Nuclear Power, Energy Markets, and Proliferation

By

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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;[1] and it has been market economics, more than any other force, that has kept most states from starting or completing these programs. 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.

With any luck, this past will be our future. Certainly, if nuclear power programs continue to be as difficult and expensive to complete as they have been compared to their nonnuclear alternatives, only additional government support and public spending will be able to save them. In this case, one needs to ask why governments would bother, especially in light of the security risks that would inevitably arise with nuclear power's further proliferation. On the other hand, if nuclear power evolves into the quickest and least expensive way to produce electricity while abating carbon emissions, little short of a nuclear explosion traceable to a "peaceful" nuclear facility would stem this technology's further spread -- no matter what its security risks might be.

Adam Smith's Invisible Hand, then, could well determine just how far civilian nuclear energy expands, and how much attention its attendant security risks deserve. Certainly, if

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1. See, e.g., Albert Wohlstetter, et. al., *Swords from Plowshares: The Military Potential of Civilian Nuclear Energy* (Chicago, IL: University of Chicago Press, 1979), pp. vii-32; Matthew Fuhrman, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security*, Summer 2009, pp. 7-41, available at http://belfercenter.ksg.harvard.edu/files/IS3401_pp007-041_Fuhrmann.pdf; and Victor Gilinsky, et al., "A Fresh Examination of the Proliferation Dangers of Light Water Reactors," in Henry Sokolski, editor, *Taming the Next Set of Strategic Weapons Threats* (Carlisle, PA: US Army War College, Strategic Studies Institute, 2005), available at http://www.npec-web.org/node/886.

nuclear power's economics remain negative, diplomats and policy makers could leverage this point, work 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 in market competitions against its alternatives, though, it is unlikely that diplomats and policy makers will be anywhere near as able or willing to prevent insecure or hostile states from developing nuclear energy programs to help them make atomic weapons.

What follows is a deeper explication of these points. The first section, "Costs," examines what the economics for nuclear power have been and are projected to be. The second, "Justifications," examines the environmental, energy security, and political reasons why nuclear power's relatively poor economic performance has been downplayed. The third section, "Concerns," explores the reasons why continuing to do this is risky, and the final section "Economics As A Way Out," examines how market economic competitions could be used to help steer us towards cheaper, safer forms of energy.

I. Costs

Nuclear Power'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."[2] An international competition, orchestrated under President Dwight D. Eisenhower's Atoms for Peace Program, ensued between the U.S. Russia, India, Japan and much of Western Europe to develop commercial reactors. Several reactor and nuclear fuel plants were designed and built, endless amounts of technology declassified and shared world-wide with thousands of technicians, and numerous research reactors exported in the 1950s. Yet ultimately relatively cheap and abundant oil and coal assured that only a handful of large power plants were actually built.[3]

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

2. Lewis L. Strauss, Chairman of the U.S. Atomic Energy Commission, Speech to the national Association of Science Writers, New York City, September 16, 1954.

3. On this history, see Joseph F. Pilat, editor, *Atoms for Peace: An Analysis after Thirty Years* (Boulder CO: Westview Press, 1985); Richard Hewlett and Jack Holl, *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission* (Berkley CA: University of California Press, 1989);

dependence on Middle Eastern oil.[4] 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 world-wide 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. were cancelled and almost ninety percent of the projected plants globally – including a surprisingly large number of proposed projects in the Middle East -- were never built.[5]

Today, 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.[6] President Obama has responded by proposing $36 billion dollars in new federal loan guarantees for nuclear power.[7] Other governments in Asia, the Middle East, and Latin America have renewed their plans for reactor construction as well. Even Europe is reconsidering its post-Chernobyl ambivalence with 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.

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4. President Richard Nixon, "Special Message to the Congress Proposing Emergency Energy Legislation," November 8, 1973, available at http://www.presidency.ucsb.edu/ws/index.php?pid=4035.

5. See, Yves Marignac, *Nuclear Power, the Great Illusion: Promises, Setbacks and Threats*, October 2008, p. 42, available at http://www.global-chance.org/spip.php?article89 and the Testimony of Thomas B. Cochran before the Senate Committee on Energy and Natural Resources, Subcommittee on Energy Research and Development, June 8, 1977, available at http://docs.nrdc.org/nuclear/files/nuc_77060801a_23.pdf.

6. See Simon Lomax, "Nuclear Industry 'Restart' Means More Loan Guarantees," *Bloomberg.com*, October 27, 2009, available at http://www.bloomberg.com/apps/news?pid=20601072&sid=aR1MVERYEgAs.

7. See U.S. Office of Management and Budget, "The Federal Budget Fiscal Year 2011: Creating the Clean Energy Economy of Tomorrow," The President's Budget: Fact Sheet, available at http://www.whitehouse.gov/omb/factsheet_key_clean_energy/

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 kept 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, 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 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 could 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.[8]

Meanwhile, 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.[9]

In the U.S., the estimated cost of two reactors that Toshiba was planning to build for NRG Energy and the city of San Antonio recently jumped from $14 billion to $17 billion. Consequently, the city board delayed its approval of $400 million in financing for the project, sued NRG, and reduced its share of the project from roughly 50 percent to less than 8 percent.[10] These estimates of the full costs to bring a new nuclear plant on line

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8. *Nucleonics Week*, "Financial crisis nips nuclear revival in the bud, WNA told," September 17, 2009, available at http://www.carnegieendowment.org/static/npp/pdf/NW_Sep2009_reprint.pdf and *Reuters*, "Analysis-Delays, hitches hamper Areva's reactor export plan, December 10, 2009, available at http://in.news.yahoo.com/137/20091210/371/tbs-analysis-delays-hitches-hamper-areva.html.

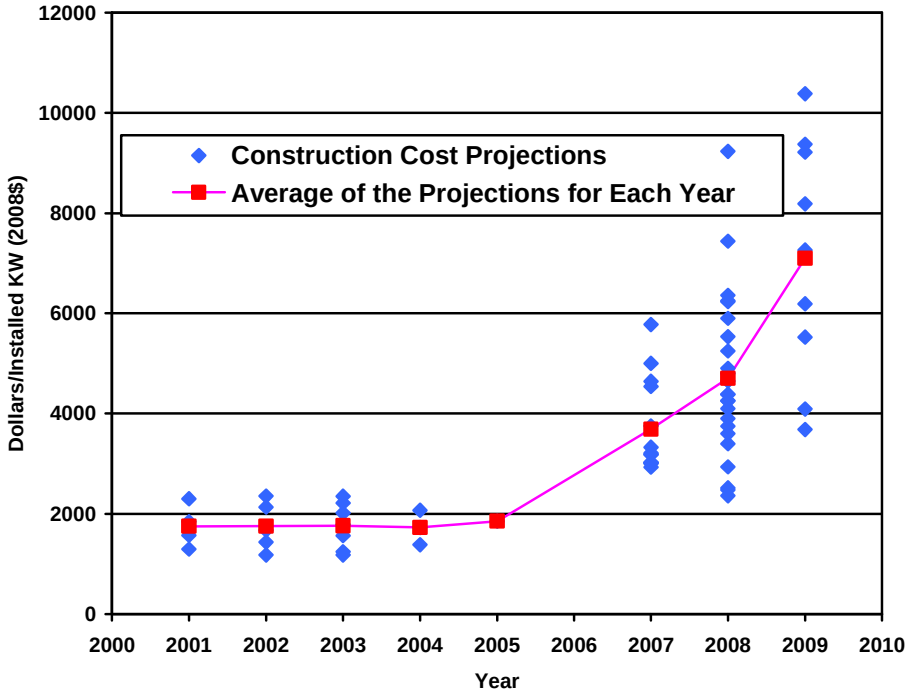
9. See, Tyler Hamilton, "$26B Cost Killed Nuclear Bid: Ontario Ditched Plan over High Price Tag that Would Wipe Out 20-Year Budget," *The Star*, July 14, 2009, available at http://www.thestar.com/article/665644.

10. See, Rebecca Smith, "Costs Cloud Texas Nuclear Plan," *The Wall Street Journal*, December 5, 2009, available at http://online.wsj.com/article/SB125997132402577475.html; Dow Jones, "CPS Energy, NRG Energy Complete Nuclear Power Project Settlement," March 1, 2010, available at http://www.nasdaq.com/aspx/stock-market-news story.aspx?storyid=201003011204dowjonesdjonline000515&title=cps-energynrg-energy-complete-nuclear-power-project-settlement; and Anton Caputo, "Nuclear Could Still Edge

reflect this pattern of cost escalation, as San Antonio's experience has been replicated in many other places. Estimated construction costs (exclusive of financing) for an installed kilowatt have jumped from a little over 1,000 dollars in 2002 to well over $7,000 in 2009 (see the range of rising estimates over the last decade in Figure 1 below):

Figure 1:

Overnight Capital Costs Projections for New Power Reactors (2008 $s/installed KW) -- High and Rising[11]



Out Gas," My SA News, December 15, 2009 available at http://www.mysanantonio.com/news/local_news/79283092.html.

11. This graph, which reflects some the most recent nuclear cost projections, 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?* Vermont University, Institute for Energy and the Environment, June 2009. available at http://www.vermontlaw.edu/Documents/Cooper%20Report%20on%20Nuclear%20Economics%20FINAL%5B1%5D.pdf and Sharon Squassoni, *The U.S. Nuclear Industry: Current Status and Prospects under the Obama Administration*, Nuclear Energy Futures Paper No. 7, The Centre for International Governance Innovation, November 2009, available at http://www.carnegieendowment.org/files/Nuclear_Energy_7_0.pdf.

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.[12] Granting these and additional government incentives, though, may not be sufficient. First, in 2003, the Congressional Budget Office estimated that the nuclear industry would probably be forced to default on nearly 50 percent these loans.[13] Second, in 2009, 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. Moody's threat to reduce credit ratings included utilities that might secure federal loan guarantees, which Moody's described as too "conditional" to be relied on.[14]

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 $8 dollars per 1,000 cubic feet (mcf) *and* carbon prices or taxes rise and stay above 25 dollars a ton.[15] Yet industry officials believe that neither condition,

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12. See the discussion of Constellation's calculations regarding its planned reactor build at Calvert Cliffs, Maryland in Doug Koplow, "Nuclear Power as Taxpayer Patronage: A Case Study of Subsidies to Calvert Cliffs Unit 3" (Washington DC: NPEC, 7 July 2009), available at http://www.npec-web.org/node/1125.

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13. U.S. Congressional Budget Office, "Cost Estimate of S.14 Energy Policy Act of 2003," May 7, 2003, available at http://www.cbo.gov/ftpdocs/42xx/doc4206/s14.pdf. The Congressional Budget office optimistically assumed that about half of the value of the projects that defaulted would be recovered in bankruptcy, for a net loss of around 25 percent of guaranteed principle. The Department of Energy (DoE) has tried to discredit even these figures, claiming that the real figures will be much lower but recently said it would not publicly disclose its own calculations of how much of an upfront loan fee to charge to cover for potential defaults on nuclear projects. Industry officials, meanwhile, have made it clear that if the DoE charges them much more than 1 or 2 percent of the amount borrowed to cover these risks, they will not take the loans. See, Kate Sheppard," Energy Sec Unaware that Nuclear Loans Have 50 Percent Risk of Default, February 16, 2010, available at http://motherjones.com/blue-marble/2010/02/chu-not-aware-nuclear-default-rates and *Etopia News*, "DoE Spokesperson Says that Credit Subsidy number is 'Proprietary and Will Remain Confidential'", available at http://etopianews.blogspot.com/2010/03/doe-spokesperson-says-that-credit.html.

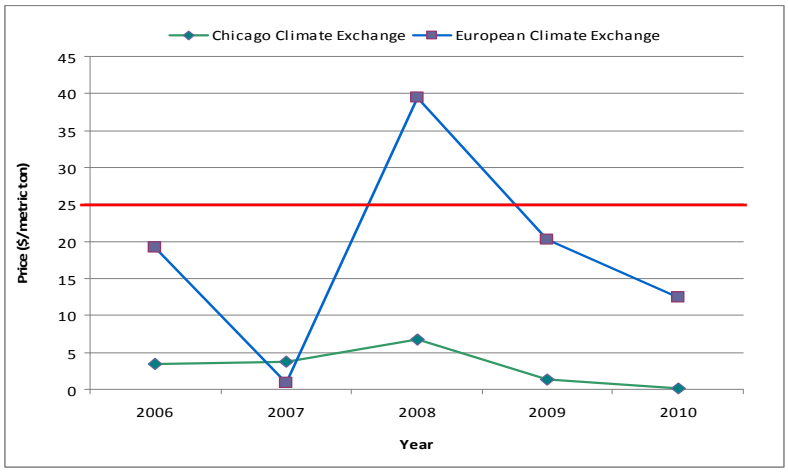
14. See Moody's Global, "New Nuclear Generation: Ratings Pressure Increasing," June 2009 available at http://www.nukefreetexas.org/downloads/Moodys_June_2009.pdf.

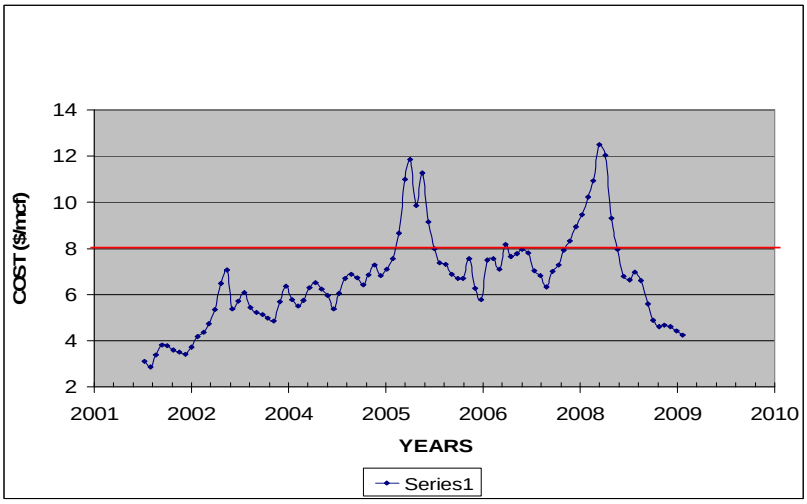
15. See *Nucleonics Week*, "Financial Crisis Nips Nuclear," note 8 above.

much less both, are likely to be met any time soon. Past price history suggests why (see Figure 2 below):

Figure 2

Natural Gas and Carbon Prices -- Hardly Steady or High Enough to Underwrite Private Nuclear Investments[16]





16. Data for these charts were drawn from Chicago Climate Exchange, "Closing Prices", December 2009. http://www.chicagoclimatex.com/market/data/summary.jsf
European Climate Exchange, "Prices, Volume & Open Interest: EXC EUA Futures Contract", December 2009. http://www.ecx.eu/EUA-Futures
http://www.bloomberg.com/apps/news?pid=20601109&sid=aNykpTP9hnIo
and the United States Energy Information Administration, "U.S. Natural Gas Electric Power Price", October 30, 2009. http://tonto.eia.doe.gov/dnav/ng/hist/n3045us3m.htm
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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. U.S. natural gas prices, 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.[17] Conclusion: Without significant additional government financial incentives, private investments in new nuclear electricity are unlikely to be made.[18]

II. Justifications

Energy Security and Global Warming

Many decision makers in the energy sector understand this. This, 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, but rather is being consumed at increasing rates to fuel a growing fleet of cars and trucks. This makes the link between oil imports and nuclear power quite tenuous at present. The argument put forth by some experts is future-oriented: Some day nuclear power could supply the electricity and hydrogen to power the world's transport fleets. For both electric and hydrogen vehicles,

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17. See, e.g., Rebecca Smith and Ben Casselman, "Lower Natural-Gas Price Leaves Coal Out in Cold," *The Wall Street Journal*, June 15, 2009, available at http://online.wsj.com/article/SB124502125590313729.html and Edward L. Morse, "Low and Behold: Making the Most of Cheap Oil," *Foreign Affairs*, September/October 2009, available at http://www.foreignaffairs.com/articles/65242/edward-l-morse/low-and-behold.

18. The most recent U.S. Department of Energy effort to skirt nuclear power's poor economic performance is to promote federal development and construction of a variety of "small modular" reactors (see http://www.nuclear.energy.gov/pdfFiles/factSheets/2010_SMR_Factsheet.pdf). The key attraction of small reactors (between 100 and 300 MWe), is that they cost less to build than the much larger commercial light water reactors that current range between 1,000 and 1,600 MWe (for a full description of these go to the World Nuclear Association at http://www.world-nuclear.org/info/inf33.html. The other is that they are more adaptable to small electrical grids than much larger reactors. For most developing states, though even these 'small" reactors are too large for their grid and the unit costs (dollars/kilowatt hour produced) for this smaller reactors is far higher than for the larger reactors they are supposed to best.

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 needed energy resources.

Unfortunately, few of these central issues are given serious attention in popular news media. Instead, France, which made a massive investment in nuclear power in the 1970s, and now produces about 80 percent of its electricity from nuclear energy, is held up as an energy-independence model for the U.S. and the world to follow.[19] This nuclear example, however, has been quite costly and hasn't really saved France from its addiction to oil. France covered much of the startup and operating cost of its civilian nuclear program by initially integrating the sector with its military nuclear-weapons-production program. It also used massive amounts of cheap French government financing to pay for the program's capital construction. As a result, it is unclear how much the French program cost overall, or how much plant costs escalated over the life of the French program – although they clearly did.[20] What is undisputed, however, is that from the 1970s to the present, France's per-capita rate of oil consumption never declined; and that the country has needed to import increasing amounts of expensive peak-load electricity from its immediate neighbors due to the supply inflexibility of base-load nuclear.[21] Despite these facts, the story of French nuclear energy independence persists.

Another assertion nuclear power supporters frequently make is that the need to abate carbon emissions will make nuclear energy economically competitive through rising carbon prices. Once carbon is no longer free, nuclear proponents believe that their zero carbon emission power plants will be the clear, clean-energy victor over coal with carbon capture systems, natural gas, and renewables. Yet, by industry's own projections, nuclear power may already have priced itself out of the running in any carbon abatement competition. Factoring industry construction cost projections, operation and decommissioning costs, and key public nuclear-specific U.S. subsidies, the total cost of

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19. See, e.g., Steve Kroft, "France: Vive Les Nukes: How France is Becoming the Mode3l for Nuclear Energy Generation, *60 Minutes*, April 6, 2007 available at http://www.cbsnews.com/stories/2007/04/06/60minutes/main2655782.shtml.

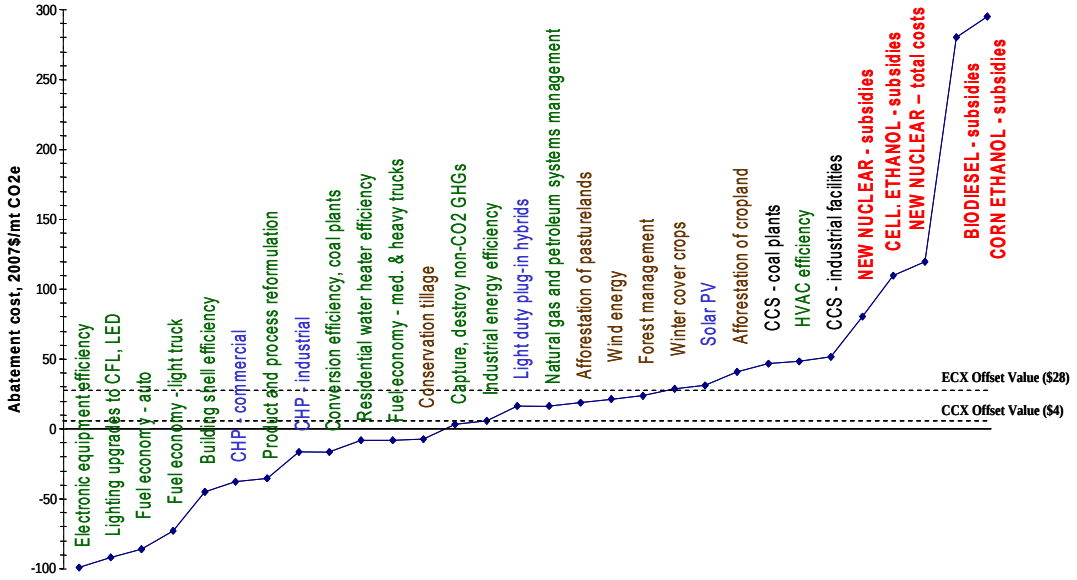
20. For the most recent and thorough attempts, see Arnulf Grubler, *An Assessment of the Costs of the French Nuclear Program, and 1970-2000*, available at http://www.iiasa.ac.at/Admin/PUB/Documents/IR-09-036.pdf and Charles Komanoff, "Cost Escalation in France's Nuclear Reactors: A Statistical Examination," January 2010, available at http://www.slideshare.net/myatom/nuclear-reactor-cost-escalationin-france-komanoff.

21. The French civilian nuclear industry and power utility system, unlike the American one, is almost entirely nationalized. As a result, France still produces incredibly opaque financial statements regarding its civilian nuclear program. What is not in dispute, however, is that because of its over investments in base-load nuclear generators, France must export much of its production and import expensive peak load capacity, which it still lacks. For an explanation of base-load and peak load electricity, see note 47. See, Mycle Schneider, "Nuclear Power in France: Beyond the Myth," (Washington, DC: NPEC, 2009), available at http://www.npec-web.org/node/1050.

abating one ton of carbon by substituting a new nuclear power plant for a modern coal-fired generator has been pegged by one critic of nuclear power at least $120. This figure assumes fairly low capital construction costs (roughly one-half of the industry's latest high-end cost projections). If one uses industry's high-end projections, the cost for each ton of carbon abated approaches $200. This is expensive. Certainly, there currently are much cheaper and quicker ways to reduce carbon emissions (see Figure 4 below):

Figure 4

New Nuclear Power: An Expensive Way to Abate Carbon[22]

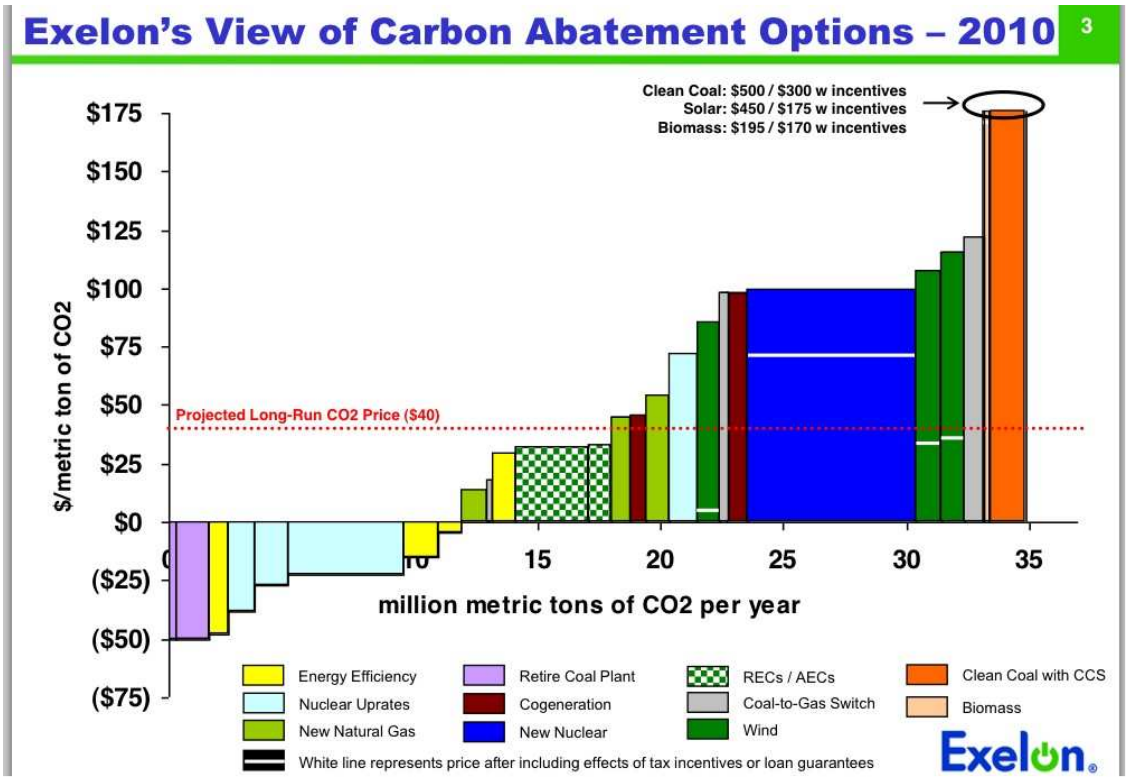


Yet another recent study completed by one of America's largest nuclear reactor operators, Exelon, confirms these points. Speaking before a Washington, D.C. meeting held May 12, 2010 at Resources for the Future's policy leadership form, John Rowe, Chairman and CEO of Exelon, presented analysis that essentially mirrored these findings. As his central and final power point slide make clear (see below), carbon prices would have to rise to roughly $100 a ton before he would recommend Exelon invest in building new power reactors. Even with federal loan guarantees, Exelon's analysis determined that carbon would have

22. Chart generated by Doug Koplow, based on data provided by McKinsey and Company. See, Doug Koplow, "Nuclear Power as Taxpayer Patronage: A Case Study of Subsidies to Calvert cliffs Unit 3, (Washington, DC: NPEC, July 2009), available at http://www.npec-web.org/files/Koplow%20-%20CalvertCliffs3_0.pdf and McKinsey & Company, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*, December.2007, available at http://www.mckinsey.com/clientservice/sustainability/greenhousegas.asp.

to be priced at roughly $75 per ton (which is nearly twice Exelon's projected "long-run CO2 price" of $40 a ton) before it would make economic sense to build new power reactors. Before Excelon would invest in new nuclear construction, it would update its existing 19 nuclear plants, shut down coal fired generating stations, bring more natural gas-fired plants on line, invest in energy efficiency programs and renewables See figure 5 below:

Figure 5[23]



Just how rapidly a nuclear approach can begin abating carbon emissions (compared to its alternatives) 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 have difficulty abating carbon competitively no matter how much carbon is taxed. That's why in North and South America and the Middle East, building natural gas burning generators is currently an attractive, near-term option.

23. See, John W. Rowe, "Fixing the Carbon Problem Without Breaking the Economy," presentation before Resources for the Future Policy Leadership Forum Lunch, May 12, 2010, Washington, DC available at http://www.rff.org/Documents/Events/PLF/100512_Rowe_Exelon/100512_Rowe_Exelon_Slides.pdf.

Advanced gas-fired power plants can halve carbon emissions as compared to coal fired plants, can serve as base or peak power generators, and be brought on line in 18 to 30 months rather than the 5 to 10 years need to build large reactors. Advanced gas-fired generator construction costs, meanwhile, are a fraction of those projected for nuclear power.[24]

Where natural gas is plentiful, as it clearly already is in the Middle East and the U.S., these economic facts should matter.[25] The benefits of gas become even more evident once one factors in the nuclear-specific burdens for nations with no current capacity to create proper regulatory agencies and prepare the grid for large base load generator.[26]

A Future Unlike Our Past?

The counter argument to this, of course, is that fossil fuel resources are finite and, in time, will run out. This is irrefutable in principle, but in practice when and how one runs out matters. Backers of renewables,[27] for example, insist that renewables' costs are coming down significantly. Proponents of wind power argue that their costs have declined by

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24. For a detailed description of natural gas fired electrical generating technologies, their cost and performance, see International Energy Agency, OECD, Energy Technology System Analysis Program, "Gas-Fired Power," available at http://www.etsap.org/E-techDS/EB/EB_E02_Gas_fired%20power_gs-gct.pdf.

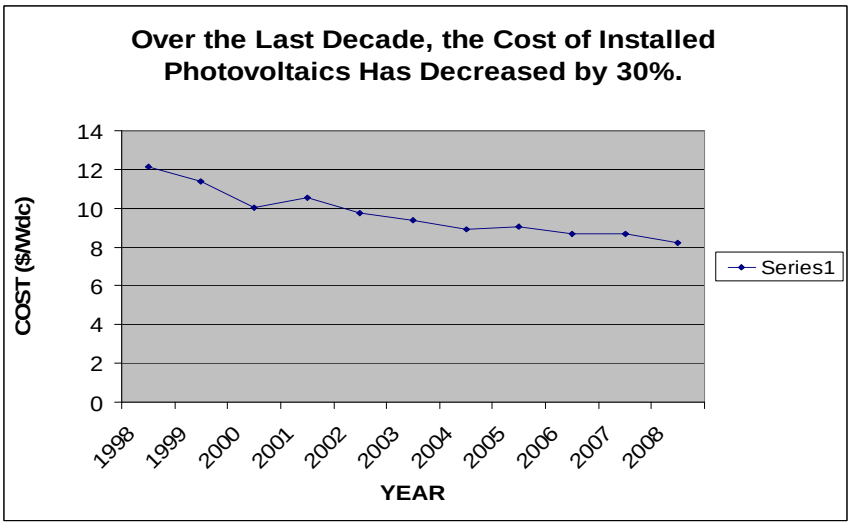
25. On the growing availability of natural gas in the Western Hemisphere**,** Europe and Asia, see "An Unconventional Glut," The Economist, pp. 72-74, available at http://www.economist.com/business-finance/displaystory.cfm?story_id=15661889; Ben Casselman, " U.S. Gas Fields Go from Bust to Boom, April 30, 2009 and "U.S. Natural-Gas Supplies Surge," *The Wall Street Journal*, April 30, 2009 and June 18, 2009, available at http://online.wsj.com/article/SB124104549891270585.html and http://online.wsj.com/article/SB124527293718124619.html and Gary Schmitt, "Europe's Road to Energy Security: Unconventional Gas Could Free the EU from Dependence on Russian Gas Supplies," *The European Wall Street Journal*, March 11, 2010, available at http://online.wsj.com/article/SB10001424052748704187204575101344074618882.html

26. For an analysis relevant to the Middle East, see Peter Tynan and John Stephenson, "Nuclear Power in Saudi Arabia, Egypt and Turkey: How Cost Effective?" (Washington, DC: NPEC) available at http://www.npec-web.org/node/1054 and Wyn Bowen and James Acton, "Atoms for Peace in the Middle East: The Technical and Regulatory Requirement," (Washington, DC: NPEC), available at http://www.npec-web.org/node/1032

27. See Amory B. Lovins, Imran Sheikh, and Alex Markevich, " Nuclear Power: Climate Fix or Folly?" updated by Amory B. Lovins December 31, 2008 for NPEC, available at http://www.npec-web.org/node/1127.

more than 80 percent over the last 20 years.[28] Solar photovoltaic generated electricity has also been falling (see, for example, the costs of delivered solar electricity in Figure 6 below).

Figure 6



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.[29] Meanwhile, nuclear power's costs are high and rising. Finally, 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. All of this presents significant uncertainty and risk for nuclear power investors.

In the mid-term, -- i.e., the next two decades, when nuclear supporters see their power source reemerging -- a number of energy developments could easily destroy whatever value might be credited to investments made in commercial nuclear energy today. As noted, new electrical grid concepts could be employed incrementally to make the transmission of intermittent wind and solar much more practical; as could the development

28. See the analysis of the American Wind Association, available at http://www.awea.org/faq/cost.html

29. For an analysis that renewables are already more economical than nuclear or coal base load generations, though, see Amory Lovins, "Mighty Mice," *Nuclear Engineering International*, December 21, 2004, available at http://www.neimagazine.com/story.asp?storyCode=2033302.

of practical electrical storage and of viable distributed electrical systems.[30] 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.

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 operate for 60 years or more after coming on line in 2020 and beyond. In fact, the uncertainties surrounding what the costs for electricity generation, distribution, transmission, storage and consumption and what form each is likely to take over the next two decades are all very much in play for the first time in over a century. This very flexible and uncertain situation not only argues for great caution in the allocation of public funds on any energy commercialization project, but also underscores the importance in ensuring neutral markets in which multiple solutions are forced to compete against each other.

Government Nuclear Power

Governments, on the other hand, view matters differently. The energy market uncertainties noted above have only encouraged them to invest more in clean energy commercialization options. In practice, this has meant they have invested most heavily in the most capital intensive 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 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 could result in significant layoffs – dislocations large enough to produce negative political results. Continuing to subsidize them, on the other hand, is politically astute.

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30. See, e.g., Mason Willrich, "Electricity Transmission for America: Enabling a Smart Grid, End-to-End," *Energy Innovation Working Paper Series*, Massachusetts Institute of Technology, July 2009, available at http://web.mit.edu/ipc/research/energy/pdf/EIP_09-003.pdf; Sharon Gauin, "Bloom Fuel Cell: Individual Power in a Box," *Business Week*, February 24, 2010, available at http://www.businessweek.com/idg/2010-02-24/bloom-fuel-cell-individual-power-plant-in-a-box.html.

Second and less immediate, commercial nuclear power's historical links to national security continues to make government support seem natural. Within the oldest and most significant nuclear states – the U.S., the U.K., France, Russia, and India – government-run, dual-use reactors were long connected to electrical grids to produce nuclear weapons fuels and electricity. In the U.S., this includes the Hanford dual-purpose reactor in Washington State (which is no longer operating), and the Tennessee Valley Authority's tritium-producing light water reactors (whose operations are about to be expanded). It includes Russia's RMBK reactors, which made plutonium for Russia's arsenal until the l990s; France's gas cooled natural uranium and breeder reactors, which did the same for France through the l980s; 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. As for the most popular of nuclear power systems, pressurized light-water reactors (versions of which Germany, France, Russia, Japan, South Korea all now export and operate), these were originally developed in the U.S. for nuclear submarine and naval propulsion.

This strong history of 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* non-nuclear, actually flies in the face of what market forces would otherwise recommend. More important, it hides the full costs and risks associated of each energy option. This, in turn, is undesirable for several reasons.

III. Concerns

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; 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.[31]

Thus, it was evident to most that the U.S. government's commercial synfuels and breeder reactor projects were economically untenable years before Congress finally decided to kill both projects. The delay in terminating these projects cost taxpayers billions of dollars. These projects, though, at least died. With government mandated energy commercialization programs, such as corn ethanol, the U.S. government has essentially mandated that the product be produced and bought by the public in increasing amounts in the face of little or no market demand. Besides costing U.S. consumers billions of dollars annually, this program is becoming institutionalized in such a manner as to make it more difficult to phase-out or end it in the future. In France, Japan, Russia, Korea, and India, where the power of the government in commercial matters is even stronger, 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. This requirement, however, can be delayed or waived entirely by the Secretary of Energy if, in his judgment, it would threaten the financial stability of the firm paying it. These retrospective premiums are paid in a nondiscriminatory fashion: They are virtually identical for both the safest and worst run utilities.[32]

31. 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* (Geneva, Switzerland: The Global Subsides Initiative, October 2009), available at http://www.globalsubsidies.org/files/assets/politics_ffs.pdf.

32. On this point see the testimony of David Lochbaum, before a hearing of the Subcommittee on Energy and Resources of the House Committee on Government Reform, "Next Generation of Nuclear Power," June 29, 2005, available at http://ftp.resource.org/gpo.gov/hearings/109h/23408.txt'.

By most accounts, such pooling lessens the cost of nuclear insurance significantly to the nuclear industry as a whole.[33] 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.[34] This certainly has been the logic behind the passage of the U.S. Terrorism Risk Insurance Act of 2002 and its repeated extension.[35] Yet, these acts are claimed by their backers only to be "temporary", i.e., designed to allow private insurers the time to adjust to a new risk market.

As both the U.S. Congressional Budget Office and the U.S. Treasury Department have argued, capping private firms' need to insure against catastrophic losses only make sense if the risks of such losses are very low and unlikely to persist. In such cases, federal subsidies for insurance "could be justified as a means of avoiding expensive and unnecessary effort to reduce losses." If, as is more likely, in the case of nuclear safety and vulnerability to terrorist attacks, the long term risks are either long-lived or -- after 9/11 and the aging of the existing reactor fleet -- likely to increase,[36] such federal "assistance" "could be costly to the economy because it could further delay owners of assets from

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33. Estimates of how much Price-Anderson nuclear accident liability limits on third party damages are worth range widely between .5 and 2.5 cents per kilowatt hour. For details see Anthony Heyes, ,"Determining the Price of Price Anderson", *Regulation*, Winter 2002 – 2003, pp. 26-30, 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/node/1125'

34. Cf. however, Peter A. Bradford, former U.S. Nuclear Regulatory Commissioner, Testimony before the United States Senate Committee on Environment and Public Works Subcommittee on Nuclear Regulation, "Renewal of Price Anderson Act", January 23, 2002 available at http://epw.senate.gov/107th/Bradford_01-23-02.htm

35. See Public Law 107-297-Nov. 26, 2002 available at http://www.treas.gov/officies/enforcement/ofac/legal/statutes/pl107_297.pdf and The Terrorism Risk Insurance Extension Act of 2005 available at http://www.cbo.gov/ftpdocs/69xx/docs6978/s467.pdf.

36. For post 9/11 overviews of the growing number of civilian nuclear-related terrorism concerns, see U.S. Congressional Research Service, Carl Behrens and Mark Holt, "Nuclear Power Plants: Vulnerability to Terrorist Attack" (Report for Congress, RS21131, August 9, 2005), available at http://www.fas.org/sgp/crs/terrror/RS21131.pdf; National Research Council of the National Academies, San Luis Obispo Mothers for Peace v. Nuclear Regulator Commission, No. 03-74628, 2006 WL 151889 (9th Cir. June 2, 2006; "Safety and Security of Commercial Spent Fuel Storage", Public Report (April 6, 2005); and Henry Sokolski, "Too Speculative? Getting Serious about Nuclear Terrorism," *The New Atlantis*, Fall 2006, pp. 119-124, available at http://www.thenewatlantis.com/publications/too-speculative.

making adjustments to mitigate their risk and reduce potential loses."[37] Here, it is worth noting that neither General Electric nor Westinghouse has yet succeeded in producing a reactor design that can meet the Nuclear Regulatory Commission's latest requirement that the plant be able to sustain a large, direct airplane hit. Westinghouse's latest submission to meet this requirement was actually found to be wanting and was rejected because it created unintended vulnerabilities to natural disasters such as earthquakes.[38]

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 only needed the protection 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 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 the case of an accident.[39]

The future, however, 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 argue that government accident insurance caps could be phased out.[40] Certainly, industry arguments against even higher coverage requirements under their

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37. See U.S. Congressional Budget Office, "Federal Terrorism Reinsurance: An Update," January 2005 section three of six, "Long-term Effects" available at http://www.cbo.gov/showdoc.cfm?index=6049&sequence=2#pt3 and The U.S. Department of the Treasury, Report to Congress, *Assessment: The Terrorism Risk Insurance Act of 2002* (Washington, DC: The U.S. Department of the Treasury, Office of Economic Policy, June 30, 2005), pp. 10-12, 111-113, and 125-140. Yet another shortcoming with the current cap on nuclear accident insurance liability for third parties in the US is the lack of commonsense differentiation between the safest and least safe and the most remotely located reactors and those located near high value urban real estate. This too discourages industry from engaging in best practices. See notes 26 and 34.

38. U.S. Nuclear Regulatory Commission, "NRC Informs Westinghouse of Safety Issues with AP1000 Shield Building," Press Release 09-173, October 15, 2009, available at http://www.nrc.gov/reading-rm/doc-collections/news/2009/09-173.html.

39. See Letter from Omer F. Brown III to Deputy Secretary of State Richard Armitage, Re: Nuclear Liability, December 18, 2003 available at http://foreignaffairs.house.gov/110/sok061208.pdf.

40. See, e.g., the testimony of David Baldwin, senior Vice President of General Atomics before a hearing of the Subcommittee on Energy and Resources of the House Committee on Government Reform, "Next Generation of Nuclear Power," June 29, 2005, available at http://ftp.resource.org/gpo.gov/hearings/109h/23408.txt.

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 their own nuclear assets. In fact, for a single power plant location, most nuclear utilities are buying over ten times the amount of insurance to protect against on-site accident damage and forced outages than Price-Anderson requires them to carry against off-site property and health damages for the entire U.S. 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 must purchase by law. 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.

Though nuclear liability coverage in the U.S. seems quite inadequate, it is regrettably even worse abroad. For example, within Europe, the second largest nuclear powered region in the world, nuclear accident insurance requirements are not just inadequate, but also egregiously inconsistent. Thus, nuclear accident insurance requirements that are much lower in Eastern Europe than in the EU currently are encouraging reactor construction in states with the least stringent liability requirements and some of the weakest nuclear safety regulatory standards. Because of this worry, some experts are now arguing that the EU should adopt a nuclear insurance pooling scheme at least as tough as that in the United States. To avoid the problems that allowing the pool to charge too little would incur, they argue that the pool should require higher payments than in the U.S. Yet, they note, any uniform insurance requirement would be better than none. [41]

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. In the Middle East, Israel, the U.S., Iran, and Iraq have launched aerial bombing or missile strikes against International Atomic Energy Agency (IAEA) safeguarded reactors – Osirak and Bushehr -- even though the owners were both members of the Nuclear Nonproliferation Treaty (NPT). If one includes the 2007 Israeli attack against Syria's reactor and Iraq's failed missile strike against Dimona during the

41. See Antony Frogget, "Nuclear Third Party Insurance, the Nuclear Sector's Silent Subsidy, and the State of Play in and Opportunities in Europe" (Washington, DC: November 5, 2007), available at http://www.npec-web.org/node/1007 and Simon Carroll, "European Challenges to Promoting International Pooling and Compensation for Nuclear Reactor Accidents (Washington, DC: NPEC, January 2, 2009), available at http://www.npec-web.org/node/1051.

first Gulf War, there have been no fewer than 13 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 US 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 the subsidies will substantially assist these states to move closer to developing nuclear weapons options.

Consider Iran. The United States, perhaps more than any other country, was responsible for encouraging the Shah to develop nuclear power in the 1970s. Because we saw the Shah as a close ally, too little thought was given to the potential security implications of our sharing advanced nuclear technology with Iran. When Iran's revolutionary government began to rebuild its Bushehr power station with Russian help, though, the U.S. rightly became concerned about the proliferation risks.

Presidents Clinton and Bush warned that Bushehr could be used as a cover for illicit nuclear weapons related activities. This problem is only likely to increase over time: Once the reactor comes on line, it produces scores of bombs' worth of weapons-usable plutonium annually, which can be diverted to make bombs.[42] The fresh fuel, meanwhile, could be used to accelerate a uranium enrichment program.[43] It was because of these facts that during the first term of the Bush 43 Administration, the State Department went to great lengths to challenge the economic viability of the Iranian nuclear program as compared to burning plentiful natural gas. President Bush also insisted publicly that no new nuclear power state needed to make nuclear fuel to enjoy the benefits of nuclear power.[44]

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42. On these points, see House Permanent Select Committee on Intelligence, Subcommittee on Intelligence, *Recognizing Iran as a Strategic Threat: An Intelligence Challenge for the United States*, staff report, August 23,2006, p. 11, at http://intelligence.house.gov/Media/PDFS/IranReport082206v2.pdf.

43. Thus, when it became clear that North Korea had reneged on its promise not attempt to enrich uranium for weapons, the Bush Administration stopped construction of two light water reactors it had promised Pyongyang because in the words of Secretary of State Rice, North Korea could not be "trusted" with them.

44. See Remarks by the President on Weapons of Mass Destruction Proliferation, Fort Leslie J. McNair, National Defense University, February 11, 2004, available at http://www.acronym.org.uk/dd/dd75/75news06.htm.

In its second term, however, the Bush Administration decided domestically to add significant new nuclear subsidies to promote nuclear power plant construction in the U.S. under the Energy Policy Act of 2005 and to encourage an expansion of nuclear fuel making with new technologies where it was already commercially underway. It was roughly during this period that the U.S. also decided to "grandfather" Bushehr and offered Iran power reactor assistance if it would only suspend its nuclear fuel making program.

With this, the U.S. essentially let go of its economic critique of Iran's power program. In July of 2007, President Bush and Russian President Putin publicly recommended that international and regional development banks make cheap loans for civilian nuclear power programs.[45] The White House also began encouraging the development of nuclear power throughout the Middle East as a way to put the lie to Iran's claim that the U.S. and its partners were trying to deny all Muslim's the "peaceful atom."[46] The economic merits of the last move, as has already been noted, are dubious. Yet, Russia, France, South Korea, the U.S., China and India are nonetheless openly competing to secure contracts in the Middle East and beyond using a variety of government supported subsidies to drive down nuclear bidding prices.

IV. Economics as A Way Out

Linking Security with Economy and the NPT

For observers and officials worried about the 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 US and other states have oversold how well international nuclear inspections can prevent military diversions from civilian nuclear programs. Even today, the IAEA cannot yet reliably track 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.[47] As for large fuel making plants, the IAEA

45. White House Press Release, "Text of Declaration on Nuclear Energy and Nonproliferation Joint Actions (July 03, 2007)," available at http://moscow.usembassy.gov/st_07032007.html.

46. See Jay Solomon and Margret Coker, "Oil-Rich Arab State Pushes Nuclear Bid with U.S. Help," *The Wall Street Journal*, April 2, 2009, available at http://online.wsj.com/article/SB123862439816779973.html and Dan Murphy, "Middle East Racing to Nuclear Power," November 1,2007, *The Christian Science Monitor*, http://www.csmonitor.com/2007/1101/p01s03-wome.html.

47 See, "In Pursuit of the Undoable, Troubling Flaws in the World's Nuclear Safeguards," *The Economist*, August, 23, 2007, available at http://www.economist.com/world/international/displaystory.cfm?story_id=9687869.

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 are unfriendly to the agency ever being able to reliably detect diversions from nuclear fuel making plants.[48]

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. It is governments and their publics, after all, which determine whether or not more large civilian energy plants will be built. If government officials and the public believe backing nuclear power is a good investment, public monies will be spent to build more plants in more countries no matter how dangerous or unsafeguardable they might be.

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 that it was too costly to use nuclear explosives for civil engineering projects (the cost of clean up 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.[49]

What, then, should be protected under the NPT as being "peaceful" today? Are large nuclear programs economically competitive, i.e., "beneficial" in places like the Middle East when compared to making power with readily available natural gas? What of making enriched uranium fuel for one or a small number of reactors? Would it not be far cheaper simply to buy fresh fuel from other producers? Does reprocessing make economic sense anywhere? Can nuclear fuel making be reliably safeguarded to detect military diversions in a timely fashion? Aren't such activities dangerously close to bomb making? Should these activities be allowed to be expanded in nonweapons states and to new locales or, like

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48. On these points, see Henry D. Sokolski, editor, *Falling Behind: International Scrutiny of the Peaceful Atom* (Carlisle, PA: US Army War College, Strategic Studies Institute, 2008), available online at http://www.npec-web.org/node/1160/.

49. On these points, see Eldon Greenberg, "The NPT and Plutonium," (Washington, DC: NCI, 1993), available at http://www.npec-web.org/node/854 and Robert Zarate, "The NPT, IAEA Safeguards, and Peaceful Nuclear Energy," in *Falling Behind*, pp. 252 ff, available at http://www.npec-web.org/node/1160/.

"peaceful" nuclear explosives, are the benefits of these program so spurious and the activities in question so close to bomb making or testing to put them outside of the bounds of NPT protection? What of large reactors, which are fueled with large amounts of fresh enriched uranium or that produce large amounts of plutonium-laden spent fuel? Should these be viewed as being safeguardable in hostile or questionable states, such as Iran or North Korea, that have a record of breaking IAEA inspection rules?

Again, getting all of the world's nations to agree on the answers to these questions will be difficult if nuclear power is truly the least expensive way to produce low or no carbon emission power. In this case, it may be impossible to prevent nuclear technology useful to making bombs from spreading world-wide. But if civilian nuclear energy projects are not economically competitive against their nonnuclear alternatives, just the opposite would ensue and the case against states spending extra to promote the commercial expansion of potentially dangerous commercial nuclear projects would be far stronger.

Uncertainties

The only thing certain about nuclear power's future ability to compete against other commercial energy alternatives in the future is its uncertainty. This is so for several reasons.

First, 20 years out, we do not know if our car will plug into our house (outlets) or if our houses will plug into our car (batteries): It is uncertain how much future power will be distributed off a centralized grid and how much will come from more distributed systems (e.g., local grids, cogeneration plants, storage batteries, and the like). This is important since two-thirds of the cost of electricity at the house or business outlet is unrelated to the cost of generating the electricity: Instead, it pertains to the cost of transporting the electricity over the grid and balancing and conditioning the power inputs and outputs on that grid to assure that it does not fail.

Second, it is unclear how many base load generators will be needed 10 to 20 years out since so much of the current demand for electrical generating capacity in advanced economies is driven by the need to have spinning follow on load capacity that frequently remains idle.[50] If one can figure out how to store electricity economically (and a number

50. Because large amounts of electricity cannot currently be stored, electrical companies must estimate how much electricity their customers will use and secure the electrical generating capacity to supply this demand. The difference between these estimates and real demand produces temporary imbalances in the electrical grid that the electrical transmission system operator must correct for by either reducing the amount of electricity being put on the grid or by bringing more electricity on to the grid. The latter is done by accessing electrical generators that are on the ready or "spinning" to supply follow on load capacity electricity. For a more detailed slide tutorial on these points, see, "Spinning Reserves, Balancing the Net", *Leonardo Energy Minute Lectures,* available at http://www.slideshare.net/sustenergy/spinning-reserve.

of schemes are now being tried out), the current premium placed on having significant reserves of additional base load follow on capacity generators -- typically supplied by large coal fired plants, large hydro, or nuclear reactors -- could be reduced significantly.

Third, there is much uncertainty with respect to carbon charges on which nuclear economics heavily depend. Will carbon be taxed and, if so, at what rate? What sectors will be grandfathered; which will benefit the most from the constraints? The EU has a cap and trade system that the U.S. Congress considering emulating. Under this system, government authorities allocate carbon allowances to different industrial concerns and sectors. Initial grants of credits follow patterns of most subsidies, with some sectors -- often the most politically powerful -- benefiting far more than others. "Winners" under the new system shift from economic and technical performance to political.

All of this seems an odd way to promote cost competitive clean energy. Instead, it would make more sense simply to focus on cost comparisons for future plants that incorporated the full value of government subsidies and reflected a standardized carbon cost (e.g., a price on the carbon content of different fuels). To foster the proper use of such information, though, we will need to rely more, not less on market mechanisms to help guide our way.

Policy Implications

Again, the general take away 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:

1. ***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.

Account for Nuclear Power's Full Costs: One way they could improve their performance is to take what few economic energy assessments they must do more seriously 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. The CBO has been asked to do this by Congress several times in the last decade. 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

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the likely default rate under proposed loan guarantee legislation at the time at 50 percent.[51] The Department of Energy, meanwhile, announced that essentially it viewed such information to be proprietary. It would be useful for the CBO to get the information it needs to update and qualify such projections. At a minimum, the CBO should tackle this question every time it estimates what any commercial energy loan guarantees will cost. Congress, meanwhile, should demand that DoE make all of its own estimates relating to these issue public. Also, every time the CBO or DoE make such projections they should be reviewed in public hearings before Congress.

Compare Nuclear with Nonnuclear: 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 (IRENA).[52] Finally, in order for any of these efforts to produce sound cost comparisons, though, more accurate tallies of what government energy subsidies are worth for each energy type will be required.

Increase the Number of Energy Subsidy Economists: 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.

2. ***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 US and many other states support, already calls on states to internalize as many of external costs (e.g., those associated with government subsidies and quantifiable environmental costs such as the probable taxes on carbon) in the pricing of 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.[53] Since

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51. On these points, see The Congressional Budget Office, "Congressional Budget Office Cost Estimate: S. 14 Energy Policy Act of 2003," May 7, 2003, available at http://www.cbo.gov/ftpdocs/42xx/doc4206/s14.pdf; Congressional Budget Office, Director's Blog, "Department of Energy's Loan Guarantees for Nuclear Power Plants," March 4, 2010, available at http://cboblog.cbo.gov/?p=478.

52. The International Renewable Energy Agency (IREA) was created in 2009. For more on its mandate, go to http://www.irena.org/.

53. For more on each of these agreements, go to http://www.encharter.org/ and

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 time line. 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 the 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.

3. ***Discouraging the use of government financial incentives to promote commercial nuclear power***. This was recommendation was made by the Congressional Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism.[54] 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 (e.g., coal, renewables, natural gas, etc.) as well, the security risks associated with the further spread of civilian nuclear energy make it especially salient in the case of nuclear. 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' (e.g., France, Japan, Germany, Russia, China, and South Korea) use of subsidized government financing to secure civilian nuclear exports. In some cases, these foreign export loan credits are being used in the US in conjunction with US 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 these projects' 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

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http://www.cmdc.net/echarter.html.

54. See, The Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism, *The World At Risk: The Report of the Commission on the Prevention of WMD Proliferation and Terrorism* (New York, NY: Vintage Books December 2008), pp. 55-56 available at http://documents.scribd.com/docs/15bq1nrl9aerfu0yu9qd.pdf.

implementing this law, this nominal figure should be covered entirely with private investment; not by resort to rate hikes for ratepayers.[55]

4. ***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. In this regard, states that use public money to close the fuel cycle by commercializing any form of spent fuel recycling will actually make nuclear power less competitive with its nonnuclear alternatives.

Managing Nuclear Waste: 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.[56] This reflects economic commonsense. Unfortunately, in many advanced states that operate nuclear power reactors, the governments own and operate the power plants. As a result, full employment, development of nuclear weapons options, and other political or military concerns often override straightforward cost benefit analysis.[57] In the United States, 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 U.S. law, which currently stipulates that all of the costs of final spent fuel storage are to be paid for by off budget federal user fees.

Making Nuclear Fuel: 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

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55. On this point see, e.g., Steven Mufson, "Nuclear Projects Face Financial Obstacles: *The Washington Post*, March 2, 2010, p. 1, available at http://www.washingtonpost.com/wp-dyn/content/article/2010/03/01/AR2010030103975.html.

56. See *World at Risk*, p. 51 and Mohamed ElBaradei, Nobel Lecture, December 10, 2005, available at http://nobelprize.org/nobel_prizes/peace/laureates/2005/elbaradei-lecture-en.html.

57. See Frank Von Hippel, Why Reprocessing Persists in Some Countries and Not in Others: The Costs and Benefits of Reprocessing (Washington, DC: NPEC, April 9, 2009), available at http://www.npec-web.org/node/1128.

such contracts in hand, it should be possible to secure private financing for such projects. 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 foreswear 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. Subsidizing these fuel services has been proposed as a way to induce states to eschew making their own nuclear fuels. This proposal however, seems unsound. First, it is unclear who the customers are. India and Canada already make their own natural uranium fuels, which require no enrichment. Several others – France, Russia, Japan, Brazil, and China -- enrich their own fuel and the remaining nuclear fuel consuming states seem content to buy their fuels from U.S. providers, Russia, URENCO, or Eurodif. Second, it is unlikely that nuclear fuel subsidies would be sufficient to block determined proliferators: After all, only a small percent of any nuclear power plant's life cycle costs are associated with its fueling requirements. Again, given the dangers of propping up dangerous reprocessing activities and the dubious requirement to provide enriched fuel, the world can well afford to depend more on market mechanisms to determine when and how these services are provided.

Use of Weapons Grade Uranium Fuels: Finally, the use of nuclear weapons usable highly enriched uranium is a nuclear fuel cycle option that is no longer necessary for the production of power or of medical, agricultural or industrial isotopes. There are fewer and fewer research reactors that use highly enriched uranium (HEU), but what few operators there are are more than willing to pay to continue to use this fuel rather than to pay the costs of converting to low enriched uranium alternatives. Given the direct usability of HEU to make nuclear weapons, however, the elimination and blending down of these fuels are 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.[58]

5. ***Increasing and further privatizing nuclear insurance liability coverage to encourage best construction and operations practices***. Officials within the nuclear industry frequently note that a nuclear industry accident anywhere would impact nuclear operators negatively everywhere. Yet, the potential financial and political fall out following a major

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58. For more detail on these points, see NRDC's Petition to the U.S. Nuclear Regulatory Commission For Rulemaking to Ban Future Civil Use of Highly Enriched Uranium, March 24, 2008, available at http://docs.nrdc.org/nuclear/files/nuc_08032501a.pdf.

56. See Information Circular 367 , 22 July 1998, Convention on Supplementary Compensation for Nuclear Damage, available at http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc567.shtml

nuclear accident would be even more significant if there were a lack of adequate nuclear accident liability insurance. For this reason alone, 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 over-ride or forgiveness by officials of the state. Here, amounts required by the international Convention on Supplementary Compensation for Nuclear Damage (CSC)[59] should be considered to be the minimum. For the EU, which is currently struggling to set a standard for its members, the coverage requirements set by CSC should be considered to be the floor from which any specific EU standard is created. Far preferable would be for the EU to adopt insurance levels that the US currently requires under its domestic Price-Anderson legislation. The US, meanwhile, needs to raise international nuclear insurance standards by first 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 US. This announcement should be made now so that the nuclear utility and vendor industry can develop their own alternative private system of insurance to cover offsite damages. At a minimum, the requisite amounts of capital to fund such a system should be amassed well in advance of the need to bring the new insurance system into force. Under any new system, each nuclear utility, service provider, and vending firm should be free to buy as much or as little third-party liability insurance for themselves as each sees fit from private insurance firms so long as the amount was at least as much as Price-Anderson currently requires to cover any one accident (roughly $10 billion for each accident). The rates for this coverage would be set for each firm by private insurers based on each firm's safety performance, the age of the plant, and the experience of the firm's staff, etc. Of course, each nuclear firm should be free to work with other nuclear utilities and companies to create private insurance pools. Even in this case, though, rates for each firm should be set in a manner that would reward the best nuclear operators and vendors. By doing this, the government would finally be able get industry to internalize the full costs of off-site nuclear accident liability insurance. Given that some US 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 15 years should go relatively smoothly.

6. ***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 (1) set standard rules for selling electricity through the grid; (2) remove conflicts of interest for existing grid or pipeline operations to block new entrants; (3) ensure regulated utilities have similar incentives to

invest in efficiencies as they do in expanding generation plants and energy supplies; (4) encourage key market constraints, be they carbon limits or liability coverage, through the market pricing systems rather than through government subsidies; and (5) increase pricing visibility for power to final customers.