International impact of U.S. spent-fuel policy

Prepared statement to the Blue Ribbon Commission on America's Nuclear Future

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Because I have only 15 minutes, I am going to focus on the international aspects of the reprocessing issue. I provide endnotes so that you can read more.

The U.S. was for reprocessing before we were against it. We were for it because our Atomic Energy Commission (AEC) grossly overestimated the rate at which nuclear power would grow, grossly underestimated how much uranium would be found and grossly underestimated the cost of reprocessing.

The failed effort to commercialize plutonium breeder reactors

This led the AEC to propose fast-neutron liquid-sodium-cooled breeder reactors that could use U-238, the abundant but non-chain-reacting isotope of uranium, as a fuel by converting it into chain-reacting plutonium. Glen Seaborg, a co-discoverer of plutonium, who was the chairman of the AEC during the 1960s, did more than anyone else to promote worldwide what he called "the plutonium economy of the future."[1]

It turned out that the AEC also grossly underestimated the cost of building and difficulty of operating breeder reactors. The basic problem is that sodium burns on contact with either air or water and we live in a world of air and water. From the 1960s through the 1980s, the U.S., France, Germany, Japan, Russia, U.K. and other countries spent about $100 billion in today's dollars on R&D and demonstration projects on fast neutron breeder reactors.[2] These are the same reactors that are, with a reconfigured core, being promoted today as plutonium *burner* reactors. Breeder or burner, these reactors require reprocessing to recycle the plutonium and uranium in their fuel.

The U.S. government began to rethink the wisdom of its promotion of reprocessing worldwide after 1974, when India used the first plutonium separated as part of its fast-neutron reactor R&D program for a "peaceful nuclear explosion."

President Ford and Secretary of State Henry Kissinger worked hard to block the transfer of reprocessing to other countries and managed to derail France's transfer of reprocessing plants to South Korea and Pakistan, and to stall Germany's transfer of reprocessing technology to Brazil. All three countries were pursuing nuclear weapons at the time.

The Carter Administration concluded that fast-neutron reactors would not in any case be economically competitive with light water reactors for the foreseeable future, and cancelled the licensing process for a large reprocessing plant in South Carolina.[3] The Reagan Administration lifted this ban in 1981 but, as a result of greatly increased cost estimates for reprocessing, U.S. utilities were no longer interested.

Congress cancelled the U.S. fast-neutron reactor demonstration project in 1983, before construction was launched, after a 5-fold increase in the cost estimate had changed a 50-50 government-utility cost-sharing arrangement to a 90-10 split.[4] (The utilities were only

willing to put into the project as much as the equivalent light-water reactor capacity would have cost them.)

The British, French, German and Japanese fast-neutron reactor demonstration programs also collapsed for reasons of cost and reliability and, in the case of Germany, safety. Although France and Japan still envision building fast-neutron reactors in the future, India and Russia are the only countries that are building demonstration reactors today.[5]

In 1977, Prime Minister Takeo Fukada stated that Japan's breeder and reprocessing programs were "a matter of life or death for Japan." Today Japan's Atomic Energy Commission says that it wants to keep breeder reactors alive as an "*option*" for Japan in the period after 2050.[6] Japan's prototype breeder reactor, *Monju,* has operated for less than a year. In 1995, it was shut down for 15 years after a sodium fire. Last month, it was shut down again after a 3-ton refueling machine fell inside the reactor vessel.[7]

The primary legacy of all these fast-neutron reactor-development efforts is 240 tons of separated plutonium – enough for 30,000 first-generation nuclear weapons – stored in the U.K., France, Russia, Japan and India.[8] Another legacy is a group of national laboratories and government-owned companies that continue to advocate for more expenditures on fast-neutron reactor R&D and demonstration projects.

Why did reprocessing continue?

With the collapse of the European breeder programs, reprocessing ended in Belgium, Germany and Italy. Reprocessing has continued in France, India, Japan, Russia and the U.K., however. In Russia and India it continues on a small scale justified by their breeder programs. But why does it continue on a large scale in France, Japan and the U.K. whose breeder programs are either dead (the U.K.) or moribund?

In the 1980s, France and the U.K. built modern reprocessing plants financed with prepaid contracts from foreign (primarily German and Japanese) utilities that were having trouble with anti-nuclear movements focused on the spent-fuel issue. The utilities bought respite by exporting their spent fuel to France and the U.K. The respite was only a temporary, however, because France and the U.K. insisted that the high-level waste from reprocessing return to the countries of origin. As a result, Germany, Japan and virtually all other countries did not renew their contracts.[9]

United Kingdom. The U.K. is expected to end its reprocessing program after it completes its foreign contracts. Because of repeated breakdowns in its reprocessing plant, contract completion is overdue at this point by six years.[10]

France. With the loss of virtually all of France's foreign reprocessing contracts,[11] the full cost of France's reprocessing program has fallen on its utility, Électricité de France EdF and Areva were unable to agree on a reprocessing price for a full year, but the French government, which owns both finally forced an agreement. [12] France currently is recycling its plutonium only once in light-water reactor "mixed oxide" (MOX) fuel but most of the plutonium remains unfissioned and Areva has acknowledged that this does not simplify the radioactive waste disposal problem.[13] The entire rationale of France's reprocessing program continues to be premised on the belief that fast-neutron reactors eventually will be commercialized.

Japan. Japan needed a prefecture willing to receive both the high-level waste coming back from Europe and the ongoing discharges of spent fuel from its power reactors. Aomori, Japan's second poorest prefecture, agreed to do so in exchange for an $80 billion reprocessing program (over 40 years), including more than $10 billion of direct subsidies to the local and prefecture governments. In 2004, the Long-range Planning Committee of Japan's Atomic Energy Commission estimated that reprocessing would increase the cost of nuclear electricity in Japan by 0.6 Yen (0.7 cents) per kilowatt hour. It insisted, however, that, because local governments are opposed to expanded on-site storage, the alternative would be to shut down all of Japan's nuclear power plants as their spent-fuel pools fill up.[14] At this point, the Rokkasho Reprocessing Plant is 15 years overdue and it will not in any case have enough capacity to keep up with the discharge of spent fuel by Japan's nuclear power plants. Japan's utilities therefore are having after all to find ways to increase their interim spent-fuel-storage capacities.[15]

Today, Japan is the only non-weapon state that reprocesses. South Korea, which is facing the same problem of local opposition to expanded on-site storage, however, is insisting that its new agreement of nuclear cooperation with the U.S. include the same prior consent to reprocess that Japan obtained from the Reagan Administration. The Obama Administration is resisting, in large part because this would make it virtually impossible to shut down North Korea's reprocessing program.[16]

Proliferation resistance. The Idaho National Laboratory and the Korea Atomic Energy Research Institute argue that pyroprocessing, the form of reprocessing they favor, is "proliferation resistant." An inter-lab study, however, "found only a modest improvement in reducing proliferation risk over existing PUREX technologies and these modest improvements apply primarily for non-state actors."[17]

Countries that reprocess or plan to (% of capacity) (GWe, [10^9 Watts])		**Customer Countries that have quit or plan to quit** (GWe)		**Countries that have not reprocessed** (GWe)	
China (30%)	10.0	Armenia (in Russia)	0.4	Argentina	0.9
France (80%)	63.3	Belgium (France)	5.9	Brazil	1.9
India (≈50%)	4.2	Bulgaria (Russia)	1.9	Canada	12.6
Japan (90% planned)	46.8	Czech Republic (Russia)	3.7	Mexico	1.3
Netherlands (in France)	0.5	Finland (Russia)	2.7	Pakistan	0.4
Russia (15%)	22.7	Germany(France/UK)	20.5	Romania	1.3
United Kingdom	10.1	Hungary (Russia)	1.9	Slovenia	0.7
		Slovak Republic (Russia)	1.8	South Africa	1.8
		Spain (France, UK)	7.5	South Korea	18.7
		Sweden (France/UK)	9.3	Taiwan	4.9
		Switzerland (France/UK)	3.2	U.S. (since 1972)	100.6
		Ukraine (Russia)	13.1		
Total (65%)	**157.6**	**Total**	**71.3**	**Total**	**145.2**

Importance of the U.S. Example

Would history have been any different if the U.S. had not adopted the policy that "we don't reprocess and you don't need to either" after India's 1974 test? Would Brazil, South Korea and other countries be nuclear-weapon states today?

The U.S. example is certainly important. We still have the world's largest nuclear-power program and our spent-fuel management policy has been followed by the majority of the world's nuclear operators, including in a dozen countries that formerly sent their spent fuel to France, Russia and the U.K. for reprocessing (Table above).

Spent fuel management choices will be even more important for the countries that are interested in joining the nuclear-power club. If you look at the 19 non-weapon states that have nuclear power plants today, 13 are in Europe of which 10 had their non-weapon status stabilized first during the Cold War by their alliances with the superpowers and since by their membership in the EU, five are non-European countries under the U.S. defense umbrella and two are former Soviet republics not in Europe. That leaves three non-weapon states that were not subject to these nonproliferation influences: Argentina, Brazil and South Africa. All used their nuclear-energy programs as covers for nuclear-weapon programs. Fortunately, all had non-violent democratic revolutions that rejected their nuclear-weapon programs. We won't necessarily be that lucky in the future.

In 2008, the OECD Nuclear Energy Agency listed 24 non-weapon states that are likely to acquire nuclear power plants soon. Relatively few of these countries are stabilized by the EU or an alliance with the U.S. (Table below).[18] There are another 40 countries behind them that are expressing interest in acquiring nuclear power plants.[19]

President George W. Bush proposed in 2004 that enrichment and reprocessing technology not be supplied "to any state that does not already possess full-scale, functioning enrichment and reprocessing plants."[20] Instead, the weapon states and Japan would provide spent-fuel disposal services for the have-not countries. That proposal was roundly rejected. The non-aligned countries are even blocking the innocuous idea of an IAEA-controlled "bank" of low-enriched uranium, seeing it as a stalking horse for a policy that would deny them their "inalienable rights" to enrichment and reprocessing technology, even though few are interested in acquiring such plants at the moment.

In any case, as I have noted, reprocessing services have been offered by France, Russia and the U.K. for decades, but the requirement by Britain and France that countries take back their high-level waste was a deal killer. In the past, Russia provided reprocessing services to East European countries under which it kept their high-level waste. But there was massive public opposition, the leadership of Russia's nuclear conglomerate, Rosatom, became ambivalent, and, for various reasons, Russia's foreign customers too have almost all not renewed.[21]

Conclusion

Looking back over this history, the U.S. has done rather well by not reprocessing:

- Our nuclear utilities have been able to save more than $100 billion; and
- Our influence, backed by our example, has helped constrain the spread of reprocessing so that only one non-weapon state (Japan) reprocesses today, versus four in the 1970s, with several more states with clandestine nuclear-weapon programs interested in joining them.

Finally, I would urge this Commission to note that countries that reprocess seem to have had no more luck in siting repositories than countries that don't. The IAEA recently cited Finland, France and Sweden as being the furthest along in the repository siting process.[22] France reprocesses but Finland and Sweden do not. Japan and the U.K., the other reprocessing countries that have tried to site repositories, have had no luck thus far.

The Current 30 Nuclear-energy States				
Weapon states	**fSU Republics**	**Europe (NATO/EU)**	**Other US Allies**	**Other**
China	Armenia	Belgium	Canada	Argentina
France	Ukraine	Bulgaria	South Korea	Brazil
India	(Lithuania)	Czech Rep.	Mexico	S. Africa
Pakistan		Finland	Japan	
Russia		Germany	Taiwan	
UK		Hungary		
United States		Netherlands		
		Romania		
		Slovakia		
		Slovenia		
		Spain		
		Sweden		
		Switzerland		

The Next 25? (OECD Nuclear Energy Agency, *Nuclear Energy Outlook, 2008,* Table 2.1)		
Weapon States	**fSU Republics**	**Other**
Israel	Belarus	Bahrain. Bangladesh, Egypt. Ghana, Indonesia. Iran, Kuwait, Libya, Malaysia, Namibia. Nigeria, Oman, Philippines, Qatar, Saudi Arabia, Thailand, Turkey, UAE, Uganda, Vietnam, Yemen
	Georgia	
	Kazakhstan	

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[1] "Thirty years from now this same man-made element can be expected to be a predominant energy source in our lives." Glenn Seaborg, Chairman, U. S. Atomic Energy Commission, speech at the Fourth International Conference on Plutonium and Other Actinides, Santa Fe. New Mexico, October S. 1970, "The Plutonium Economy of the Future."

[2] *Fast Breeder Reactor Programs: History and Status* (International Panel on Fissile Materials, 2010) available at www.fissilematerials.org.

[3] "[W]e will defer , indefinitely the commercial reprocessing and recycling of the plutonium produced in the U.S. nuclear power programs. From our own experience, we have concluded that a viable and economic

nuclear power program can be sustained without such reprocessing and recycling," President Carter, "Nuclear Power Policy," 7 April 1977.

[4] Congressional Budget Office, *Comparative Analysis of Alternative Financing Plans for the Clinch River Breeder Reactor Project,* Staff Working Paper, 20 Sept1983.

[5] China recently completed a small experimental breeder reactor and is talking with Russia about buying two demonstration reactors.

[6] Tatsujiro Suzuki (now Vice Chair of Japan's Atomic Energy Commission), "Japan's Plutonium Breeder Reactor and its Fuel Cycle" in *Fast Breeder Reactor Programs: History and Status, op. cit.*

[7] "Fuel replacement device dropped into Monju fast-breeder reactor vessel" (Mainichi Japan) 27Aug. 2010, http://mdn.mainichi.jp/mdnnews/news/20100827p2a00m0na053000c.html

[8] *Global Fissile Material Report 2009* (IPFM) available at www.fissilematerials.org.

[9] Frank von Hippel, "Why reprocessing persists in some countries and not in others: The Costs and Benefits of Reprocessing" in *Expanding Nuclear Power: Weighing the Costs and Risks,* Henry Sokolski, ed., Non-proliferation Education Center (2010, forthcoming), http://www.npolicy.org/files/vonhippel%20-%20TheCostsandBenefits.pdf.

[10] Martin Forwood, *The Legacy of Reprocessing in the United Kingdom* (IPFM, 2008).

[11] France has completed all of its foreign reprocessing contracts except for a continuing contract for the fuel from one small old reactor in the Netherlands and a contract to reprocess the fuel of the reactors that Italy shut down after the 1986 Chernobyl accident.

[12] Ann MacLachlan, "EDF, Areva in tug-of-war over reprocessing price," *Nuclear Fuel*, February 25, 2008; "EDF-Areva pact ensures reprocessing, recycle," *Nuclear Fuel,* 29 Dec. 2008. For more information on France's reprocessing program, see Mycle Schneider and Yves Marignac, *Spent Nuclear Fuel Reprocessing in France* (IPFM, 2008).

[13] "[D]isposal of MOX [in a geological repository] is not considered to be a viable option," Boston Consulting Group, *Economic Assessment of Used Nuclear Fuel Management in the United States* (2006), Appendix 10. This study was funded by Areva and based on Areva's proprietary data and analysis. For a critique, see Frank von Hippel, *Managing Spent Fuel in the United States: The Illogic of Reprocessing* (IPFM, 2007).

[14] "Long-Term Nuclear Program Planning Committee publishes costs of nuclear fuel cycle," Citizens Nuclear Information Center, *Nuke Info, Tokyo* 103, Nov/Dec. 2004.

[15] For background, see Tadahiro Katsuta and Tatsujiro Suzuki, *Japan's Spent Fuel and Plutonium Management Challenges* (IPFM, 2006) and Masa Takubo, "Wake Up, Stop Dreaming: Reassessing Japan's Reprocessing Program," in *Nonproliferation Review*, Vol. 15, No. 1, March 2008, p. 72. For government updates, see Hisanori Nei, "Back end of fuel cycle regulation in Japan," session 2A; and M. Kato et al, "Activities Related to Safety Regulations of Spent Fuel Interim Storage at Japan," session 5A, *International Conference on Management of Spent Fuel from Nuclear Power Reactors, IAEA, Vienna, 31 May – 4 June 2010.*

[16] Frank von Hippel, "South Korean Reprocessing: An Unnecessary Threat to the Nonproliferation Regime," *Arms Control Today,* March 2010, p. 22.

[17] R.Bari, et al, "Proliferation Risk Reduction Study of Alternative Spent Fuel Processing," BNL-90264-2009-CP, 2009.

[18] See, for example, the comparison between the states with existing nuclear-energy programs and countries aspiring to launch programs with regard to World Bank indices corruption, stability, government "effectiveness," regulatory quality and democracy in Steven Miller & Scott Sagan, "Nuclear power without nuclear proliferation?" Deadelus, Fall 2009, p. 7.

[19] *International Status and Prospects of Nuclear Power* (IAEA, 2 Sept. 2010) para. 35.

[20] The White House, "Fact Sheet: Strengthening International Efforts against WMD Proliferation," 11 February 2004.

[21] Anatoli Diakov, "Russia's Nuclear-energy Complex and its Roles as an International Fuel-Cycle-Services Provider," chapter 8 in *Global Fissile Material Report 2007* (IPFM). Recently Ukraine has resumed shipping spent fuel for temporary storage in Russia.

[22] *International Status and Prospects of Nuclear Power, op. cit.,* para. 28.