The Case Against a Near-Term Decision to Reprocess Spent Nuclear Fuel in the United States

TESTIMONY OF
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MADAM CHAIRWOMAN AND MEMBERS OF THE COMMITTEE: It is an honor to be here today to discuss a subject that is very important to the future of nuclear energy and efforts to stem the spread of nuclear weapons – reprocessing of spent nuclear fuel.

I believe that, while research and development (R&D) on advanced concepts that may offer promise for the future should continue, a near-term decision to reprocess U.S. commercial spent nuclear fuel would be a serious mistake, with costs and risks far outweighing its potential benefits. Let me make seven points to support that view.

First, reprocessing by itself does not make any of the nuclear waste go away. Whatever course we choose, we will still need a nuclear waste repository such as Yucca Mountain.[1] Reprocessing is simply a chemical process that separates the radioactive materials in spent fuel into different components. In the traditional process, known as PUREX, reprocessing produces separated plutonium (which is weapons-usable), recovered uranium, and high-level waste (containing all the other transuranic elements and fission products). In the process, intermediate and low-level wastes are also generated. More advanced processes now being examined, such as UREX+ and pyroprocessing, attempt to address some of the problems of the PUREX process, but whether they will do so successfully remains to be seen. Once the spent fuel has been reprocessed, the plutonium and uranium separated from the spent fuel can in principle be recycled into new fuel; in the more advanced processes, some other long-lived species would also be irradiated in reactors (or accelerator-driven assemblies) to transmute them into shorter-lived species.

More Expensive

[1] Some residents of Nevada seem to see reprocessing, incorrectly, as an alternative to Yucca Mountain, but none of the strategies now proposed would eliminate the need for a repository for highly toxic nuclear waste. Indeed, it might surprise Nevadans to know that a stated purpose of the Advanced Fuel Cycle Initiative is to make it possible to bury the nuclear waste from a much larger quantity of electricity generation in Yucca Mountain – albeit after transmutation that, it is hoped, would reduce the long-term radioactive dangers posed by this waste.

Second, reprocessing and recycling using current or near-term technologies would substantially increase the cost of nuclear waste management, even if the cost of both uranium and geologic repositories increase significantly. In a recent Harvard study, we concluded, even making a number of assumptions that were quite favorable to reprocessing, that shifting to reprocessing and recycling would increase the costs of spent fuel management by more than 80% (after taking account of appropriate credits or charges for recovered plutonium and uranium from reprocessing).[2] Reprocessing (at an optimistic reprocessing price) would not become economic until uranium reached a price of over $360 per kilogram – a price not likely to be seen for many decades, if then. Government studies even in countries such as France and Japan have reached similar conclusions.[3] The UREX+ technology now being pursued adds a number of complex separation steps to the traditional PUREX process, in order to separate important radioactive isotopes for storage or transmutation,[4] and there is little doubt that reprocessing and transmutation using this process would be even more expensive. Other processes might

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[2] See Matthew Bunn, Steve Fetter, John P. Holdren, and Bob van der Zwaan, *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel* (Cambridge, MA: Project on Managing the Atom, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, December 2003, available as of June 9, 2005 at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/repro-report.pdf). For quite similar conclusions, see John Deutch and Ernest J. Moniz, co-chairs, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Cambridge, MA: Massachusetts Institute of Technology, 2003, available as of June 9, 2005 at http://web.mit.edu/nuclearpower/). The MIT study presents the results of its fuel cycle cost calculations differently, comparing the cost of a new low-enriched uranium fuel element to those of a new plutonium fuel element, assigning all the costs of reprocessing to the plutonium incorporated in the new fuel element, rather than considering reprocessing as part of the cost of spent fuel management and comparing the cost of managing a fuel element by direct disposal to those of managing it by reprocessing and recycling, as the Harvard study does. But these are differences of presentation, which have no effect on the estimated per-kilowatt-hour costs of the two fuel cycles; with the exception of a few differences in assumptions (more favorable to reprocessing in the case of the Harvard study), the conclusions of the two studies on the economics are very similar.

[3] France and Japan have been two of the countries most dedicated to reprocessing spent nuclear fuel; in both countries, and in the U.K., reprocessing continues not because it is economic but because of the inertia of past decisions and investments, the lack of available space for multi-decade interim storage of spent fuel, and arguments that the process will eventually have environmental and energy-security benefits. The French study compared a scenario in which all of the low-enriched uranium fuel produced in French reactors was reprocessed to a hypothetical scenario in which reprocessing and recycling had never been introduced, and found that not reprocessing would have saved tens of billions of dollars compared to the all-reprocessing case, and would have reduced total electricity generation costs by more than 5 percent. See Jean-Michel Charpin, Benjamin Dessus, and René Pellat, *Economic Forecast Study of the Nuclear Power Option* (Paris, France: Office of the Prime Minister, July 2000, available as of December 16, 2003 at http://fire.pppl.gov/eu_fr_fission_plan.pdf), Appendix 1. In Japan, the official estimate is that reprocessing and recycling will cost more than $100 billion over the next several decades. Studies performed by both the government and the utilities a decade ago concluded that direct disposal of spent fuel would be much less costly; new analyses performed for an advisory committee to the Japan Atomic Energy Commission in 2004 came to similar conclusions. See, for example, Mark Hibbs, "AEC Advisory Panel Clears Japan's Rokkashomura for Reprocessing," *Nuclear Fuel*, November 8, 2004; and Mark Hibbs, "Japan's Look at Long-Term Policy May Solve Rokkashomura Puzzle," *Nuclear Fuel*, July 19, 2004. The government's withholding of the data on these past studies caused a scandal in Japan. In France, the electric utility is state-owned, and so can be directed to pursue reprocessing even if it is the more expensive approach; in Japan, the utilities are seeking legislation that would subsidize the costs of reprocessing with a government-imposed charge to all electricity users.

[4] George F. Vandegrift et al., "Designing and Demonstration of the UREX+ Process Using Spent Nuclear Fuel," paper presented at "ATALANTE 2004: Advances for Future Nuclear Fuel Cycles," Nimes, France, June 21-24, 2004, available as of June 10, 2005 at http://www.cmt.anl.gov/science-technology/processchem/Publications/Atalante04.pdf.

someday reduce the costs, but this remains to be demonstrated, and a number of recent official studies have estimated costs for reprocessing and transmutation that are far higher than the costs of traditional reprocessing and recycling, not lower.[5]

To follow this course, either the current 1 mill/kilowatt-hour nuclear waste fee would have to be substantially increased, or billions of dollars in tax money would have to be used to subsidize the effort. Since facilities required for reprocessing and transmutation would not be economically attractive for private industry to build, the U.S. government would either have to build and operate these facilities itself, give private industry large subsidies to do so, or impose onerous regulations requiring private industry to do so with its own funds. All of these options would represent dramatic government intrusions into the nuclear fuel industry, and the implications of such intrusions have not been appropriately examined. I am pleased that the subcommittee plans a later hearing with representatives from the nuclear industry to discuss these economic and institutional issues.

Unnecessary proliferation risks

Third, traditional approaches to reprocessing and recycling pose significant and unnecessary proliferation risks, and even proposed new approaches are not as proliferation-resistant as they should be. It is crucial to understand that any state or group that could make a bomb from weapon-grade plutonium could make a bomb from the reactor-grade plutonium separated by reprocessing.[6] Despite the remarkable progress of safeguards and security technology over the last few decades, processing, fabricating, and transporting tons of weapons-usable separated plutonium every year – when even a few kilograms is enough for a bomb – inevitably raises greater risks than not doing so. The dangers posed by these operations can be reduced with sufficient investment in security and safeguards, but they cannot be reduced to zero, and these additional risks are unnecessary.

Indeed, contrary to the assertion in the Energy and Water appropriations subcommittee report that plutonium reprocessing in other countries poses little risk because the plutonium is immediately recycled as fresh fuel – a conclusion that would not be correct even if the underlying assertion were true – the fact is that reprocessing is far outpacing the use of the resulting plutonium as fuel, with the result that over 240 tons of separated, weapons-usable civilian plutonium now exists in the world, a figure that will soon surpass the amount of plutonium in all the world's nuclear weapons arsenals combined. The British Royal Society, in a 1998 report, warned that even in an advanced industrial state like the United Kingdom, the

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[5] See, for example, Organization for Economic Cooperation and Development, Nuclear Energy Agency, *Accelerator-Driven Systems (ADS) and Fast Reactors (FR) in Advanced Nuclear Fuel Cycles: A Comparative Study* (Paris, France: NEA, 2002, available as of December 16, 2003 at http://www.nea.fr/html/ndd/reports/2002/nea3109-ads.pdf), p. 211 and p. 216; U.S. Department of Energy, Office of Nuclear Energy, *Generation IV Roadmap: Report of the Fuel Cycle Crosscut Group* (Washington, DC: DOE, March 18, 2001, available as of July 25, 2003 at http://www.ne.doe.gov/reports/GenIVRoadmapFCCG.pdf.), p. A2-6 and p. A2-8.

[6] For an authoritative unclassified discussion, see *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, DOE/NN-0007 (Washington DC: U.S. Department of Energy, January 1997), pp. 38-39.

possibility that plutonium stocks might be "accessed for illicit weapons production is of extreme concern."[7]

Moreover, a near-term U.S. return to reprocessing could significantly undermine broader U.S. nuclear nonproliferation policies. President Bush has announced an effort to convince countries around the world to forego reprocessing and enrichment capabilities of their own; has continued the efforts of past administrations to convince other states to avoid the further accumulation of separated plutonium, because of the proliferation hazards it poses; and has continued to press states in regions of proliferation concern not to reprocess (including not only states such as North Korea and Iran, but also U.S. allies such South Korea and Taiwan, both of which had secret nuclear weapons programs closely associated with reprocessing efforts in the past). A U.S. decision to move toward reprocessing itself would make it more difficult to convince other states not to do the same.

Advocates argue that the more advanced approaches now being pursued would be more proliferation-resistant. Technologies such as pyroprocessing are undoubtedly better than PUREX in this respect. But the plutonium-bearing materials that would be separated in either the UREX+ process or by pyroprocessing would not be radioactive enough to meet international standards for being "self-protecting" against possible theft.[8] Moreover, if these technologies were deployed widely in the developing world, where most of the future growth in electricity demand will be, this would contribute to potential proliferating states building up expertise, real-world experience, and facilities that could be readily turned to support a weapons program.[9]

Proponents of reprocessing and recycling often argue that this approach will provide a nonproliferation benefit, by consuming the plutonium in spent fuel, which would otherwise turn geologic repositories into potential plutonium mines in the long term. But the proliferation risk posed by spent fuel buried in a safeguarded repository is already modest; if the world could be brought to a state in which such repositories were the most significant remaining proliferation risk, that would be cause for great celebration. Moreover, this risk will be occurring a century or more from now, and if there is one thing we know about the nuclear world a century hence, it is that its shape and contours are highly uncertain. We should not increase significant proliferation risks in the near term in order to reduce already small and highly uncertain proliferation risks in the distant future.[10]

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[7] The Royal Society, *Management of Separated Plutonium* (London: Royal Society, 1998, summary available at http://www.royalsoc.ac.uk/displaypagedoc.asp?id=11407 as of June 10, 2005.

[8] See Jungmin Kang and Frank von Hippel, "Limited Proliferation-Resistance Benefits From Recycling Unseparated Transuranics and Lanthanides From Light-Water Reactor Spent Fuel," *Science & Global Security*, forthcoming.

[9] For a discussion of the importance of these elements of proliferation resistance, see Matthew Bunn, "Proliferation Resistance (and Terror-Resistance) of Nuclear Energy Systems," lecture for "Nuclear Energy Economics and Policy Analysis," Massachusetts Institute of Technology, April 12, 2004, available as of June 10, 2005 at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/prolif-resist-lecture04.pdf.

[10] For a discussion, see John P. Holdren, "Nonproliferation Aspects of Geologic Repositories," presented at the "International Conference on Geologic Repositories," October 31-November 3, 1999, Denver, Colorado; available as of June 10, 1995 at http://bcsia.ksg.harvard.edu/publication.cfm?program=CORE&ctype=presentation&item_id=1.

As-yet-unexamined safety and terrorism risks

Fourth, reprocessing and recycling using technologies available in the near term would be likely to raise additional safety and terrorism risks. Until Chernobyl, the world's worst nuclear accident had been the explosion at the reprocessing plant at Khystym in 1957, and significant accidents at both Russian and Japanese reprocessing plants occurred as recently as the 1990s. No complete life-cycle study of the safety and terrorism risks of reprocessing and recycling compared to those of direct disposal has yet been done by disinterested parties. But it seems clear that extensive processing of intensely radioactive spent fuel using volatile chemicals presents more opportunities for release of radionuclides than does leaving spent fuel untouched in thick metal or concrete casks.

Limited waste management benefits

Fifth, the waste management benefits that might be derived from reprocessing and transmutation are quite limited. Two such benefits are usually claimed: decreasing the repository volume needed per kilowatt-hour of electricity generated (potentially eliminating the need for a second repository after Yucca Mountain); and greatly reducing the radioactive dangers of the material to be disposed.

It is important to recognize that reprocessing and recycling as currently practiced (with only one round of recycling the plutonium as uranium-plutonium mixed oxide (MOX) fuel) does not have either of these benefits. The size of a repository needed for a given amount of waste is determined not by the volume of the waste but by its heat output. Because of the build-up of heat-emitting higher actinides when plutonium is recycled, the total heat output of the waste per kilowatt-hour generated is actually higher – and therefore the needed repositories larger and more expensive – with one round of reprocessing and recycling than it is for direct disposal.[11] And the estimated long-term doses to humans and the environment from the repository are not noticeably reduced.[12]

Newer approaches that might provide a substantial reduction in radiotoxic hazards and in repository volume are complex, likely to be expensive, and still in an early stage of development. Most important, even if they achieved their goals, the benefits would not be large. The projected long-term radioactive doses from a geologic repository are already low. No credible study has yet been done comparing the risk of increased doses in the near term from the extensive processing and operations required for reprocessing and transmutation to the reduction in doses thousands to hundreds of thousands of years in the future that might be achieved by this method.

With respect to reducing repository volume, while the Department of Energy (DOE) has not yet performed any detailed study of the maximum amount of spent fuel that could be

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[11] See, for example, Brian G. Chow and Gregory S. Jones, *Managing Wastes With and Without Plutonium Separation*, Report P-8035 (Santa Monica, CA: RAND Corporation, 1999).

[12] This is because the uranium and plutonium separated by the traditional PUREX process, not being very mobile in the geologic environment, are not significant contributors in models of the long-term radiation releases from a geologic repository.

emplaced at Yucca Mountain, there is little doubt that even without reprocessing, the mountain could hold far more than the current legislative limit. There are a variety of approaches to providing additional capacity at Yucca Mountain or elsewhere without recycling. Indeed, as a recent American Physical Society report noted, it is possible that even if all existing reactors receive license extensions allowing them to operate for 60 years, Yucca Mountain will be able to hold all the spent fuel they will generate in their lifetimes, without reprocessing.[13] While proponents of reprocessing and transmutation point to the likely difficulty of licensing a second repository in the United States after Yucca Mountain's capacity is filled, it is likely to be at least as difficult to gain public acceptance and licenses for the facilities needed for reprocessing and transmutation – particularly as such facilities will likely pose more genuine hazards to their neighbors than would a nuclear waste repository.[14]

Limited energy benefits

Sixth, the energy benefits of reprocessing and recycling would also be limited. Additional energy can indeed be generated from the plutonium and uranium in spent fuel. But in today's market, spent fuel is like oil shale: getting the energy out of it costs far more than the energy is worth. In the only approach to recycling that is commercially practiced today – which involves a single round of recycling as MOX fuel in existing light-water reactors – the amount of energy generated from each ton of uranium mined is increased by less than 20%.[15] In principle, if, in the future, fast-neutron breeder reactors become economic, so that the 99.3% of natural uranium that is U-238 could be turned to plutonium and burned, the amount of energy that could be derived from each ton of uranium mined might be increased 50-fold.

But there is no near-term need for this extension of the uranium resource. World resources of uranium likely to be economically recoverable in future decades at prices far below the price at which reprocessing would be economic are sufficient to fuel a growing global nuclear enterprise for many decades, relying on direct disposal without recycling.[16]

Nor does reprocessing serve the goal of energy security, even for countries such as Japan, which have very limited domestic energy resources. If energy security means anything, it means that a country's energy supplies will not be disrupted by events beyond that country's control. Yet events completely out of the control of any individual country – such as a theft of poorly guarded plutonium on the other side of the world – could transform the politics of plutonium overnight and make major planned programs virtually impossible to carry out. Japan's

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[13] Nuclear Energy Study Group, American Physical Society Panel on Public Affairs, *Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risk* (Washington, D.C.: American Physical Society, May 2005, available as of June 9, 2005 at http://www.aps.org/public_affairs/proliferation-resistance), p. 17.

[14] For an initial discussion of these points, see Bunn, Fetter, Holdren, and van der Zwaan, *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel*, pp. 64-66.

[15] John Deutch and Ernest J. Moniz, co-chairs, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Cambridge, MA: Massachusetts Institute of Technology, 2003, available as of June 9, 2005 at http://web.mit.edu/nuclearpower/), p. 123. They present this result as uranium consumption per kilowatt-hour being 15% less for the recycling case; equivalently, if uranium consumption is fixed, then electricity generation is 18% higher for the recycling case.

[16] For discussion, see "Appendix B: World Uranium Resources," in Bunn, Fetter, Holdren, and van der Zwaan, *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel.*

experience following the scandal over BNFL's falsification of safety data on MOX fuel, and following the accidents at Monju and Tokai, all of which have delayed Japan's plutonium programs by many years, makes this point clear. If anything, plutonium recycling is much *more* vulnerable to external events than reliance on once-through use of uranium, whose supplies are diverse, plentiful, and difficult to cut off.

Premature to decide – and no need to rush

Seventh, there is no need to rush to make this decision in 2007, or in fact any time in the next few decades. Dry storage casks offer the option of storing spent fuel cheaply, safely, and securely for decades. During that time, technology will develop; interest will accumulate on fuel management funds set aside today, reducing the cost of whatever we choose to do in the long run; political and economic circumstances may change in ways that point clearly in one direction or the other; and the radioactivity of the spent fuel will decay, making it cheaper to process in the future, if need be. Our generation has an obligation to set aside sufficient funds so that we are not passing unfunded obligations on to our children and grandchildren, but it is not our responsibility to make and implement decisions prematurely, thereby depriving future generations of what might turn out to be better options developed later. Indeed, because the repository will remain open for 50-100 years, with the spent fuel readily retrievable, moving forward with direct disposal will still leave all options open for decades to come.

Similarly, there is no need to rush to set up new interim storage sites on DOE or military sites, and no possibility of performing the needed reviews and getting the needed licenses to do so by 2006, as the Energy and Water appropriations subcommittee proposed.[17] There is a legitimate debate as to whether such interim spent fuel storage prior to emplacement in a geologic repository should be centralized at one or two sites, or whether in most cases the fuel should continue to be stored at existing reactor sites. In any case, the government should fulfill its obligations to the utilities by taking title to the fuel and paying the cost of storage. At the same time, we should continue to move toward opening a permanent geologic repository as quickly as we responsibly can – in part because public acceptance of interim spent fuel storage facilities is only likely to be forthcoming if the public is convinced that they will not become permanent waste dumps.

Nor is there any need to rush on deciding whether a second nuclear waste repository will be needed. While existing nuclear power plants will have discharged enough fuel to fill the current legislated capacity limit within a few years, the reality is that it will be decades before sufficient fuel to fill Yucca Mountain has in fact been emplaced. We can and should defer this decision, and take the time to consider the options in detail. Congress should consider amending current law and giving the Secretary of Energy another decade or more before reporting on the need for a second repository.

Proponents of deciding quickly on reprocessing sometimes argue that such decisions are necessary because no new nuclear reactors will be purchased unless sufficient geologic repository capacity for all the spent fuel they will generate throughout their lifetimes has already

[17] See, for example, Allison Macfarlane, "Don't Put Waste on Military Bases," *Boston Globe*, June 4, 2005.

been provided. I do not believe this is correct. I believe that if the government is fulfilling its obligation to take title to spent fuel and pay the costs of managing it, and clear progress is being made toward opening and operating a nuclear waste repository, investors will have sufficient confidence that they will not be saddled with unexpected spent fuel obligations to move forward. By contrast, if the government were seriously considering drastic changes in spent fuel management approaches which might major increases in the nuclear waste fee, investors might well wish to wait to see the outcome of those decisions before investing in new nuclear plants.

It is a good thing there is no need to rush, as we simply do not have the information that would be needed to make a decision on reprocessing in 2007. The advanced reprocessing technologies now being pursued are in a very early stage of development. As of a year ago, UREX+ had been demonstrated on a total of one pin of real spent fuel, in a small facility – and had not met all of its processing goals in that test.[18] Frankly, in my judgment there is little prospect that further development of complex multi-stage aqueous separations processes such as UREX+ will result in processes that will provide low costs, proliferation resistance, and waste management benefits sufficient to make them worth implementing in competition with direct disposal. Pyroprocessing has been tried on a somewhat larger scale over the years, but the process is designed for processing metals, and significant development is still needed to be confident in industrial-scale application to the oxide spent fuel from current reactors. Other, longer-term processes might offer more promise, but too little is known about them to know for sure.

So far, we do not have a credible life-cycle analysis of the cost of a reprocessing and transmutation system compared to that of direct disposal; DOE has yet to do any detailed estimate of how much spent fuel can be placed in Yucca Mountain, and of non-reprocessing approaches to extending that capacity; we do not have a realistic evaluation of the impact of a reprocessing and transmutation on the existing nuclear fuel industry; we do not have a serious evaluation of the licensing and public acceptance issues facing development and deployment of such a system; we do not have any serious assessment of the safety and terrorism risks of a reprocessing and transmutation system, compared to those of direct disposal; and we do not yet have assessments of the proliferation implications of the proposed systems that are detailed enough to support responsible decision-making. In short, now is the time for continued research and development, and additional systems analysis, not the time for committing to processing using any particular technology.

Recommendations

For the reasons just outlined, I recommend that we follow the advice of the bipartisan National Commission on Energy Policy, which reflected a broad spectrum of opinion on energy matters generally and on nuclear energy in particular, and recommended that the United States should:

(1) "continue indefinitely the U.S. moratoria on commercial reprocessing of spent nuclear fuel and construction of commercial breeder reactors";

[18] Vandegrift et al., "Designing and Demonstration of the UREX+ Process Using Spent Nuclear Fuel."

(2) establish expanded interim spent fuel storage capacities "as a complement and interim back-up" to Yucca Mountain;
(3) proceed "with all deliberate speed" toward licensing and operating a permanent geologic waste repository; and
(4) continue research and development on advanced fuel cycle approaches that might improve nuclear waste management and uranium utilization, without the huge disadvantages of traditional approaches to reprocessing.[19]

At the same time, the U.S. government should redouble its efforts to: (a) limit the spread of reprocessing and enrichment technologies, as a critical element of a strengthened nonproliferation effort; (b) ensure that every nuclear warhead and every kilogram of separated plutonium and highly enriched uranium (HEU) worldwide are secure and accounted for, as the most critical step to prevent nuclear terrorism;[20] and (c) convince other countries to end the accumulation of plutonium stockpiles, and work to reduce stockpiles of both plutonium and HEU around the world. The Bush administration should, in particular, resume the effort to negotiate a 20-year U.S.-Russian moratorium on separation of plutonium that was almost completed at the end of the Clinton administration.

Similar recommendations have been made in the MIT study on the future of nuclear energy,[21] and in the American Physical Society study of nuclear energy and nuclear weapons proliferation.[22]

It remains possible that someday approaches to reprocessing and recycling will be developed that make security, economic, political, and environmental sense. Research and development should explore such possibilities. Continued investment in R&D on advanced fuel cycle technologies is justified, in part to ensure that the United States will have the technological expertise and credibility to play a leading role in limiting the proliferation risks of the fuel cycle around the world. But the leverage of these technologies in meeting the most serious energy challenges of the 21st century is likely to be somewhat limited in comparison to the promise of other potential future energy technologies, and the emphasis that nuclear fuel cycle R&D should receive in the overall energy R&D portfolio should reflect that.

The global nuclear energy system would have to grow substantially if nuclear energy was to make a substantial contribution to meeting the world's 21st century needs for carbon-free energy. Building the support from governments, utilities, and publics needed to achieve that kind of

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[19] National Commission on Energy Policy, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges* (Washington, D.C.: National Commission on Energy Policy, December 2004, available as of June 9, 2005, at http://www.energycommission.org/ewebeditpro/items/O82F4682.pdf), pp. 60-61.
[20] For detailed recommendations, see Matthew Bunn and Anthony Wier, *Securing the Bomb 2005: The New Global Imperatives* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, May 2005, available as of June 10, 2005 at http://www.nti.org/cnwm).
[21] John Deutch and Ernest J. Moniz, co-chairs, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Cambridge, MA: Massachusetts Institute of Technology, 2003, available as of June 9, 2005 at http://web.mit.edu/nuclearpower/).
[22] Nuclear Energy Study Group, American Physical Society Panel on Public Affairs, *Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risk* (Washington, D.C.: American Physical Society, May 2005, available as of June 9, 2005 at http://www.aps.org/public_affairs/proliferation-resistance).

growth will require making nuclear energy as cheap, as simple, as safe, as proliferation-resistant, and as terrorism-proof as possible. Reprocessing using any of the technologies likely to be available in the near term points in the wrong direction on every count.[23] Those who hope for a bright future for nuclear energy, therefore, should oppose near-term reprocessing of spent nuclear fuel.

[23] For earlier discussions of this point, see, for example, John P. Holdren, "Improving US Energy Security and Reducing Greenhouse-Gas Emissions:The Role of Nuclear Energy," testimony to the Subcommittee on Energy and Environment, Committee on Science, U.S. House of Representatives, July 25, 2000, available as of June 10, 2005 at http://bcsia.ksg.harvard.edu/publication.cfm?program=CORE&ctype=testimony&item_id=9; and Matthew Bunn, "Enabling A Significant Future For Nuclear Power: Avoiding Catastrophes, Developing New Technologies, Democratizing Decisions -- And Staying Away From Separated Plutonium," in *Proceedings of Global '99: Nuclear Technology- Bridging the Millennia*, Jackson Hole, Wyoming, August 30-September 2, 1999 (La Grange Park, Ill.: American Nuclear Society, 1999, available as of June 10, 2005 at http://bcsia.ksg.harvard.edu/publication.cfm?program=CORE&ctype=book&item_id=2).