the latest reactor designs claim that their new machines will be dramatically safer than those currently operating and, for this reason, government accident insurance caps could be phased out. Certainly, industry arguments against even higher coverage requirements under their Price-Anderson coverage seem implausible. The nuclear industry in the U.S. is already more than willing to pay for insurance to cover damages to its own nuclear assets. In fact, what most utilities spend at a single nuclear site to insure the associated nuclear equipment (and possible outages that that this hardware can cause if it malfunctions) is ten times more than what all U.S. nuclear utilities are required to spend to cover damages that might be done to property and people living off nuclear reactor sites throughout the entire United States At a minimum, this suggests that the insurers and utilities are able to provide substantially more than the $300 million in primary coverage for off-site accidents that they currently purchase under the requirements of Price-Anderson. Finally, several U.S. nuclear reactor vendors rely heavily upon taxpayer appropriations to help pay for their advanced, "safer" commercial reactor designs. These "accident-resistant" reactors are precisely the ones that industry says will come on line by 2025 — the date the current nuclear insurance liability limits under Price-Anderson legislation will run out.

With commercial nuclear energy projects there is a major additional worry: nuclear energy's link to nuclear weapons proliferation.

Proliferation. Finally, with commercial nuclear energy projects, especially those exported overseas, there is a major additional worry: nuclear energy's link to nuclear weapons proliferation. Here, the security risks are real. Israel, the U.S., Iran, and Iraq have launched aerial bombing or missile strikes against International Atomic Energy Agency safeguarded reactors (Osirak and Bushehr) even though the owners of these plants (Iran and Iraq) were active members of the IAEA and were members of the NPT. If one includes the 2007 Israeli attack against Syria's reactor and Iraq's failed missile strike against Dimona during the first Gulf War, there have been no fewer than thirteen acts of war directed against nuclear reactors.

Such facts should put a security premium on efforts to subsidize the construction of such projects both here and abroad. Certainly, the more the U.S. and other advanced economies go out of their way to use government financial incentives to promote the expansion of nuclear power programs domestically or overseas, the more difficult it is to dissuade developing nations from making similar investments. This dynamic will exist even if the nuclear

projects in question are clearly uncompetitive with nonnuclear alternatives; and move them closer to developing nuclear weapons options, their nuclear programs will appear to be no less sound than ours.

For observers and officials worried about nuclear power's proliferation risks, merely arguing for governments to be more consistent and neutral economically in their selection of different power generation systems might seem cynically inattentive to the substantial security dangers nuclear power's expansion poses. Certainly, the U.S. and other states have oversold how well international nuclear inspections can prevent military diversions from civilian nuclear programs. Even today, the IAEA cannot yet keep reliable track of spent or fresh fuel for roughly two-thirds of the sites it monitors. Worse, diversions of this material, which can be used as feed for nuclear weapons fuel-making plants, could be made without the IAEA necessarily detecting them. As for large fuel-making plants, the IAEA acknowledges that it cannot reliably spot hidden facilities and annually loses track of many bombs' worth of material at declared plants. With new money and authority, the IAEA could perhaps track fresh and spent fuel better; however, the laws of physics make it unlikely that the agency will ever be able to reliably detect diversions from nuclear fuel-making plants.

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If international nuclear inspections cannot protect us against possible nuclear proliferation, though, what can? It would help if there were more candor about the limits of what nuclear inspections can reliably detect or prevent. But just as critical is more frankness about how little economic sense most new nuclear power programs make.

In this regard, it is useful to note that the NPT is dedicated to sharing the "benefits" of peaceful nuclear energy. These benefits presumably must be measurably "beneficial." At the very least, what nuclear activities and materials the NPT protects as being peaceful and beneficial ought not to be clearly dangerous and unprofitable. That, after all, is why under Articles I and V, the NPT bans the transfer of civilian nuclear explosives to nonweapons states and their development by nonweapons states. It is also is why the NPT's original 1968 offer of providing nuclear explosive services has never been acted upon and is dead letter now: Not only was it determined to be too costly to use nuclear explosives for civil engineering projects (the cost of cleanup was off the charts), but some states (e.g., Russia and India) claimed they were developing peaceful nuclear explosives when, in fact, they were conducting nuclear weapons tests.

What, then, should be protected under the NPT as being "peaceful" today? Is the activity or material in question dangerously close to bomb-making? Should these activities be allowed to be expanded in nonweapons states and to new locales or, like "peaceful" nuclear explosives, are the bene-

fits of these programs so negative and the activities in question so close to bomb-making or -testing to put them outside of the bounds of NPT protection? Again, getting all of the world's nations to agree on the answers to these questions will be difficult. But if civilian nuclear energy projects are economically uncompetitive against their nonnuclear alternatives, the case against states spending extra to promote the commercial expansion of potentially dangerous commercial nuclear projects would be far stronger.

Policy implications

AGAIN, THE GENERAL takeaway is that governments should spend less time trying to determine what energy technologies should be commercialized and focus instead on how market mechanisms might best be employed to make these determinations possible. This, in turn, suggests six specific steps governments might consider:

Encouraging more complete, routine comparisons of civilian nuclear energy's costs with its nonnuclear alternatives. The starting point for any rational commercial energy investment decision is a proper evaluation of the costs of selecting one option over another. Here, as already detailed, governments have a weak track record. One way they could improve their performance is to take more seriously what few economic energy assessments they must do and conduct them routinely. The U.S. Congressional Budget Office (CBO), for example, must score the public costs of guaranteeing commercial energy loans, including the nuclear industry in the U.S. Yet, the last time the CBO made the assessment for proposed loan guarantees in 2008, it failed to give a figure for the probable rate of default on nuclear projects. The CBO's director claims that without proprietary information, the CBO has no way to make such estimates. The last time CBO attempted such projections was in 2003, when it pegged the likely default rate under proposed loan guarantee legislation at the time at 50 percent. The Department of Energy, meanwhile, announced that it essentially viewed such information as proprietary. It would be useful for the CBO to get the information it needs to update and qualify such projections. Congress, meanwhile, should demand that DOE make all of its own estimates relating to these issues public.

Yet another way the U.S. government could improve its commercial energy cost comparisons is by finally implementing Title V of the Nuclear Nonproliferation Act of 1978, which calls on the executive branch to conduct energy assessments in cooperation with, and on behalf of, key developing states. The focus of this cooperation was to be on nonnuclear, nonfossil-fueled alternative sources of energy. Yet, for these cost assessments to have any currency, they would have to be compared with the full life-cycle costs of nuclear power and traditional energy sources estimates. This work also should be supported by the United Nations' newly proposed International Renewable Energy Agency. In order for any of these efforts to produce

sound cost comparisons, more accurate tallies of what government energy subsidies are worth for each energy type will be required.

Finally, the number of full-time energy subsidy economists is currently measured in the scores rather than in the hundreds. Government and privately funded fellowships, full-time positions, and the like may be called for to increase these numbers.

Increasing compliance with existing international energy understandings that call for internalizing the full costs of large energy projects and for competing them in open international bidding. The Global Energy Charter for Sustainable Development, which the U.S. and many other states support, already calls on states to internalize many external costs (e.g., those associated with government subsidies and quantifiable environmental costs such as the probable taxes on carbon) in pricing large energy projects. Meanwhile, the Energy Charter Treaty, which is backed by the EU, calls on states to compete any large energy project or transaction in open international bidding. Since these agreements were drafted, international interest in abating carbon emissions in the quickest, cheapest fashion has increased significantly. The only way to assure this is to include all the relevant government subsidies in the price of competing energy sources and technologies, assign a range of probable prices to carbon, and use these figures to determine what the lowest cost energy source or technology might be in relation to a specific timeline.

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This suggests that any follow-on to the Kyoto understandings should require international enforcement of such energy comparisons by at least referencing the principles laid out in the Energy Charter Treaty and the Global Energy Charter for Sustainable Development. Enforcing international adherence to these principles will be challenging. A good place to start would be to work with G-20 to agree to a modest follow-on action plan to Copenhagen that would include establishing common energy project-cost accounting and international bidding rules that track these agreements. Beyond this, it would be useful to call on the G-20 to give the IAEA notice of any state decisions they believe might violate these principles to favoring nuclear power over cheaper alternatives. The aim here would be to encourage the IAEA to ascertain the true purpose of such nuclear projects.

Discouraging the use of government financial incentives to promote commercial nuclear power. This recommendation was made by the Congressional Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism. It would clearly include discouraging new, additional federal loan guarantees for nuclear fuel or power plant construction of the type now being proposed by President Obama and the nuclear industry. Although this stricture should also be applied against other types of energy (coal, renew-

ables, natural gas, etc.) as well, the security risks associated with the further spread of civilian nuclear energy make it especially salient in nuclear's particular case. This same prohibition should also be applied against U.S. support for developmental bank loans (i.e., subsidized loans) for commercial nuclear development and against other states' use of subsidized government financing to secure civilian nuclear exports. In some cases, these foreign export loan credits are being used in the U.S. in conjunction with U.S. federal loan guarantees and local state tax incentives to all but eliminate the risks of investing in new nuclear power plant construction. This should be discouraged. In the case of every large civilian nuclear project, domestic or foreign, every effort should be made to place as much private capital at risk as possible in order to assure due diligence in their execution. Even under the existing U.S. federal loan guarantee program, 20 percent of each nuclear project must be financed without federal protection. For purposes of implementing this law, this nominal figure should be covered entirely with private investment; not by resort to rate hikes for ratepayers.

Recycling spent fuel is not only more expensive but runs much greater proliferation, terrorism, and nuclear theft risks.

Employing more market mechanisms to guide national and international nuclear fuel cycle and waste management decisions. One of the clear advantages of civilian nuclear power plants over other conventional fossil fueled plants is that nuclear power is much cheaper to fuel. Governments, however, can undermine this advantage by taking steps to increase nuclear fuel cycle costs that are unrelated to the need to assure safety or international security.

Today, the lowest cost interim solution to storing spent fuel (good for 50 to several hundred years) is dry cask storage, above ground, at reactor sites. Recycling spent fuel, on the other hand, is not only more expensive, but runs much greater proliferation, terrorism, and nuclear theft risks. For these reasons, President Bush in 2004, the IAEA in 2005, and the bipartisan U.S. Congressional Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism in 2008 all called for the imposition of a moratorium on commercial reprocessing. This reflects economic common sense. Unfortunately, in many countries, full employment, development of nuclear weapons options, and other political or military concerns often override straightforward cost-benefit analysis. In the U.S., this tendency can be avoided by having the nuclear utilities themselves assume a significant portion of the costs of nuclear waste management and reactor site decommissioning. This would require changing the law in the U.S., which stipulates that all of the costs of final spent fuel storage are to be paid for by off-budget federal user fees.

As for the front end of the nuclear fuel cycle, firm nuclear fuel contracts in hand, rather than government funding or loan guarantees secured, should

dictate any new construction of nuclear fuel-making facilities or their expansion. With such contracts in hand, it should be possible to secure private financing. There currently is substantial interest in creating international fuel banks to assure reliable supply of fresh nuclear fuel and of reprocessing services to states that forswear making their own nuclear fuel. If any such banks are created, though, they should charge whatever the prevailing market price might be for the nuclear products and services they provide. The rationale for this is simple: subsidizing the price risks creating a false demand for risky near-weapons-usable fuels, such as mixed oxide and other plutonium-based fuels. Currently, states can satisfy their demand for fresh fuel without having to resort to any international bank and no state has a need to reprocess for any reason.

Finally, the use of nuclear-weapons-usable highly enriched uranium is a nuclear fuel cycle option that is no longer necessary in the production of power or isotopes. Given the direct usability of HEU to make nuclear weapons, however, the elimination and blending down of these fuels is imperative to avoid nuclear proliferation and terrorism risks. In the U.S., the handful of remaining HEU-fueled plants receive government funding. This should end by establishing a date certain for these few remaining reactors to be converted to use LEU-based fuels.

The use of nuclear-weapons-usable highly enriched uranium is a nuclear fuel cycle option that is no longer necessary.

Increasing and further privatizing nuclear insurance liability coverage to encourage best construction and operations practices. Efforts should be made to increase the minimum amounts of liability insurance coverage currently required of any civilian nuclear plant operators and to make those requirements less subject to override or forgiveness by officials of the state. Here, amounts required by the international Convention on Supplementary Compensation for Nuclear Damage should be considered to be the international minimum. Far preferable would be for other nuclear power operators to adopt insurance levels that the U.S. currently requires under its domestic Price-Anderson legislation. The U.S., meanwhile, needs to raise these standards even further by announcing its intention to back out of underwriting insurance against terrorist incidents as it currently does and instead require private insurance firms to assume this requirement, as they did before 9/11. Second, Washington needs to make good on its original objective under the 1957 Price-Anderson legislation to eventually stop underwriting coverage for damages a nuclear operator might inflict on off-site third parties. Washington would do best to go about this early and incrementally by announcing that starting in 2025, federal Price-Anderson coverage will no longer apply to any civilian nuclear facility operating in the U.S. Given that some U.S. nuclear firms already believe that their products are safe enough for them to soon forgo Price-Anderson subsidies and that the nuclear industry generally is arguing that their safety record

has improved and will only get better, this transition over the next fifteen years should go relatively smoothly.

Increasing experimentation in the commercial distribution of and the tapping of alternative sources of energy through federal government-led regulatory reform. To foster energy experimentation and competition, the federal government should promote regulatory reforms that would, among other things: set standard rules for selling electricity through the grid; remove conflicts of interest for existing grid or pipeline operations to block new entrants; ensure regulated utilities have similar incentives to invest in efficiencies as they do in expanding generation plants and energy supplies; encourage key market constraints, be they carbon limits or liability coverage, through the market pricing systems rather than through government subsidies; and increase pricing visibility for power to final customers.