# Risky Appropriations:

## Gambling US Energy Policy on the Global Nuclear Energy Partnership

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# Risky Appropriations: Gambling US Energy Policy on the Global Nuclear Energy Partnership


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## ACRONYM KEY

| | |
|---|---|
| **ABR** | Advanced Burner Reactor |
| **AEC** | Atomic Energy Commission |
| **AFCF** | Advanced Fuel Cycle Facility |
| **CFTC** | Consolidated Fuel Treatment Center |
| **DOE** | United States Department of Energy |
| **EPRI** | Electric Power Research Institute |
| **GAO** | Government Accountability Office |
| **GNEP** | Global Nuclear Energy Partnership |
| **IAEA** | International Atomic Energy Agency |
| **LWR** | Light Water Reactor |
| **MIT** | Massachusetts Institute of Technology |
| **MOX** | mixed-oxide reactor fuel |
| **NAS** | National Academy of Sciences |
| **NEI** | Nuclear Energy Institute |
| **NRC** | United States Nuclear Regulatory Commission |
| **R&D** | Research & Development |
| **RD&D** | Research, Development & Deployment |
| **SNF** | spent nuclear reactor fuel |
| **TDP** | Technical Development Plan |

The Global Nuclear Energy Partnership (GNEP) has been promoted as a component of the Bush administration's commitment to a renaissance of nuclear power. The Administration, along with longtime nuclear advocates in the national laboratories and the Department of Energy (DOE), claims that GNEP would:

- Reduce dependence on fossil fuels;
- Provide abundant energy without generating carbon emissions or greenhouse gases;
- Reduce the amount of high-level radioactive wastes in a geological repository;
- Recycle used nuclear fuel to minimize waste and curtail misuse [proliferation] concerns;
- Enable developing nations to safely and securely deploy nuclear power to meet energy needs;
- Assure maximum energy recovery from used nuclear fuel; and
- Reduce the number of required U.S. geologic waste repositories to one for the remainder of this century.

However, this investigation by Synapse Energy Economics has found that, in general, GNEP is an ill-conceived, poorly supported, rushed, and technically and economically risky program that only will begin to produce benefits, if it ever does, four or more decades in the future. Even if its unproven technologies are shown to be viable, GNEP also has the potential to inhibit the adoption of more reasonable solutions to global climate change by diverting resources into an unproven and, most likely, a prohibitively expensive nuclear option. GNEP also would increase the danger of nuclear proliferation and the potential for weapons grade materials falling into the hands of hostile or unstable nations and terrorist groups. Finally, GNEP would make the United States the dumping ground for radioactive wastes from the other participating nations.

More particularly, we have made the following findings:

1. The Bush administration's announced plan for GNEP lacks important details about technical viability, proliferation risks, waste streams and ultimate life-cycle costs.

2. The administration has presented no economic analysis of the costs and benefits of the GNEP plan. Nor has it compared GNEP to other technically feasible and cost-effective alternatives. Such an economic justification should be provided before significant funds are appropriated for GNEP.

3. Full implementation of GNEP would represent a significant expansion and redirection of the nuclear industry.

4. The reference technologies and processes for GNEP already have been selected by the DOE. However, none of these technologies and processes currently exist in commercially viable applications. In fact, few of the technologies and processes that would be required for GNEP have even been shown to be viable in large engineering-scale demonstration projects.

5. The Bush administration's proposed schedule for deployment of GNEP is not feasible—the technologies that would be required to implement GNEP successfully would take decades to develop if, in fact, they can be made technically and commercially viable at all.

6. The administration's plan for GNEP would rashly lock the United States into decisions to deploy certain nuclear technologies and processes well before R&D is completed, demonstration projects are tested and operated and the chosen technologies and processes are shown to be feasible and cost-effective.

7. Developing and deploying the new facilities required for GNEP would likely be prohibitively expensive.

8. GNEP would be an unreasonably expensive and slow option for addressing global climate change.

9. GNEP would reverse the U.S. practice of not reprocessing reactor wastes.

10. It is unclear whether GNEP would eliminate the need for additional geologic waste repositories.

11. GNEP is unlikely to reduce the risk of the proliferation of nuclear materials.

12. Deployment of the facilities that would be required in GNEP could entail significant risks to the public health and safety.

13. Implementation of GNEP would require overcoming a number of significant political challenges.

A recent study by the National Academies has concluded that the GNEP program should not go forward. This assessment by Synapse Energy Economics reaches the same conclusion.

The Bush administration launched the Global Nuclear Energy Partnership (GNEP) in early 2006 with the aim of expanding the international nuclear industry and forging partnerships with other counties to address fuel supply, spent nuclear fuel and proliferation of nuclear weapons through the use of nuclear power. According to the administration, under GNEP, the U.S. and other leading nuclear countries would provide an assured supply of reactor fuel and take back spent fuel from other countries that were willing to forego development of their own uranium enrichment and reprocessing programs.

The administration claims that GNEP would:

- Reduce dependence on fossil fuels;
- Provide abundant energy without generating carbon emissions or greenhouse gases;
- Reduce the amount of high-level radioactive wastes in a geological repository;
- Recycle used nuclear fuel to minimize waste and curtail misuse [proliferation] concerns;
- Enable developing nations to safely and securely deploy nuclear power to meet energy needs;
- Assure maximum energy recovery from used nuclear fuel; and
- Reduce the number of required U.S. geologic waste repositories to one for the remainder of this century.[1]

As announced, GNEP would involve the construction and operation of a substantial number of new nuclear fuel cycle facilities, including:

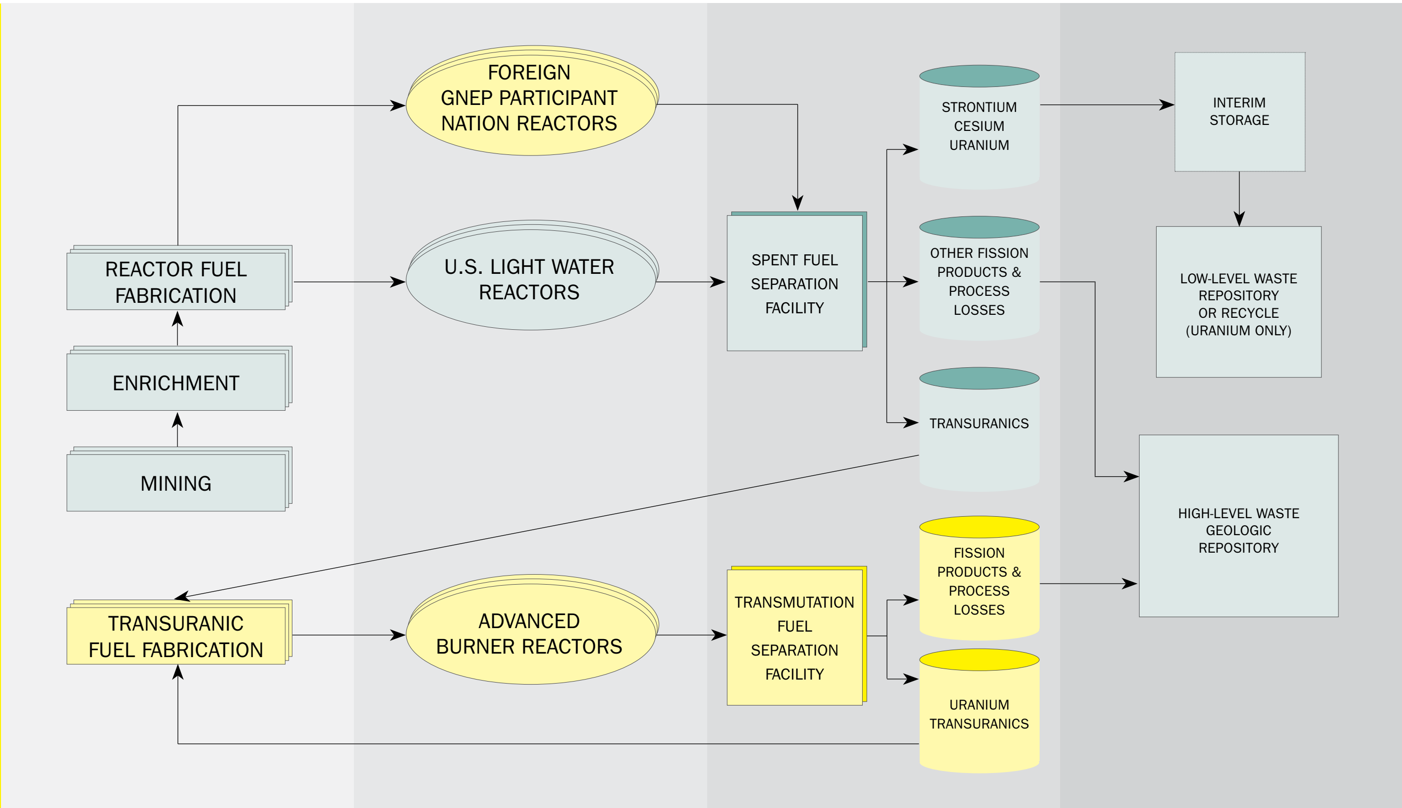
- A Consolidated Fuel Treatment Center (CFTC) for the chemical separation and recycling of spent fuel materials and disposal of wastes from existing Light Water Reactors (LWR);
- A number of fast-neutron Advanced Burner Reactors (ABR or "fast" reactors) which would use transuranic materials, including plutonium, as their basic fuel;
- Facilities to reprocess the spent fuel wastes from ABRs;

- An Advanced Fuel Cycle Facility (AFCF) to serve as a research and development center for developing fuels for the ABRs and for improved fuel cycle technology.

- Smaller "grid-appropriate" reactors, scaled for use in developing countries.

The fuel cycle envisioned for GNEP is presented in Figure 1.

**Figure 1** GNEP Fuel Life-Cycle and Waste Streams




As shown in Figure 1, according to the GNEP plan, the transuranic elements in the LWRs spent nuclear fuel (SNF) would be separated from the uranium, strontium-90, cesium-137, and fission product wastes. The transuranics are those elements with atomic numbers higher than uranium—element 92. The main transuranics of concern would be plutonium (element 94), neptunium (element 93), americium (element 95), and curium (element 96). The transuranics account for much of the risk posed by spent fuel waste after the first several hundred years. The separated transuranic elements then would be fabricated into fuel for the ABRs.

The uranium that was extracted during the reprocessing of the LWR spent fuel would be recycled or disposed. The separated strontium-90 and cesium-137 fission products would be placed initially in near-surface storage and, after hundreds of years, disposal. According to the DOE, the remaining fission products left after the separation of these waste streams would be stored in a high-level waste geologic repository.

Under the GNEP plan, ABRs would be used to change the transuranics (also called burning or transmutation) and other long-lived radionuclides into shorter-lived radionuclides that could be more easily disposed of. The ABRs would use fast-neutrons to achieve this transmutation of the transuranics. Several cycles of burning in the ABRs would be required for the nearly complete transmutation of the transuranics into shorter-lived radionuclides. Thus, the plan is to reprocess and recycle the wastes from the ABRs into new ABR fuel. The fission product wastes created in the ABR during each burning cycle would be stored in a high-level waste geologic repository.

Current DOE thinking appears to be that the ABR waste processing and fuel fabrication facilities would be co-located with the ABRs in 'power parks' in order to reduce transport requirements. The DOE also is proposing that the ABRs would be liquid sodium cooled with designs adapted from the Plutonium Breeder Reactors that the nuclear industry was interested in commercializing back in the 1970s and early 1980s.

In addition to reprocessing the spent fuel wastes produced at LWRs in the United States, GNEP also would involve the transport of reactor-ready fuel to participating developing nations and the return of LWR SNF wastes from those nations. The LWR SNF wastes being returned from participating developing nations would add to the flows of radioactive wastes that would have to be surface stored, disposed in the near surface, buried in the high-level waste geologic repository, or recycled into ABR fuel.

***Reprocessing spent fuel wastes would significantly increase the risks of proliferation of nuclear weapons and nuclear materials.***

The administration is rushing into the development and deployment of GNEP when none of the technologies and processes that would be used in the GNEP fuel cycle actually has been shown to be commercially viable. In fact, except for the conceptual ABR design, the refeence technologies and processes that have been selected for GNEP (i.e., UREX + LWR waste reprocessing; ABR waste reprocessing and grid appropriate reactors) have not been proven to be technically viable in large engineering-scale demonstrations. And the DOE acknowledges that there are high programmatic risks associated with develoment of the ABRs. A 1996 National Academies study of the potential for reprocessing and recycling spent LWR fuel, *Nuclear Wastes: Technology for Separations and Transmutation*[2] (hereinafter "1996 National Academies study"), concluded that the reprocessing plants and transmutation reactors on which a GNEP-like reprocessing strategy would depend represented as-yet unproven technology.[3] This conclusion remains valid today. Thus, GNEP is a tremendous gamble with taxpayer money, especially considering the extremely accelerated deployment schedule announced by DOE and the Bush administration.

The basic closed fuel cycle planned for GNEP is not a new concept. Rather, the idea of converting to a closed nuclear fuel cycle that would involve the reprocessing of LWR wastes had been a goal of several earlier plans for a nuclear renaissance in the United States. However, a number of studies have shown that the transition to reprocessing of spent fuel wastes would be significantly more expensive and would increase the risks of the proliferation of nuclear weapons and nuclear materials into the hands of terrorists or hostile or unstable nations. For example, the 1996 National Academies study concluded that a GNEP-like, closed fuel cycle system could cost as much as $500 billion (in 1992 dollars) and take 150 years to eliminate the stockpiles of spent reactor fuel from existing LWRs in the United States.

The 1996 National Academies study also concluded that "successful implemetation of [an] integrated reprocessing/irradiation strategy [i.e., the transmutation of transuranics and fission products recovered from spent LWR fuel] would require a major financial commitment to the development, design, construction and operation of a series of reprocessing plants and transmutation reactors based largely on as-yet unproven technology."[4] Eleven years later, in 2007, this conclusion remains valid.

*The extent of the risk and price uncertainty involved in GNEP should be a serious red flag to policymakers.*

The 1996 National Academies study also warned that "in the present context of institutional relationships in the United States, developing, siting, and licensing an entire system of high-technology nuclear facilities, for which few precedents exist, are likely to take a very long time, cost a great deal, and continue to lack the assurance of eventual success. Any decision to build and operate [a GNEP-like reprocessing and recycling] system must take these constraints into account."[5] The study also warned that "the continuing delays in the planned operation of Yucca Mountain are indicative of the difficulties licensing and siting [a GNEP-like] system could encounter."[6]

DOE and the Bush administration apparently hope that movement on the GNEP proposal would enhance prospects for the recycling of LWR spent fuel wastes and, consequently, reduce the fierce opposition to the siting of a permanent fuel repository at Yucca Mountain. The principal advantage claimed by the administration for the reprocessing of LWR SNF wastes in GNEP would be that doing so would result in less long-lived waste per ton of spent fuel and that the residue from more spent fuel could be stored in the Yucca Mountain repository before a second repository would be required.

However, as will be explained in this report, the proposed GNEP is unlikely to successfully address these factors. In particular, it is clear that GNEP would not affect the prospects for the proposed Yucca Mountain permanent high level waste geologic repository. Nor does it appear that GNEP would produce wastes that are more proliferation-resistant. Moreover, GNEP will likely be so expensive that the federal government will have to own the facilities outright, perhaps with private industry participating as contractor/operators, or will have to provide hundreds of billions of dollars in subsidies and incentives to private industry in order to make the various facilities commercially viable. Thus, the extent of the risk and price uncertainty involved in GNEP should be a serious red flag to policymakers.

## 2007 National Academies study

A 2007 National Academies *Review of theDOE's Nuclear Energy Research and Development Program* ("2007 National Academies study") recommended that the GNEP program not go forward and that it should be replaced by a less aggressive research program.[7] This was based on the following findings:

1. Domestic waste management, security and fuel supply needs are not adequate to justify early deployment of commercial scale-scale reprocessing and fast reactor facilities.

2. The state of knowledge surrounding the technologies required for achieving the goals of GNEP is still at an early stage, at best a stage where one can justify beginning to work on an engineering scale. However, it seems to the committee that DOE has given more weight to schedule than to conservative economics and technology. To carry out or even initiate efforts on a scale larger than the engineering-scale in the next decade would be inconsistent with safe economic and technical practice.

3. The cost of the GNEP program is acknowledged by DOE not to be commercially competitive under present circumstances. There is no economic justification to go forward with this program at anything approaching commercial scale. Continued research and development are the appropriate level of activity, given the current state of knowledge.

4. Several fuel cycles could potentially meet the eventual goal of creating a justifiable recycling system. However none of the cycles proposed, including UREX+ and the sodium fast reactor, is at a stage of reliability and understanding that would justify commercial-scale construction at this time.

5. The qualification of multiple-recycled transuranic fuel is far from reaching a stage of demonstrated reliability.[8]

## CONCLUSION:

The administration's rush to develop and deploy GNEP is unnecessary and imprudent. Instead of committing to a program that may ultimately cost more than $700 billion, the administration should take a more reasoned approach and study whether there are less costly and more proliferation-resistant alternatives than a dramatic expansion of the nuclear industry for achieving the goals of reducing reliance on fossil fuels and greenhouse gas emissions and finding a viable long-term storage option for the existing stockpiles of spent reactor fuel wastes.

The administration's plan calls for a decision by the Secretary of Energy in 2008 on the path forward for GNEP. However, it is clear through review of available DOE documents that the administration is already fixated on the use of certain technologies and processes even though these technologies and processes have not been shown to be technically feasible or economically viable. Nor is there any evidence that the numerous facilities that the administration intends would be built and operated as part of GNEP actually can operate reliably for the tens and hundreds of years that will be required to eliminate the stockpiles of spent fuel wastes that have already been produced by LWRs in the United States and that will be produced in the future by reactors in the U.S. and other countries.

There is no evidence that GNEP actually would reduce the threat of proliferation of nuclear weapons and nuclear materials to other nations and terrorists. Indeed, the flows and stockpiles of radioactive wastes, and potential nuclear bomb making materials, would actually increase significantly under GNEP. Not only will more radioactive materials that are less "self-protecting" be produced under GNEP, but their wide deployment over myriad transport routes will create additional access points at which these materials could be intercepted and diverted.

Under GNEP, the United States would become a final dumping ground for the spent fuel wastes from other countries. If the administration's plans for reprocessing and recycling these wastes are not proven to be viable, future generations of Americans will have the health, environmental and economic burdens of disposing of them.

*If the administration's plans for reprocessing and recycling these wastes are not proven to be viable, future generations of Americans will have the health, environmental and economic burdens of disposing of them.*

Finally, the administration has provided very few details on GNEP other than a detailed Technical Development Plan that merely represents a list of possible deadlines by which the DOE hopes that it will produce further GNEP studies and analyses. In particular, the administration has produced no information on the ultimate life-cycle cost of GNEP or the magnitude of the waste streams that would be produced under GNEP.

For these reasons, Congress should not appropriate funds for GNEP.

### *The Bush administration's announced plan for GNEP lacks important details about technical viability, proliferation risks, waste streams, and ultimate life-cycle costs.*

The Bush administration has claimed that GNEP is a comprehensive strategy to increase U.S. and global energy security, reduce the risk of nuclear proliferation, encourage clean energy development around the world, and improve the environment. However, the administration's information releases on GNEP have been long on "vision" and very short on any details concerning the technical achievability, cost, and schedule of reaching these goals through GNEP. The administration has provided especially few details about the expected ultimate cost of GNEP.

The administration's proposed GNEP also has been described as "something of a moving target:"

> When first announced, GNEP was cast as a bold new approach toward the global nuclear economy, aimed at attacking the dangers of proliferation and significantly reducing the nuclear waste problem at the same time… The story presented to the US Congress is decidedly domestic, focusing almost entirely on a way to stretch the capacity of Yucca Mountain. [9]

Indeed, in May 2006, the House Energy and Water Development Appropriations Subcommittee in the Republican-controlled 109th Congress expressed "serious reservations about GNEP as proposed by the administration" even though it strongly endorsed the overall concept of recycling spent nuclear fuel.[10] The "overriding concern" of the Subcommittee was "simply that the Dept. of Energy has failed to provide sufficient detailed information to enable Congress to understand fully all aspects of this initiative, including the cost, schedule, technology development plan, and waste streams from GNEP."[11]

The Subcommittee also warned that the GNEP proposal fell short in a number of critical areas. Among these were inclusion of Advanced Burner (ABR) or fast reactors, lack of linkage to Yucca Mountain, and inadequate information on waste streams and life-cycle costs.[12]

More specifically, the Subcommittee noted that when Congress provided funding in Fiscal Year 2006 for integrated spent fuel recycling, the DOE's plan had been to recycle reprocessed LWR wastes in mixed-oxide (MOX) fuel for LWRs. However, the GNEP plan proposed in early 2006 now included fast reactors, which "adds significant cost, time and risk to the recycling effort."[13] But, the DOE had "failed to provide any comparison of the relative costs and benefits of the two approaches to convince Congress and the public that the UREX+ [reprocessing technology] coupled with fast reactors is the best approach to recycling spent fuel."[14]

The Subcommittee also expressed concern that it appeared that the DOE had "decided to put its emphasis on GNEP and put Yucca Mountain on the back burner." In addition, the DOE had failed to produce a complete accounting of the estimated volumes, composition, and disposition of the waste streams that will be involved in GNEP.[15]

The House Committee on Appropriations in the current 110th Congress reached similar conclusions concerning the absence of critical information on GNEP. The Committee also expressed concern about the administration's failure to justify the urgency underlying the rush to implement GNEP.

> ***"DOE has failed to provide sufficient detailed information to enable Congress to understand fully all aspects of this initiative, including the cost, schedule, technology development plan, and waste streams from GNEP."***
>
> —House Energy and Water Development Appropriations Subcommittee, May 2006

For example, in its June 2007 report to the entire House on the 2008 Energy and Water Development Appropriations Bill, the Committee found that the aggressive GNEP program proposed by DOE "is at best premature."[16] The Committee further reported that it does not support the DOE's "rushed, poorly-defined, expansive, and expensive Global Nuclear Energy Partnership proposal. There is no compelling urgency to reach a decision point in the summer of 2008, nor is there urgency to begin the development of commercial-scale recycling facilities. Further research is required before the U.S. should commit the magnitude of funding proposed under the GNEP initiative."[17]

In addition, the House Appropriations Committee expressed concern about the inclusion of fast reactors and the spent fuel recycling approach in GNEP:

> *GNEP's inclusion of fast reactors*—The Department's concept of the GNEP includes the development of fast burner reactors. The ultimate benefit of reducing the requirements for permanent geologic disposal largely results from the destruction of long-lived radionuclides in fast reactors and requires multiple cycles of reprocessing spent fuel fast reactor fuel. Considerable research is needed before it is possible to judge the actual technology to be used or the costs and economic viability of this critical element of the GNEP approach.
>
> There are also concerns with the development of fast reactors in general. To date, virtually all fast reactors have been configured as breeder reactors, and breeder reactors, as the name implies, create more plutonium

> than they consume in fissionable material. Encouraging the development of this technology and reliance on fast reactors as part of spent fuel management poses proliferation risks.
>
> *Divergence of Congressional and Department concepts for spent nuclear fuel recycling*—.... GNEP envisions a very different process, using fast burner reactors to destroy more completely the plutonium and other actinides in the spent fuel. The Department has failed to convince the Committee that advanced separations technology coupled with fast reactors is a viable, comprehensive approach to recycling spent fuel.[18]

As a result, DOE had failed "to persuade the Committee of the critical need to proceed with GNEP now."[19]

In late July 2007, the GNEP Technical Integration Office at the Idaho National Laboratory prepared a GNEP Technology Development Plan (TDP) for the DOE. However, rather than providing any of the detailed information that the Congress deemed essential for a reasoned evaluation of the GNEP proposal, the TDP identified in great detail the many areas where the technologies and processes that would be required for GNEP do not exist and, consequently, where significant research and development efforts are required before it can even be determined whether those technologies and processes are technically and economically feasible.

The TDP also listed a significant number of studies and analyses that would be prepared over the next five years. However, it provided no detailed information on the projected overall cost of GNEP, the estimated volumes, compostion, and disposition of the waste streams that would be created in GNEP, the relative costs and benefits of including fast reactors and the UREX + fuel reprocesing in GNEP, the risks that deployment of the facilities that would be required in GNEP would pose to the public health and safety, or the implications of GNEP for the proliferation of nuclear weapons and weapons making technologies and materials to terrorists. Congress should not appropriate any funds for GNEP without detailed review and analysis of all of this information.

***Rather than providing the detailed information that Congress deemed essential for a reasoned evaluation, the DOE's 2007 Technology Development Plan for GNEP identified in great detail the many areas where the requisite technologies and processes do not exist and, consequently, where significant research and development efforts are necessary.***

## FINDING NO. 2

***The administration has presented no economic analysis of the costs and benefits of the GNEP plan. Nor has it compared GNEP to other technically feasible and cost-effective alternatives. Such an economic justification should be provided before significant funds are appropriated for GNEP.***

The House of Representatives Energy and Water Development Appropriations Subcommittee in the 109th Congress noted in May 2006 that the Bush administration had not presented any economic analysis to justify the huge expenditures that would be required to develop, build and operate the facilities that would be required as part of GNEP:

> The Department has failed to produce even the most rudimentary estimate of the life-cycle costs of GNEP. Before the Department can expect the Congress to fund a major new initiative, the Department should provide Congress with a complete and credible estimate of the life-cycle costs of the program.[20]

In June 2007, the House Appropriates Committee in the new 110th similarly found that the DOE had failed to provide adequate information on GNEP's waste streams and life-cycle costs:

> The cost estimates for construction and commissioning of the Hanford Waste Treatment Plan (WTP) have gone from $4.3 billion to over $12 billion in just three years, and there are numerous other examples of major construction projects with considerable cost growth and poor project management by the Department. Embarking on a costly process leading to major new construction projects is unwise, particularly where there is no urgency, and the Department has failed to persuade the Committee of the critical need to proceed with GNEP now. In addition, before the Department can expect the Committee to support funding for a major new initiative, the Department must provide a complete and credible estimate of the life-cycle costs of the program [and] demonstrate that it can manage and control the costs of its ongoing projects.[21]

Prudent management of the nation's economic and financial resources requires that the claimed costs and benefits of GNEP should be measured against the costs and benefits of other alternatives for generating power and for addressing the long-term disposal of the country's existing stockpiles of spent reactor fuel. Such an assessment should begin, as the House Subcommittee as noted, with a complete and credible estimate of the life-cycle costs for the program. But the administration has yet to provide even the most cursory information on GNEP's expected life-cycle costs:

> One might hope that the DOE would be backing up its recycling proposal with a detailed economic analysis, but only the sketchiest assertions about costs have been made thus far. The report to Congress says that one of the goals of the R&D program is to make recycling "economic" but little else. The value of recovered fuel will not make recycling worthwhile for the many decades that cheap uranium supplies are expected to last. Moreover, fast-neutron burner reactors will inevitably be more expensive than their thermal cousins. Cheaper electricity is not the justification for recycling. The cost of operating reprocessing facilities and fast-neutron reactors will be reflected in their management, ownership and control.[22]

The GNEP TDP issued in late July 2007 states that economic analyses will be included in the Deployment System Analysis to be completed during Fiscal Year 2007.[23] However, it remains very unclear how detailed the life-cycle costs that will included in these economic analyses will be given the significant uncertainty surrounding the unproven technologies and processes that will employed in GNEP. It also does not appear that the DOE intends to complete any economic analyses that compare the costs and benefits of GNEP to any other alternatives (nuclear or non-nuclear) for generating power, addressing the growing stockpiles of spent LWR reactor fuel and reducing the risks of nuclear weapons and materials proliferation.

*Prudent management of the nation's economic and financial resources requires that the claimed costs and benefits of GNEP be measured against the costs and benefits of other alternatives for generating power as well as for addressing the long-term disposal of the country's existing stockpiles of spent reactor fuel.*

The federal budget for Fiscal Year 2006 requested a review by the National Academy of Sciences (NAS) of the nuclear energy research programs and budget at DOE. The Commitee that was tasked with performing this review released its findings in late October 2007, in which members expressed concern that the administration had not provided any economic basis for their plan to move rapidly to recycling of reactor wastes and the fast ABRs, and that there is no economic justification to go forward with GNEP at anything approaching commercial scale.[24] The Committee also noted that:

> The DOE has not yet completed a cost analysis of the alternative pathways of research, development and deployment (RD&D) that could be pursued to achieve the goals of GNEP. Documents reviewed by the committee indicate that the only costs that have been estimated so far are those for a single path and a single scale, with no contingencies or uncertainties… The amounts of spent fuel, uranium needs, and the shipments of spent fuel or high-level waste to repositories should be determined as well as their volumes, radiotoxicity, vulnerability to diversion or theft. Costs, benefits and cash flow, including the fees

that would be charged to nuclear electricity consumers, should be estimated as a function of the dates for initial deployment of commercial fast reactors, their capital costs, and their growth rate. The GNEP Strategic Plan implies that these analyses will be part of a business plan to be provided to the Secretary of Energy in June 2008. The committee does not find it credible that such analyses, with uncertainties, can be accomplished by that time. Even implementing an effort to develop such a plan, implying that a credible decision can be made by June 2008, is a matter of concern to the committee.[25]

> ***"The only costs that have been estimated so far are those for a single path and a single scale, with no contingencies or uncertainties…"***
>
> —National Academy of Sciences, 2007

## *Full implementation of GNEP would represent a significant expansion and redirection of the nuclear industry.*

The United States currently has a once-through nuclear fuel cycle in which the wastes from the existing fleet of approximately 100 LWRs ultimately are intended for permanent disposal in a geologic repository. In contrast, GNEP would be a closed fuel cycle in which the plutonium created in LWRs could be burned in a substantial number of ABRs. The transuranic and long-lived radionuclides in the fuel would be burned (i.e., "transmuted") into short-lived radionuclides. This process, it is claimed, would significantly increase the amounts of radioactive wastes that could be stored in the geologic repository.

As Professor Richard Lester from the Massachusetts Institute of Technology (MIT) has noted, "The GNEP vision entails a complex large-scale extension of the existing nuclear power industry, with scores of burner reactors and associated reprocessing and fuel fabrication facilities and major additional stocks and flows of nuclear materials."[26] Professor Lester also commented that, if adopted, "GNEP would constitute the biggest shift in U.S. nuclear fuel cycle policy in decades."[27]

For example, it is estimated that the complete fissioning of LWR wastes planned as part of the closed reprocessing cycle in GNEP would require a large number of ABRs—somewhere between two ABRs for every five LWRs and three ABRs for every four LWRs.[28] This would suggest that approximately 40 to perhaps 75 fast-neutron ABRs would have to be built, along with the associated fuel fabrication and reprocessing facilities.

> *If adopted, "GNEP would constitute the biggest shift in U.S. nuclear fuel cycle policy in decades."*
>
> —Richard Lester, MIT, 2006

In addition, GNEP would require a number of LWR spent fuel reprocessing facilities to recycle the stockpiles of existing LWR wastes and to reprocess the additional wastes that would be created in the future by LWRs both in the United States and in participating developing countries. Extensive infrastructure for transporting spent nuclear fuel also would be required, as would sites for surface storage of the strontium-90 and cesium-137 fission product wastes for hundreds of years.

Finally, smaller, grid-specific reactors, with as-yet undermined designs, would be sited in developing countries that participated in GNEP. According to the recent TDP, fully meeting the GNEP vision may require the deployment of thousands of reactors in dozens of countries, many of which are in the developing world and currently do not use nuclear energy.[29] As is explained in the TDP, some of these reactors will be large-scale (>1000 MWe).[30] However, because the electric grids in many countries are small in comparison to the U.S. grid, the currently available large-scale reactors would be unsuitable because they would be "too large, too expensive and too complex."[31] Therefore, GNEP envisions the development of new types of reactors that would be "right sized" for the developing countries.[32]

**The GNEP system would have to be even larger and include more fuel handling and reprocessing facilities and ABRs than were considered by in the 1996 National Academies study.**

The 1996 National Academies study considered a contemporary plan that was very similar to GNEP, except for the provision of reactor fuel and spent fuel reprocessing services to other countries.[33] This study concluded that the closed-cycle system that would be required to have a significant benefit for disposal of the 62,000 ton stockpile of LWR spent fuel that would be accumulated by 2011 "would comprise many interdependent components, e.g., waste-transmutation reactors, spent-fuel reprocessing plants, recycled fuel fabrication plants, plants to package the residual waste for ultimate disposal, and mechanisms to transport fuel and waste between the facilities."[34]

Such a system would include tens of reactors and their associated fuel-cycle facilities.[35] Moreover, according to the 1996 National Academies study, merely developing, building and operating the individual components of the system would yield little or no benefit for waste disposition. Indeed, to even begin to have a significant benefit for disposing of spent LWR fuel wastes, an entire system of many facilities would be needed in which all the components operate with high reliability in a synchronized fashion for many decades or centuries.[36] System viability could be maintained only if the right facilities were built and put into operation at the right times.[37] The magnitude of the "concerted effort and the institutional complexity (involving long-term linkages among many private and governmental organizations) are comparable to large military initiatives that endure for much shorter periods than would be required for a [closed cycle nuclear] system."[38] Furthermore, the study concluded that the effort required to develop and deploy this GNEP-like plan would be "unprecedented in the civilian sector."[39] A cohesive national intent would have to be established, a tightly managed development program organized, and the funds for effective implementation regularly provided. However, the previous two decades of government-led programs gave the study's authors "little confidence that such conditions can be established and maintained."[40]

It is important to recognize that the system envisioned in the 1996 National Academies study was not as extensive as the administration's plan for GNEP. In particular, the system studied by the NAS did not envision that the system of ABRs and associated fuel-cycle facilities would have be extensive enough to be able to reprocess and recycle the spent LWR fuel wastes generated at reactors in other nations in addition to the wastes produced at reactors in the United States. Nor did it envision that the reprocessed wastes from other nations would ultimately be stored in repositories within the United States. Thus, the system that would be required under GNEP to address wastes, both domestic and those imported to the United States from other nations, would have to be even larger and include more fuel handling and reprocessing facilities and ABRs than were considered by in the 1996 National Academies study.

Yet the 1996 National Academies study found that the deployment and operation of a system that would be extensive enough to have a significant effect on the disposal of just domestic United States LWR spent fuel could cost as much as 500 billion dollars, in 1992 dollars, and take some 150 years decades to implement.[41] The cost of such a plan would exceed $700 billion in 2007 dollars. A full GNEP plan that would reprocess and dispose of spent reactor fuel wastes from what may be thousands of reactors in other countries can be expected to be significantly more expensive.

***The magnitude of the "concerted effort and the institutional complexity (involving long-term linkages among many private and governmental organizations) are comparable to large military initiatives that endure for much shorter periods than would be required for a [closed cycle nuclear] system."***—1996 National Academies study

## FINDING NO. 4

***The reference technologies and processes for GNEP already have been selected by the DOE. However, none of these technologies and processes currently exists in commercially viable applications. In fact, few of them have even been shown to be viable in large, engineering-scale demonstration projects.***

The DOE holds that the Secretary of Energy will make a decision in 2008 on the path forward for GNEP. However, it is clear that decisions already have been made concerning the key technologies and processes that will be developed and deployed as part of GNEP. For example, the GNEP TDP notes that the "reference technologies already have been chosen that meet the GNEP goals."[42] These technologies include LWR spent fuel reprocessing based on the UREX + separation process, recycling of transuranics in sodium-cooled fast reactors, and separating uranium from other wastes at high enough purity that it might be disposed of as low-level waste or stored for future use. The remaining wastes would be placed in long-term disposal.[43]

Successful implementation of GNEP will require research, development, engineering-scale demonstrations, construction and operation of a number of new technologies that now only exist, if at all, in laboratory-scale facilities. The GNEP TDP paints an optimistic picture and repeatedly forecasts the successful development of each of myriad of technologies and processes needed for deployment of GNEP. However, the optimistic tone of the TDP is contradicted by its own evidence concerning the early state of most of the technologies and processes that will be required for GNEP as well as by the evidence presented in other relevant government and industry studies.

For example, the UREX+ process for recycling of LWR spent fuel that DOE has said would be used in GNEP only has been demonstrated at laboratory -scale tests and then only for short periods of time. There are significant programmatic risks involved in the development of the envisioned fleet of ABRs. At the same time, the operating performance of fast-neutron reactors provides little reassurance that the ABRs planned for GNEP will operate reliably and cost effectively over the long-term. There is little, if any, actual data and testing results concerning the processes that will be used to recycle the spent fuel from the ABRs. There also is very little information concerning the design(s) of what the administration hopes will be thousands of grid-appropriate reactors that would be deployed in developing nations or regarding the facilities that would be required to transport the spent fuel from these reactors back to LWR reprocessing plants in the United States.[44]

The 1996 National Academies study, which examined a GNEP-like system, concluded that "Successful implementation of [an] integrated reprocessing/irradiation strategy [i.e., transmutation of transuranics and fission products recovered from spent LWR fuel] would require a major financial commitment to the development, design, construction and operation of a series of reprocessing plants and transmutation reactors based largely on as-yet unproven technology."[45] As confirmed in the 2007 National Academies study, this conclusion remains valid in 2007.

The very preliminary stage of the research and development work on the UREX+ reprocessing technology is illustrated in testimony provided to the Energy Subcommittee of the U.S. House of Representatives Committee on Science at a June 16, 2005 hearing on nuclear fuel reprocessing by Phillip J. Finck, Deputy Associate Laboratory Director for Applied Science and National Security at Argonne National Laboratory. Mr. Finck identified the following "greatest technological hurdles in developing and commercializing advanced reprocessing technologies." [46]

> The first major hurdle is the current inability to test the chemical processing steps at a pilot scale using spent nuclear fuel (both as individual process steps and in an integrated manner simulating plant operations) to verify that both the process itself and the larger-scale equipment will function as intended, and to minimize the technical risks in designing the commercial-scale plant. The processing methods currently being refined under the scope of the DOE [Advanced Fuel Cycle Initiative] program are being designed to very high standards for purity of products and efficiency of recovery, in order to reduce costs and minimize the hazardous content of high-level wastes. The processes have been successfully tested at laboratory-scale (about 1/1 000 000 of industrial scale). Normal expectations for scale-up of industrial chemical processes are that the processes proven in the laboratory will perform well at full scale, provided that the process and equipment function as intended. In order to test process operations and equipment designs, it is necessary to conduct pilot plant operations at 1/100 to 1/1000 of industrial scale with the complete process.
>
> The second major hurdle is related to the first, in that there is an insufficient supply of some of the various chemical elements needed for the development and testing of product storage forms and waste disposal forms. However, it is anticipated that these would become available as a result of pilot-scale testing, but the lack of materials will hinder progress prior to that time.[47]

***The current status of testing of the UREX+ technology and process appears to be that it works in laboratory tests at one-one millionth of commercial size, but has not been tested in any larger scale facilities.***

In other words, the current status of testing of the UREX+ technology and process appears to be that it works in laboratory tests at one-one millionth of commercial size but has not been tested in any larger scale facilities. Moreover, as the GNEP TDP notes, though very small scale results have shown excellent agreement with model predictions, the specific UREX process has only been for short periods and with fresh solvent.[48] Therefore, any variations in process chemistry over the longer-term have not been truly identified or studied. Also, the more important processes that would be needed to successfully recycle the separated spent LWR wastes into fuel for the ABRs have never been attempted on a large scale.[49] Some have not yet even been demonstrated in laboratory testing.

*The development of fast reactor fuels containing uranium and transuranics offers a number of unique challenges compared to currently used power reactor fuels.*

In addition, experimental and demonstration liquid sodium cooled fast-neutron reactors do exist in other countries. While small fast units formerly produced some power in the United States, there are no operating commercial reactors of this design in the United States at this time. The industry's attempt to commercialize a fast breeder reactor ended in the early 1980s with the decision by Congress to cut off funding for the very expensive Clinch River Reactor program.[50]

Moreover, the operational histories of fast reactors have been not been very consistent, to say the least, and none of the plants has gained commercial success. In particular:

- The EBR-1 fast reactor began operations in the United States in 1951 but experienced a partial meltdown in 1955 and was permanently shutdown in 1963.
- Fermi-1, a 100 MWe (nominal) fast breeder reactor, was the first commercial fast reactor in the nation. It began full power operations in August 1966 but experienced a local fuel meltdown on October 6, 1966. The plant was permanently closed in 1972.
- Rapsodie, France's first sodium cooled fast breeder reactor, operated between 1967 and 1982, when it was shut down following detection of a leak.
- The French Phenix fast breeder reactor was originally rated at 250 MW. However, due to materials problems, it was decided to relicense the plant at 170 MW on two of the original three loops. The Phenix also has been shutdown for extended periods during its operating life. It is planned to be permanently retired in 2010.
- The French Superphenix was the largest (1200 MW) fast breeder reactor. The Superphenix began commercial operations in 1986 but was permanently shutdown in 1998. A lengthening series of problems kept the plant offline for most of its existence and, in fact, the plant operated for only 30 months of this twelve year period. The Superphenix was limited to only 30 percent power starting in 1994 and, thereafter, was mainly limited as a research reactor.

- Initial criticality was achieved at the 280 MW Monju fast reactor in Japan in April 1994. The plant has been shut down since it experienced a serious sodium leak and, consequently, damage in secondary system piping, in December 1995. Restart of the plant is currently projected for 2008.

- The Russian BN-600 fast reactor has been in operation since 1980 but has experienced a large number of sodium coolant leaks and fires during that period.

Indeed, as noted earlier, the Appropriations Committee of the House of Representatives in the 109th Congress warned that the plan to use fast reactors in GNEP "adds significant cost, time, and risk" to previous, less ambitious plans to recommence commercial reprocessing in the U.S.[51] Observations in the GNEP TDP support this conclusion. For example, the Plan acknowledged that:

- In general, the technologies required to demonstrate transmutation of fuels and separations are at the early stages of the feasibility effort.[52]

- There are no fuels containing uranium and transuranics that are now ready for use in fast reactors.[53]

- Neither of the two processes under consideration for extracting transuranics from spent fast reactor fuel wastes has been tested at an adequately large scale to assess their viability for commercialization.[54]

- The development of fast reactor fuels containing uranium and transuranics offer a number of unique challenges compared to currently used power reactor fuels. In addition, the fundamental mechanisms characterizing the fuel fabrication and performance are not well understood. Thus extensive testing is required.[55]

The GNEP TDP also observed that a key programmatic challenge for the development and demonstration of the liquid sodium-cooled fast reactor technology "is re-establishing the U.S. infrastructure for designing, manufacturing, and testing this technology:"

> Although many of the base sodium technology components were originally developed in the U.S., there are only limited remaining facilities and human resources, and no current industrial fabrication and testing capabilities for sodium-cooled fast reactor components. An urgent need is to re-establish the domestic manufacturing and testing infrastructure to support advanced recycling reactor deployment. International partners can provide contributions in this technology area; however, reliance on external contributions also entails significant program risk. Therefore, without a reinvigorated domestic supporting technology base, there is a large programmatic risk of not meeting programmatic and mission objectives.[56]

Thus, the GNEP TDP identified a number of critical areas concerning the development and deployment of the ABRs needed for GNEP in which the programmatic risk is high (See Figure 2).[57] As a result, considerable research and fuel demonstrations will be required before regulatory and quality assurance requirements exist in the form of ABR fuel specifications.[58]

**Figure 2** Programmatic Risks of ABR development, deployment and infrastructure

| Fast Reactor Infrastructure | Programmatic Risk |
|---|---|
| **Component Design Infrastructure** | Demonstrated at full scale. The U.S. has not built a fast reactor in decades and human resources are limited.<br><br>Programmatic risk is high because of the lack of U.S. infrastructure to support commercial deployment of fast reactor technology. |
| **Component Testing Infrastructure** | Programmatic risk is high because of the lack of U.S. infrastructure to support fast reactor component testing and development. International infrastructure is also severely degraded. |
| **Manufacturing Infrastructure** | Programmatic risk is high for ABR prototype. Infrastructure for manufacturing fast reactor components is currently insufficient to support technology demonstration. Subsequent advanced recycling reactors will benefit from the infrastructure development activities during the ABR prototype development. |
| **Fast Reactor Safety Analysis Tools** | Programmatic risk is medium because of the personnel infrastructure to support safety code development and maintenance. Updating and validation of safety analysis and design tools is recommended. In addition, test facilities for safety testing and code validation will be required. |
| **Licensing Infrastructure** | Programmatic risk is high. Licensing strategy is unknown. The Nuclear Regulatory Commission (NRC) has very few staff who understand sodium technology.<br><br>Technical criteria for licensing need to be clarified and the regulatory structure re-established. |

The DOE has acknowledged that there are significant technological challenges to the development of GNEP and that there is a great deal of new technology that is needed to fully implement GNEP.[59] However, DOE claims that "many of the technologies essential for the successful implementation of GNEP have been demonstrated at laboratory and bench-scale."[60] But even the DOE admits that "uncertainties – such as scaling up the chemical separations for the recycle process, or fabricating and qualifying the transmutation fuel for the advanced burner reactor—exist and require consideration."[61]

Many nuclear experts are not as optimistic as the DOE about even the existence of proven technologies at the laboratory and bench scale. For example, Professor Richard Lester of MIT has noted that GNEP involves a "formidably expensive and long-term development program:"

> The list of development needs for the GNEP plan is long. It includes a modification to the PUREX reprocessing process known as UREX+. PUREX currently separates plutonium in pure form. In the UREX+ modification, plutonium extracted from light-water reactors would never be fully separated from its more radioactive actinide cousins. The idea is to preserve a barrier of radiation that would complicate unauthorized attempts to recover weapons-usable material. GNEP will also require the development of advanced burner reactor systems, new fuels and actinide targets for those reactors, fabrication methods for such materials, and new reprocessing technologies for reactor fuels.[62]

The 2007 National Academies study, which evaluated the GNEP program, found that the technologies that would be needed for GNEP are at an early stage:

> The state of knowledge surrounding the technologies required for achieving the goals of GNEP is still at an early stage, at best a stage where one can justify beginning to work at an engineering scale. However, it seems to the committee that DOE has given more weight to schedule than to conservative economics and technology. To carry out or even initiate efforts on a scale larger than the engineering-scale in the next decade would be inconsistent with safe economic and technical practice.[63]

The 2007 National Academies study also found that the qualification of the fuel that would be required for the ABRs proposed for GNEP "is far from reaching a stage of demonstrated reliability."[64] Moreover, the study concluded that "significant technical problems remain to be solved before either [LWR recycling processes being discussed for GNEP] can be considered to have been successfully demonstrated."[65] As a result, none of the cycles proposed for GNEP "is at a stage of reliability and understanding that would justify commercial-scale construction at this time."[66]

In sum, there are tremendous technological challenges and process uncertainties that merit significantly more analysis and debate than would be afforded in the DOE's accelerated decision-making process and deployment schedule for GNEP.

> ***The state of knowledge surrounding the technologies required for achieving the goals of GNEP is still at an early stage... However, it seems …that DOE has given more weight to schedule than to conservative economics and technology.***—2007 National Academies study

## FINDING NO. 5

***The Bush administration's proposed schedule for deployment of GNEP is not feasible—the technologies that would be required to implement GNEP successfully would take decades to develop, if in fact, they can be made technically and commercially viable.***

The Bush administration announced a very ambitious schedule for the deployment of the technologies that will be needed in GNEP. This accelerated deployment included an engineering-scale demonstration of the LWR reprocessing process in 2011 and a demonstration ABR to be operational in 2014, with commercial deployment of the first ABR starting in 2023. Unfortunately, DOE was silent on the deployment schedules for the subsequent reprocessing facilities and ABRs that would be required for successful implementation of GNEP.

However, another, slightly slower, milestone schedule for the deployment of the initial GNEP facilities was presented in the July 2007 by DOE:

**Figure 3** GNEP TDP Milestone Schedule for Deployment of Initial Facilities[67]

| | |
|---|---|
| **Fiscal Year 2020** | initial operation of the LWR spent nuclear fuel separations facility |
| **Fiscal Year 2020** | operations to begin in the first module of the Advanced Fuel Cycle Facility (AFCF) |
| **Fiscal Year 2022** | startup of the prototype fast reactor designed to demonstrate the destruction of transuranics |

Information in the GNEP TDP also suggests that startup testing and safety tests of the prototype ABR fast reactor actually wouldn't be completed until 2026 or so.[68] Thus, it appears that the planned initial operation of the prototype ABR may have slipped by about twelve years (from 2014 to 2026) in just the first eighteen months after GNEP was announced by the Bush administration in early 2006. The Plan also contains a caveat that the deployment schedules for the GNEP facilities remain under review by DOE and would be updated once acquisition strategies are finalized.[69] Thus, it is possible, or perhaps likely, that the announced GNEP deployment schedule will slip even further over time.

The accelerated deployment plan for spent fuel reprocessing and fast-neutron ABRs in GNEP is faster than a similar pre-GNEP deployment plan issued by the DOE in May 2005, less than a year before GNEP was announced, as part of its AFCF. For example, in its Report to Congress on the AFCI, DOE projected that advanced fast reactors would be ready for initial demonstration in approximately 2030, with commercial deployment possibly by 2040.[70] These dates are significantly later than the 2014 and 2023 ABR first demonstration and commercial dates originally announced for GNEP, but may be consistent with the later dates discussed in the GNEP TDP. However, the TDP does not include any projected dates for commercial deployment of ABRs.

Even the nuclear industry has publicly acknowledged that the rapid deployment schedule that was announced for GNEP is unrealistic. For example, Marvin Fertel, Senior Vice President and Chief Nuclear Officer at the industry's Nuclear Energy Institute (NEI), has testified before a NAS panel reviewing DOE's nuclear energy program that the quick deployment of GNEP is not likely—"It's not going to happen fast [whether] it's a good or a bad idea."[71] Mr. Fertel also explained that nuclear industry CEO's are "open minded about looking at closing the fuel cycle," but do not want to make a rush to the fast reactors. He also said that the rush on GNEP, "doesn't make sense." Instead, he recommended that the key decisions on the waste reprocessing and recycling program should wait until 2020 or 2030.[72]

*Even the nuclear industry has publicly acknowledged that the rapid deployment schedule that was announced for GNEP is unrealistic.*

John Deutsch, Professor of Nuclear Engineering at MIT and former official in the DOE, Pentagon and Central Intelligence Agency, has called GNEP a "goofy idea" and has concluded that a "more accurate timeline" for GNEP would be 2150, which he said is a "very, very, very, very, very long time in the future."[73] Professor Deutsch also testified that GNEP is "hugely expensive, hugely misdirected and hugely out of sync with the needs of the [nuclear] industry and the nation."[74]

The Electric Power Research Institute (EPRI) similarly believes that the GNEP implementation schedule is too fast. Instead, it estimates that the reprocessing of LWR spent nuclear fuel in a large-scale demonstration facility could begin operation by about 2030, with a fast reactor ABR technology demonstration in about same timeframe. Full scale commercial development of ABRs would occur in the 2050 time frame. As David Modeen, the Vice President and Chief Nuclear Officer at EPRI noted in April 2006 testimony before the Energy Subcommittee of the U.S. House of Representatives Science Committee, "These timelines are more conservative than corresponding deployment estimates provided in GNEP documents. We believe that the significant technical, resource, and licensing challenges facing these advanced technologies will drive deployment dates."

A number of nuclear policy experts, including those who support other future nuclear development, have similarly criticized the Administration's announced rapid implementation schedule for GNEP. For example, Dr. Matthew Bunn of Harvard University has warned that:

> While it is too slow to meet the industry's immediate needs, these proposed [GNEP deployment] schedules are far too fast to be realistic or to be a sensible approach to managing a long-term research and development (R&D) effort. The schedules seem to be driven more by impatience than analysis.[75]

Dr. Bunn also labeled as "absurd" DOE's expectation that it will be able to design and build a demonstration ABR that will be operational by 2014.

> DOE expects that it will not be able to open a [mixed oxide fuel] plant which is effectively a copy of existing European plants, using well-demonstrated technology until 2015, although the design is nearly complete and the NRC has already authorized construction. Yet it simultaneously expects to be able to design from scratch, get approval for, and build a prototype ABR that will be operational one year earlier, which is absurd.[76]

The 1996 National Academies study concluded that "in the present context of institutional relationships in the United States, developing, siting, and licensing an entire system of high-technology nuclear facilities, for which few precedents exist, are likely to take a very long time, cost of great deal, and continue to lack the assurance of eventual success. Any decision to build and operate [a GNEP-like reprocessing and recycling] system must take these constraints into account."[77] The study also warned that "the continuing delays in the planned operation of Yucca Mountain are indicative of the difficulties licensing and siting [a GNEP-like] system could encounter."[78]

The 2007 National Academies study found that the case presented by the promoters of GNEP for an accelerated schedule for commercial construction is "unwise."[79] In particular, it will take a very long time to have the fast ABR reactors licensed, operating competitively, and accepted commercially as power producers.[80] Indeed, the Committee concluded that "to make the GNEP closed fuel cycle a reality, fast reactors would have to account for a significant fraction of new construction in the coming decades."[81] The Committee viewed this scenario as "completely implausible."

At the same time, achieving a qualified fuel for the ABRs will take many years, "because of the time required to test the fuel through repeated fabrication cycles."[82] Thus, it regarded the development and qualification of advanced reactor fuels as a major technical challenge.

Former NRC Commissioner Gilinsky and Dr. Allison Macfarlane, Associate Professor of Environmental Policy and Social Science at George Mason University, were members of the Committee that examined the DOE's current nuclear energy research and development program for the National Academies. Although they agreed with the overall Committee conclusion that GNEP should not go forward, Commissioner Gilinsky and Dr. Macfarlane dissented to the level of DOE research and development funding that the majority of the Committee recommended in the 2007 National Academies study. In their dissent, they explained that their position that it is premature at this time to even think of going beyond the laboratory with reprocessing and fast reactor technologies:

> ...It would take many cycles through the fast reactors to burn up a large fraction of the actinides. That means, in effect, the spent actinide fuel from the fast reactors would be processed many times (each time separating the hot fission products for *surface storage*). The fast reactors' spent fuel would need an entirely new and different reprocessing technology. Each cycle—residence in the fast reactor, cooling, reprocessing, and fuel fabrication—would take a good many years. So in the best of circumstances many cycles would take the better part of a century. But no one has yet fabricated such an actinide fuel, or designed a reactor to burn it, or developed a reprocessing scheme that could handle it. It is premature to be thinking of going beyond the laboratory with reprocessing and fast reactor technologies.[83]

***The planned initial operation of the prototype ABR may have slipped by about twelve years—from 2014 to 2026—in just the first eighteen months after GNEP was announced by the Bush administration in early 2006.***

## FINDING NO. 6

***The administration's plan for GNEP would effectively and rashly lock the United States into decisions to deploy certain nuclear technologies and processes well before R&D is completed, demonstration projects are tested and operated and the chosen technologies and processes are shown to be feasible and cost-effective.***

Remarkably, the GNEP TDP cites from a 1999 Government Accountability Office (GAO) Report on the importance of not incorporating new technologies into product development programs until those technologies have demonstrated a high level of maturity:

> As discussed in a GAO Report, the experiences of government and commercial technology development programs indicate that demonstrating a high level of maturity before new technologies are incorporated into product development programs puts those programs in a better position to succeed.… It is a rare program that can proceed with a gap between product requirements and the maturity of key technologies and still be delivered on time and within costs.[84]

This reference is remarkable because the entire GNEP program is proceeding on exactly the opposite track—that is, the Bush administration decided at the outset to use the UREX+ technology for reprocessing LWR spent fuel wastes and ABRs with liquid sodium coolant even though none of the necessary technologies and processes have been shown to be technically feasible and commercially viable at medium or large-scale and most have not even been shown to be feasible at laboratory-scale. There has been no assessment of whether these are the preferred technologies and processes for achieving the stated goals of generating electricity, reducing dependence on fossil fuels and CO2 emissions and reducing proliferation risks. Nor were any electricity generation alternatives, nuclear or non-nuclear, evaluated. Instead, the various analyses that the DOE proposes to undertake are solely to justify the initial selections and to determine how they can and should be implemented.

The administration's haste in making decisions as to the technologies and processes to employ is illustrated in the observation in the GNEP TDP that there is uncertainty on the licensing requirements for the ABR fast reactors because the NRC's promulgation of design requirements and criteria will likely follow much of the study efforts and selection of the preferred design option for the advanced recycling reactor.[85] Thus, the preferred design of the ABR will be adopted by the government before the NRC determines what the applicable design requirements should be.

Former NRC Commissioner Victor Gilinsky has criticized the DOE plan for GNEP for "skipping steps," noting that the idea of skipping steps in the development of complex and difficult nuclear technologies is "ill-advised, to say the least. It has been the source of enormous problems in the past." [86] Commissioner Gilinsky also warned Congress that:

> … GNEP reminds me a lot of the [Atomic Energy Commission's] fast breeder program of the 1960s. In its eagerness to jump to the next stage of nuclear power the agency neglected a lot of technical issues that were important in the short run. That led to lots of nuclear power problems in the 1970s and I would say to the Three Mile Island accident, too. The nuclear industry learned from that accident and focused on making its plants run safely and well and that technological progress has to be incremental by moving from success to success. I get the impression the DOE and the national laboratories have not learned that lesson.
>
> There is an even more fundamental problem. So far as I know there is no historical example of the Energy Department and the national laboratories developing technologies to full scale and have them successfully adopted by the private section. Whatever happens, any DOE facilities of significant size, whether fuel cycle plants or power reactors, that are intended to develop technology for the private sector should be subject to NRC licensing. That will slow DOE down, but it will also help them to keep their feet on the ground.[87]

The government and nuclear industry's haste in the 1960s and 1970s to license and build more than one hundred new LWRs in the United States without adequate construction and operating experience also led to significant problems including construction cost increases of more than 200% to 300% at many reactors. Retrofits were required at plants based on the operating experiences gained during the first years of operation of other plants. These retrofits were often very expensive because the plants had not been designed to facilitate such design changes. Plant operating events and accidents also occurred as a result of the industry's immaturity. As Commissioner Gilinsky noted in his testimony to Congress, overtime the industry learned from the accident at Three Mile Island and other events.[88] However, it is clear that the administration and DOE have forgotten many of the important lessons learned, often at great price, from the rapid expansion of nuclear power in the 1960s through 1980s.

***The preferred ABR design will be adopted by the government before the NRC determines what the applicable design requirements should be.***

Even important elements within the nuclear industry appear not to agree with the administration's rush to make decisions about what technologies to employ in GNEP. As noted earlier, Marvin Fertel, from the industry's NEI, has testified that the key decisions on waste reprocessing and recycling program should wait until 2020 or 2030.[89] According to Mr. Fertel, by then the industry and government will have a reasonable idea of the deployment of new reactors and whether there will be a market for GNEP's international fuel services and whether the uranium supply and price situation will require reprocessed fuel.[90] Also, by that time, given the R&D of reprocessing and recycling technologies—primarily the advanced reactors that would burn the reprocessed fuel—NEI believes that the DOE would have a better idea of which spent fuel separation technology would work.[91]

Finally, as explained by Dr. Bunn, the government has a poor record of picking technology winners:

> … the proposed new separations and transmutation approaches are at a very early stage of development, and moving quickly toward selecting particular technologies, carrying out engineering-scale demonstrations, and building commercial-scale facilities risks locking in to poor choices (as has so often happened before in nuclear history). Despite the poor record of government choosing technology winners, DOE is already making this mistake: UREX+ and sodium-cooled fast reactors were chosen not because they are the only technologies that might provide attractive for the purpose, but because they were the only ones that might possibly be made available on the rushed schedule now being demanded.[92]

*"Despite the poor record of government choosing technology winners, DOE is already making this mistake: UREX+ and sodium-cooled fast reactors were chosen not because they are the only technologies that might provide attractive for the purpose, but because they were the only ones that might possibly be made available on the rushed schedule now being demanded."*

—Dr. Bunn, Harvard University, 2006

## *Developing and deploying the facilities required for GNEP would likely be prohibitively expensive.*

While the DOE has provided no evidence or information about the expected life-cycle cost of GNEP, some relevant cost information is available in the 1996 National Academies study on the reprocessing and recycling of spent LWR fuel wastes. However, the reprocessing system examined in that study was not as extensive as GNEP is planned to be because it did not include the additional facilities that would be needed to provide the fuel for reactors in other countries and to take back and reprocess the spent fuel from those reactors.

The 1996 National Academies study concluded that the licensing, construction and initial operation of a system of sufficient scale to reprocess the 62,000 tons of LWR spent fuel that will be created by the existing generation of nuclear plants in the United States through 2011 under a declining nuclear (phase-out) scenario would cost some $500 billion and require approximately 150 years to accomplish the transmutation.[93] However, this $500 billion cost estimate was in 1992 dollars. The cost of this system would be more than $700 billion in constant 2007 dollars, and would be significantly higher in nominal future year as-spent dollars.

The study also concluded that the additional costs of recycling the 62,000 tons of SNF wastes compared to a once-through system where the wastes would be stored in a geological repository were uncertain but were "likely to be no less than $50 billion and easily could be over $100 billion."[94] These incremental costs would be $72 billion to $145 billion in 2007 dollars and would be even higher if it were calculated in future year dollars.

According to the study, to start up a system that would even *begin* to affect spent-fuel emplacement in a geological repository would require one to two decades after a system demonstration and an expenditure of $20 to $40 billion beyond the costs of development and demonstration.[95] (Emphasis in original) Additional time and a much larger investment of funds would be necessary for a [Separations and Transmutation] system of sufficient scale to reduce repository hazards significantly or to affect the need for a second repository.[96]

*The $50 billion to $100 billion incremental cost that the 1996 National Academies attributed to reprocessing only reflects the additional costs of reprocessing the 62,000 tons of LWR spent fuel that will be accumulated through 2011.*

Moreover, the $50 billion to $100 billion incremental cost that the 1996 National Academies attributed to reprocessing only reflects the additional costs of reprocessing the 62,000 tons of LWR spent fuel that will be accumulated through 2011. The DOE expects that current and future LWRs will produce more than 200,000 tons of spent fuel through 2100, even under conservative future nuclear energy scenarios.[97] Under less conservative scenarios, the amount of spent fuel generated by LWRs could rise to 1.4 million tons. These figures do not include any LWR spent fuel wastes that would be brought to the United States, under GNEP, for reprocessing. The overall cost of reprocessing all of this spent fuel waste can be expected to be significantly higher than even the $500 billion figure estimated by the 1996 National Academies study.[98]

These figures do not include any reactor wastes that would be brought to the United States under GNEP from foreign participant nations, the overall cost of which can be expected to be significantly higher than even the $500 billion figure estimated in the 1996 National Academies study.

The conclusion of the 1996 National Academies study that the reprocessing of LWR spent fuel would be significantly more expensive than continued use of a once-through cycle has been supported by more recent assessments. For example, the 2003 Future of Nuclear Power study at MIT concluded that over at least the next 50 years the once-through fuel cycle best meets the criteria of low costs and proliferation resistance:[99]

> Closed fuel cycles may have an advantage from the point of view of long-term waste disposal and, if it ever becomes relevant, resource extension. But closed fuel cycles will be more expensive than once-through cycles, until [uranium] ore resources become very scarce. This is unlikely to happen, even with significant growth in nuclear power, until at least the second half of this century, and probably considerably later still. Thus our most important recommendation is:
>
> For the next decades, government and industry in the U.S. and elsewhere should give priority to the deployment of the once-through fuel cycle, rather than the development of more expensive closed fuel cycle technology involving reprocessing and new advanced thermal or fast reactor technologies.[100]

*"For the next decades, government and industry in the U.S. and elsewhere should give priority to the deployment of the once-through fuel cycle, rather than the development of more expensive closed fuel cycle technology involving reprocessing and new advanced thermal or fast reactor technologies."*

—Future of Nuclear Power, MIT, 2003

A 2003 study by the Managing the Atom Project at Harvard University study reached the same conclusion, finding that the electricity price for fast reactors (including reprocessing) "will remain significantly higher than that for LWRs operating on a once-through cycle until the uranium price increases to at least several times its current level—a development that is not likely to occur for many decades to come."[101] This conclusion is broadly consistent with the results of other recent studies.[102] This conclusion also remains valid in spite of the run up in uranium costs experienced in the past few years.

It does not appear that the cost estimates for the spent fuel reprocessing system in the 1996 National Academies study reflect any potential cost overruns and delays in the design, construction and operation of the large number of facilities that would need to be built as part of a GNEP-like project. Nevertheless, there are a number of reasons why such cost overruns and delays should be considered as likely in the development of GNEP.

First, as noted by the National Academies in its 1996 study, "severe underestimation of capital costs is the norm for *all* advanced technologies."[103] (Emphasis in original) For example, a 1988 RAND Corporation study of 52 mega-projects found that these new billion dollar mega-projects traditionally cost much more than their original estimates.[104] This is especially true for first-of-a-kind projects. The April 2007 Idaho National Laboratory report on the *Advanced Fuel Cycle Cost Basis*, similarly noted that unit cost projections usually increase as a research and development programs proceeds.[105]

***The estimated cost for construction and commissioning of the Hanford Waste Treatment Plant has increased from $4.3 billion to over $12 billion in just three years.***

Second, the history of nuclear power plant projects in the United States suggest that cost overruns and delays are likely in a project of the scale of GNEP. For example, the nuclear industry seriously underestimated the actual construction costs of the existing 100 nuclear power plants in the United States. Indeed, data on plant construction costs gathered by the DOE shows that the actual costs of 75 of the currently operating nuclear power plants in the United States were more than triple, in constant year dollars, the estimated costs of the plants.[106] The actual costs of some individual plants were five or more times higher than their estimated costs. Notably, the DOE data was conservative in that it did not include all of the cost overruns at all of the 75 plants considered and did not include many of the most expensive nuclear power plants. The cost overrun data also did not include financing costs or cost escalation due to the very extended project delays experienced by many of these projects.

Similarly, after a four year shutdown, Nuclear Fuel Services determined in the 1970s that it was too expensive to bring its commercial reprocessing facility in West Valley, New York up to regulatory standards and so abandoned the site. The DOE originally estimated in 1978 that the cleanup effort at the site would cost $1.1 billion (in 2000 dollars) and could be completed by about 1990. However, in May 2001, the GAO determined that cleanup was not nearly complete and would take up to another 40 years to finish. At the same time, GAO projected that the West Valley cleanup costs would total about $4.5 billion (also in 2000 dollars), or four times what was estimated back in 1978.[107]

More recently, the estimated cost for construction and commissioning of the Hanford Waste Treatment Plant has increased from $4.3 billion to over $12 billion in just three years and could increase further.[108]

Third, there are many other examples of cost overruns and delays in DOE funded and managed projects. For example, the DOE has contracted with Areva to build a MOX fuel fabrication plant to deal with 34 tons of excess U.S. weapon plutonium at a rate of 3.5 tons per year. It has been reported that the original estimated cost of this MOX-fuel facility, as presented to Congress in 2002, was $1 billion. By July 2005—a mere three years later—the estimated cost had ballooned to $3.5 billion and the project was already 2.5 years behind schedule.[109]

*GAO assessment in 2002 of DOE projects with estimated costs greater than $200 million similarly found that over half of the projects reviewed by the GAO had experienced both schedule delays and cost increases.*

In fact, a 1996 assessment of DOE projects by the GAO reported that:

> From 1980 through 1996, DOE conducted 80 projects that it designated as major system acquisitions. DOE has completed 15 of these projects, and most of them were finished behind schedule and with cost overruns. Three of the completed projects have not yet been used for their intended purpose. Thirty-one other projects were terminated prior to completion, after expenditures of over $10 billion. The remaining 34 projects are ongoing. Cost overruns and "schedule slippages" have occurred and continue to occur on many of the ongoing projects.[110]

A subsequent GAO assessment in 2002 of DOE projects with estimated costs greater than $200 million similarly found that over half of the projects reviewed by the GAO had experienced both schedule delays and cost increases.[111] Six of the 16 projects reviewed by the GAO had current cost estimates that were more than double the initial cost estimate.[112] Six of the projects also had experienced schedule delays of five years or longer.[113]

In May 2007, the GAO found that the DOE continues to suffer chronic project management problems, leading to schedule delays and cost increases:

> For years, GAO has reported in DOE's inadequate management and oversight of its contracts and projects and on its failure to hold contractors accountable for results. The poor performance of DOE's contractors has led to schedule delays and cost increases for many of the department's major projects. Such problems led us to designate DOE's contract management—defined broadly to include both contract administration and project management—as a high-risk area for fraud, waste, abuse and mismanagement in 1990… Ultimately, in January of this year, we concluded that despite DOE's efforts to address contract and project management weaknesses, performance problems continued to occur on DOE's major projects, and DOE contract management remained at high risk for fraud, waste, abuse and mismanagement.[114]

Moreover, significant cost overruns, and related delays, have been experienced at fuel handling and reprocessing facility projects in other nations. For example, the initial capital cost estimate of the Rokkasho-Mura spent fuel reprocessing facility in Japan has approximately tripled—from $7 billion (US$) to $20 billion (US$)—since the project was originally announced, and its completion was delayed by more than five years.[115] This experience has been offered as a cautionary tale for any country contemplating going down this road [of reprocessing SNF wastes].[116]

Finally, the cost estimates in the 1996 National Academies study do not reflect the recent skyrocketing of power plant construction costs caused by the current, more competitive environment for the design, labor and commodity resources needed to build power plants. This competitive environment has been fueled by a significant increase in the worldwide demand for power plants, particularly from China and India, and a rising domestic U.S. demand for new generating facilities.

Combined with the limited capacity of engineering and construction firms and manufactures, this worldwide demand means fewer bidders for work, higher prices, earlier payment schedules, and longer delivery times. For example, Duke Energy has said that coal plant construction costs have increased by approximately 90 to 100 percent since 2002, with costs increasing by more than 40 percent just since 2006.

It is not only reasonable to expect that these same factors will lead to significant increases in the costs of new nuclear power plants. The expansion of the nuclear industry envisioned under GNEP would further increase the demand for power plant design and construction resources and, consequently, lead to even higher prices and longer delivery schedules. Thus, the actual cost of GNEP will almost undoubtedly be higher than the $500 billion cost estimate for a GNEP-like program presented in the 1996 National Academies Study.

*The expansion of the nuclear industry envisioned under GNEP would further increase the demand for power plant design and construction resources and, consequently, lead to even higher prices and longer delivery schedules.*

FINDING NO. 8

## *GNEP would be an unreasonably expensive and slow option for addressing global climate change.*

One of the claims made for GNEP is that it would provide abundant energy without generating carbon emissions or greenhouse gases.[117] However, a number of recent studies by experts at Princeton University, MIT and the Institute for Energy and Environmental Research have shown that a significant expansion of the number of operating reactors would be required in order for nuclear power to make a meaningful contribution to addressing global climate change.

For example, Stephen Pacala and Robert Socolow of Princeton have estimated that keeping atmospheric $CO_2$ concentrations at current levels would require a reduction of $CO_2$ emissions of approximately seven billion tons per year by approximately 2054.[118] Achieving just one-seventh of this amount, or a reduction of one billion tons of $CO_2$ emissions per year, would require a tripling of the world's nuclear capacity.[119] However, because all of the existing nuclear plants are likely to have been retired by that time, approximately 1,000 new reactors would have to be built in the next 50 years.

> ***A growth scenario of tripling the world's nuclear capacity would only increase nuclear electricity's market share from 17 percent in 2000 to 19 percent in 2050.***

The 2003 MIT Future of *Nuclear Power Study* posited a similar growth scenario of tripling the world's nuclear capacity but noted that such a strategy, would only increase nuclear electricity's market share from 17 percent in 2000 to 19 percent in 2050.[120] Like, the analysis by Pacala and Socolow, the MIT Study would require the building of 1,000 new reactors over the next 50 years and would bring two new reactors on line every month.

Finally, the Institute for Environmental and Energy Research has estimated that maintaining global $CO_2$ emissions through nuclear power would require perhaps as many as 3,000 new reactors.[121] This would require the completion of more than one reactor per week over the next 40 or so years.

As shown above, such an expansion of nuclear power would be prohibitively expensive and risky.[122] It also would be an extremely slow process, taking decades to achieve any reductions in world $CO_2$ emissions, if, indeed, it ever does. This would be a much longer time frame than implementing energy efficiency measures, distributed generation, or renewable alternatives, such as wind and biomass. Such a massive expansion of nuclear power also would divert capital resources from investments in other faster and more easily deployed alternatives for reducing world $CO_2$ emissions.

In addition, tripling the world's nuclear capacity over the next 40 to 50 years would necessitate the development of a large number of additional permanent waste repositories and/or reprocessing facilities, just to handle the ongoing wastes that would be created each year by 1,000 nuclear reactors. For example, the MIT *Future of Nuclear Power Study* estimated that, in a once-through system, the disposal of the wastes from steady state deployment of approximately 1,000 reactors would require new permanent repository capacity equal to the nominal capacity of Yucca Mountain to be created in the world every three to four years.[123]

In the unlikely event that the reprocessing proposed as part of GNEP is shown to be technically and commercially feasible, perhaps as many as 30 to 40 2000-ton per year reprocessing facilities would have to be built and operated. These facilities would be located in the United States because, under GNEP, we would be responsible for the reprocessing of the world's spent reactor fuel and the ultimate disposal and storage of wastes.

A recent study for the Council on Foreign Relations has concluded that for the foreseeable future, nuclear energy will not be a major part of the solution to global warming or energy insecurity:

> Expanding nuclear energy use to make even a relatively modest contribution to combating climate change would require constructing nuclear plants at a rate so rapid as to create shortages in building materials, trained personnel, and safety controls.[124]

***Such an expansion of nuclear power would be expensive, risky, and occur over a much longer timeframe than implementing energy efficiency measures, distributed generation, or renewable alternatives.***

FINDING NO. 9

## *GNEP would reverse the U.S. practice of not reprocessing reactor wastes.*

The United States government decided not to reprocess spent nuclear fuel in the late-1970s after India used recovered plutonium to create a nuclear explosion. By the time the U.S. ban on domestic reprocessing was lifted in the early 1980s, the previously favorable conditions for the nuclear power no longer existed and there were no economic incentives for reprocessing.[125]

President Reagan reversed the official policy against reprocessing but no steps have been taken in the United States to actually reprocess spent nuclear waste. GNEP would reverse this course. It would use an unproven process, UREX+ being the current favorite, to separate LWR wastes into four streams—uranium; plutonium mixed with other transuranic elements; the 30-year half life fission products, strontium-90 and cesium-137; and other fission products. According to the GNEP plan, the transuranic elements would be recycled in the fast-neutron ABRs. Several cycles would be required to transmute the transuranics into shorter-lived radionuclides that would not require long-term storage in a geologic repository.

It has been argued that the U.S. practice of not-reprocessing spent fuel has been successful in encouraging other nations to refrain from doing so. According to Frank von Hippel of Princeton University:

> In comparison [to reprocessing], the U.S. policy, which is in effect, that "we don't reprocess and you don't need to either" has been much more successful. During the 30-year period it has been in force, no non-weapon state has initiated commercial reprocessing and seven countries have abandoned their interest in civilian reprocessing. In Belgium, Germany and Italy domestic developments were more important than U.S. policy. In Argentina, Brazil, South Korea and Taiwan, however, countries that were interested in developing a nuclear-weapon option, U.S. pressure played a key role. Today, Japan is the only non-weapon state that engages in commercial reprocessing.[126]
>
> In 2006, in response to Congressional pressure to start moving spent fuel off U.S. power-reactor sites, the Department of Energy proposed U.S. Government-funded reprocessing of the fuel and recycling of the recovered plutonium and minor transuranic elements. If carried through, this proposal would reverse a nonproliferation policy established by the Ford and Carter Administrations after India, in 1974, used the first plutonium it extracted as part of a U.S.-supported reprocessing program, to make

a nuclear explosion. U.S. policy became to oppose reprocessing where it was not already established and not to reprocess domestically. Four years later, in 1981, the Reagan Administration reversed the ban on domestic reprocessing. By that time, however, U.S. utilities had learned that reprocessing would be very costly and were unwilling to pay for it.[127]

Prof. von Hippel also has warned that a U.S. decision to pursue reprocessing could backfire and lead other nations to follow the U.S. in building fuel enrichment and reprocessing facilities.[128] Indeed, some observers have reported that the GNEP proposal already has backfired in stimulating a revival of interest in France in exporting reprocessing technology and in South Korea in acquiring its own national reprocessing capabilities.[129] As Professor von Hippel has explained:

> The idea that other countries can be permanently barred from acquiring enrichment and reprocessing plants has not gained international acceptance, however. An international panel of experts convened by the IAEA found that "there is consistent opposition by many [non-nuclear weapon states] to accept additional restrictions on their development of peaceful nuclear technology without equivalent progress on disarmament."
>
> This issue is currently joined primarily with regard to the assertion by non-weapon states of their rights to have national uranium-enrichment plants. Since the Bush Administration's 2004 proposed ban on additional countries acquiring enrichment plants, six non-possessing countries have expressed increased interest in acquiring them. The U.S. GNEP proposal has, however, already revived interest in South Korea and Areva has floated the idea of exporting the plant that it is designing for the American market to a number of non-weapon states that do not currently reprocess.[130]

Edwin Lyman from the Union of Concerned Scientists has noted the Bush administration's announcement of the GNEP project has already encouraged Areva NC, the French national nuclear fuel cycle company, to declare its intention to:

> develop a new generation of reprocessing plants for export to at least a dozen countries, potentially including the other four nuclear weapon states, Japan, Germany, Canada, Australia, the Netherlands, Argentina, Brazil, and South Africa. Such a plan would have been unthinkable before DOE's GNEP announcement in February 2006. An Areva official said that the prospects for this plan were "boosted" by the goal of organizing world commerce in spent fuel reprocessing under the GNEP program.[131]

***According to Prof. von Hippel, a U.S. decision to pursue reprocessing could backfire and lead other nations to follow the U.S. in building fuel enrichment and reprocessing facilities.***

## FINDING NO. 10

### *It is unclear whether GNEP would eliminate the need for additional geologic waste repositories.*

The 1982 Nuclear Waste Policy Act imposed a legislatively mandated limit of 70,000 metric tons of high-level radioactive wastes could be stored in the nation's first geologic repository. Under the law, commercial nuclear plant spent fuel waste were to make up no more than 90 percent of this amount, or 63,000 tons: DOE spent fuel and high level wastes are to make up the remaining ten percent or 7,000 metric tons.

The nation's commercial reactors are expected to reach the 63,000 metric ton limit of spent fuel by 2010 or 2011. The total amount of spent fuel that is expected to be generated by the existing generation of reactors over their full operating lives is about double this amount. Moreover, the DOE projects that with the continuation of the once-through fuel cycle more than 200,000 tons of spent fuel waste will be produced domestically by 2100 even under conservative scenarios for nuclear energy generation.[132] The total amount of spent fuel produced could reach 1.4 million metric tons under DOE's more optimistic nuclear growth scenarios.

*DOE projects that with the continuation of the once-through fuel cycle more than 200,000 tons of spent fuel waste will be produced domestically by 2100.*

The maximum amount of high level wastes that can be stored in a geologic repository is dependent upon the total heat load of the wastes. In order to reduce the total heat in the spent fuel wastes, it is necessary to reduce the amount of the minor transuranics, i.e., neptunium, americium, and curium. GNEP plans to do this by transmuting or burning these LWR waste products into shorter-lived radionuclides through several cycles of operation in the fast-neutron ABRs. Since one of the goals of GNEP is to reduce the long-lived hazard of high-level waste, it would also be necessary to separate and transmute the long-lived isotopes technitium-99 and iodine-129.

Whether this is a realistic plan depends on a number of factors that are uncertain at this time. First, although the DOE claims that the effectiveness of fast spectrum systems for transmutation of transuranics has been well documented,[133] it is unclear how effective this process will be when actually attempted in operating facilities. Separation of americium, curium, Tc-99 and I-129 has never been attempted on a large scale. DOE documents concerning GNEP do not provide much detail on the reprocessing technologies that will be used for the ABR fuel. Therefore, it is not possible at this time to evaluate how effective the overall ABR recycling process will be in transmuting the minor transuranics and other long-lived radionuclides.

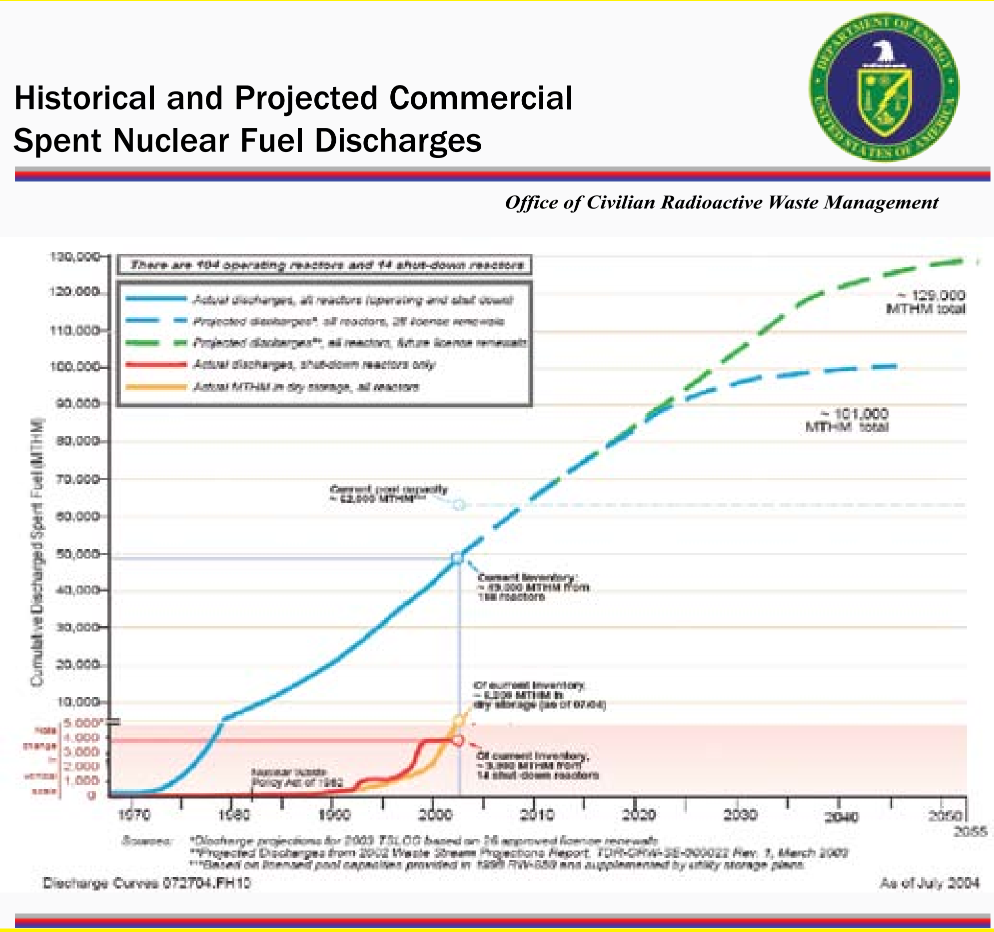



Figure 4

Moreover, unless the separation and transmutation processes are 100 percent effective, which is not likely, small quantities of long-lived radionuclides will be present in the waste. These will affect the heat load and, consequently, the total amount of high level wastes that can be stored in the geologic repository.

In addition, the amount of stockpiled LWR spent fuel that can be reprocessed will depend on when the reprocessing facilities and ABRs actually begin functioning on a consistent basis, what the total capacity of those reprocessing facilities will be, and the total amount of stockpiled spent fuel waste at that time. For example, Dr. Bunn has noted:

> GNEP envisions an engineering-scale demonstration of the UREX+ technology beginning in 2011. This would be followed, presumably many years later, by the opening of a commercial-scale plant with a capacity of over 2000 tons of heavy metal per year (tHM/yr). While that is far larger than any current commercial reprocessing plant, it is only enough to address the spent fuel US nuclear power plants generate each year—so it would do nothing to work off the backlog of tens of thousands of tons of spent fuel that will exist by the time the plant comes on line.[134]

As a result, it appears likely that existing spent fuel wastes will remain at reactor sites or at centralized reprocessing facilities for many years or decades before they are reprocessed, if, indeed, they ever are.

In their dissent to the recommendation in the 2007 National Academies study that Congress continue to fund research on reactor waste recycling, Commissioner Gilinsky and Dr. Macfarlane explained that GNEP only would reduce the amount of geologic repository capacity required by leaving the hottest fission products, cesium-137 and strontium-90 on the surface for hundreds of years:

> GNEP plans to finesse Yucca Mountain's design capacity—limited by temperature constraints on the repository rock—by leaving the heat generating waste out of the repository. In particular, it would leave the hottest fission products in surface storage. This does not expand repository capacity; it just puts less of each reactor's waste inside….
>
> Note that GNEP would leave the radioactive cesium-137 and strontium-90 on the surface. The half-lives of these isotopes are about 30 years, so they would have to remain in such storage for at least 300 years. As this would involve roughly as much storage capacity as would the original spent fuel, it is difficult to see any gain over the current once-through fuel cycle, especially considering that reprocessing would produce other waste streams as well.[135]

Indeed, Commissioner Gilinsky and Dr. Macfarlane argue persuasively that GNEP likely would exacerbate the nuclear waste problem for hundreds of years:

> Even if GNEP worked as planned it would likely exacerbate the nuclear waste problem, at least for a long time. The most important thing to remember is that the hottest fission products would accumulate on the surface for hundreds of years. These fission products are the reason that the National Research Council, the last time it looked at separation and closed fuel cycles in 1996, recommended the need for geologic repositories.[136] (Emphasis in original)

***It appears likely that existing spent fuel wastes will remain at reactor sites or at centralized reprocessing facilities for many years or decades before they are reprocessed, if, indeed, they ever are.***

## *GNEP is unlikely to reduce the risk of proliferation of nuclear materials.*

Supporters claim that GNEP will contribute to nonproliferation by establishing an international consortium of advanced nuclear nations to provide fuel enrichment and reprocessing services to other countries in exchange for a guarantee not to pursue development of fuel cycle facilities on their own. Supporters also claim that GNEP will use proliferation-resistant reprocessing and fuel cycle technologies that will not produce separated plutonium that could be used in weapons.

There have been a number of excellent assessments of the proliferation consequences of GNEP.[137] These assessments together present evidence that the optimistic claims of GNEP's supporters are wrong and that, instead, GNEP is unlikely to reduce—and may well increase—the risk of proliferation of nuclear materials.

*The plutonium-bearing materials that would be separated in the UREX+ process still would only be 1 percent to 0.1 percent of the intensity required to meet international standards for being "self-protecting" against possible theft.*

First, the proposed UREX+ LWR reprocessing strategy of keeping plutonium mixed with other, more radioactive transuranic elements would not produce much of a radiation barrier to potential proliferators.[138] In fact, several versions of the UREX+ process have been proposed in order to increase the magnitude of the radioactive shield around the separated plutonium. Unfortunately, it appears that under these iterations, the radioactivity of the plutonium-bearing materials that would be separated in the UREX+ process still would only be 1 percent to 0.1 percent of the intensity required to meet international standards for being "self-protecting" against possible theft.[139]

Under some of the versions of the UREX+ reprocessing technology being proposed, the radioactivity barrier would be so low that enough plutonium for a few bombs could be separated in a glove box without the workers receiving a large radiation dose.[140] In another version, called UREX+1, a class of radioactive fission products, the lanthanides, would remain mixed with the transuranics until the mix was transported to the ABR sites. At each ABR site, the lanthanides would be stripped out from the mix in an aqueous separation facility and the remaining plutonium and other transuranics would be fed into a fuel fabrication facility. Thus, each ABR site would have its own final stage reprocessing and fuel-fabrication plant. This would add costly steps to the GNEP fuel cycle.[141] Professor von Hippel has criticized the complexity of this proposal as approaching "that of a Rube Goldberg cartoon."[142]

Second, under GNEP, there would be dramatically increased flows of highly radioactive wastes and stocks of contaminated plutonium that might be only marginally more protected against theft than pure plutonium. Spent LWR fuel would be transported to the central reprocessing facilities located around the United States, or in one specific site, from reactors both in the United States and from foreign participant nations. Reprocessed fuel, containing plutonium and other isotopes as a radiation barrier, would be transported from the LWR reprocessing plants to the ABR sites. Then, the burned ABR fuel would have to be transported for reprocessing and new fuel fabrication unless the ABR fuel cycle facilities were co-sited with the ABRs themselves. These increased flows would create significantly more opportunities for plutonium to be diverted for potential weapons use.

Third, according to Dr. Bunn, while reactor-grade plutonium would not be the preferred material for making nuclear bombs, it does not require advanced technology to make a bomb from reactor-grade plutonium—any state or group that could make a bomb from weapon grade plutonium could do so from reactor grade plutonium.[143] Consequently, "despite the remarkable process 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."[144]

In summary, there appears to be little reason to believe that the GNEP plan would produce more proliferation-resistant waste or actually would reduce the potential for bomb-making materials falling into the hands of terrorists. Instead, GNEP has the potential for making the world less safe because of the boost it would give to reprocessing:

> The Bush Administration has failed to make a convincing case that implementation of the GNEP plan would lead to a reduction in the proliferation and nuclear terrorism threats inherent in the nuclear fuel cycle. In fact, because of the boost the plan has given to conventional reprocessing programs worldwide, it may well result in a vast increase in the worldwide flow of weapon-usable nuclear materials, and a corresponding increase in the threat that such materials will fall into the hands of rogue states or terrorists.[145]

***Increased flows of radioactive wastes and plutonium stocks would create significantly more opportunities for plutonium to be diverted for potential weapons use.***

## *Deployment of the facilities that would be required in GNEP might entail significant risks to the public health and safety.*

A series of significant events at fuel handling facilities and liquid sodium cooled fast reactors cause concern that the deployment of the LWR reprocessing facilities, possibly 40 to 75 ABRs, and associated fuel fabrication and reprocessing facilities under GNEP will threaten public health and safety.

The most serious fuel handling events appears to have been the 1957 explosion at the Russian reprocessing plant at Khyshtym of a tank containing highly radioactive wastes. The explosion spread radioactive contamination over a tract of land in the southern Urals 105 kilometers-long and 8 kilometers-wide.[146] More than 10,000 residents of the contaminated area were evacuated eventually and follow-up studies identified serious negative health effects.

The British THORP reprocessing facility was shutdown in 2005 following discovery of a substantial leak of radioactive acid solution, which was reported to have contained tens of tons of uranium and some 160 kilograms of plutonium from spent fuel.[147] The leak had not been noticed for more than three months. It is said that none of the radioactive materials escaped into the environment.

Similarly, there have been leaks from radioactive waste tanks at the Hanford facility in the United States from the 1950's to the 1970s and into the ocean from Britain's Sellafield plant in 1995. In addition, there was a nuclear criticality incident in fuel fabrication in 1999 at Japan's Tokai Mura fuel fabrication facility. Two workers were killed in this incident and a third was badly injured.

More recently, approximately 35 liters of high-enriched uranium solution leaked uncontrolled into a glove box and subsequently spilled onto the floor at the Nuclear Fuel Services facility in Erwin, Tennessee. According to the NRC's "Report to Congress on Abnormal Occurrences: Fiscal Year 2006," issued in April 2007, a criticality event was possible both in the glove box and at an uncontrolled accumulation point in a nearby elevator pit.[148]

As explained in a July 3, 2007, letter to the Chairman of the NRC from the U.S. House of Representatives Committee on Energy and Commerce, the volume of high-enriched uranium solution involved was "more than enough for criticality to be possible." If criticality had occurred, "it is likely that at least one worker would have received an exposure high enough to cause acute health effects or death."[149]

There also have been a large number of leaks and fires at liquid sodium cooled fast reactors. Sodium carries off heat extremely well as a coolant. However, sodium's major drawback is its combustibility when in contact with water. In fact, the 2007 National Academies study expressed concern that "accidents involving sodium can be serious, even disastrous, and there have been notable accidents with sodium-cooled reactors."[150]

Leaks of liquid sodium have led to the partial meltdowns of the EBR-1 test fast reactor in 1955 and the Fermi-1 reactor in 1966. A leak of approximately 650 kilograms of sodium coolant also led to the extended shutdown of Japan's Monju fast breeder reactor in December 1995—the plant remains off-line with a planned restart of 2008. France's Phenix and Superphenix fast reactors experienced a large number of leaks—the Superphenix was permanently shut down in 1998 after only a twelve year of operating life, during which it operated for a total of only 30 months. Russia's BN-600 has been in operation since 1980 but has reportedly experienced 15 sodium fires in that time.[151]

**The MIT study on the *Future of Nuclear Power* expressed concern about the risks to the public that might be posed by the new commercial reprocessing plants that would be built under certain nuclear global growth scenarios involving the reprocessing of LWR spent fuel.**[152]

**The study also explained that:**

> … There are varying degrees of risk to public safety associated with these facilities, and therefore a need for systematic evaluation of risk on a consistent basis that takes into account evaluations performed heretofore on individual fuel cycle facilities.
>
> The need for such an evaluation is especially important in the case of reprocessing plants…. Aqueous separation plants have high inventories of fission products, as well as fissile material of work in process, and many waste streams. Future improvements in separation technology may be capable of reducing radioactive material inventories, measured as a fraction of annual throughput, but inventories will continue to be large, because of the large annual product required, if and when reprocessing comes into wider commercial use many years in the future.
>
> We are concerned about the safety of repro plants because of large radioactive material inventories, and because of the record of accidents, such as the waste tank explosion at Chelyabinsk in the FSU, the Hanford waste tank leakages in the United States and the discharges to the environment

> at the Sellafield plant in the United Kingdom. Releases due to explosion or fire can be sudden and widespread. Although releases due to leakage may take place slowly, they can have serious long-term public health consequences, if they are not promptly brought under control. Although the hazards of reprocessing plants differ from those of reactors, the concepts and methods and practices of reactor safety are broadly applicable to assuring the safety of reprocessing plants. We do not see the need for commercial reprocessing in the global growth scenario, but we believe the subject requires careful study, [fn 14] and action, if and when reprocessing becomes necessary.[153]

Although the MIT study noted that it did not know of a complete inventory of accidents at reprocessing facilities, it did cite the following incidents: Chelyabinsk, FSU, reprocessing waste explosion (1957); Hanford, Washington State, waste storage tank leakage, (1970-); Sellafield, UK, reprocessing waste discharges into ocean, (1995-), Tokai-Mura, Japan, nuclear criticality incident in fuel fabrication, (1999).

Thorough analyses of the potential risks to the public health and safety of all technologies and facilities that are being considered for deployment as part of GNEP should be completed before decisions are made that will lock the nation into technology and energy infrastructure choices.

In addition, the UREX+ process that DOE plans to use in GNEP would separate the 30-year half-life fission products, strontium-90 and cesium-137 from other spent LWR fuel wastes. The highly radioactive strontium-90 and cesium-137 would likely be placed into interim surface storage for perhaps 300 to 600 years while they decay to safe levels. Presumably, this surface storage would take place at the reprocessing site, which would result in the largest source of high-heat radioactivity in the United States and possibly the world. Concentrations of strontium and cesium could be so large that if they were disposed of in shallow land burial as low-level wastes, shortly after separation they would have to be diluted to a volume as large as 500 million cubic meters.[154]

*Thorough analyses of the potential risks to the public health and safety should be completed before decisions are made that will lock the nation into technology and energy infrastructure choices.*

Professor von Hippel has offered that, along with the great cost of DOE's reprocessing plan, this proposal to "store the most dangerous isotopes in the spent fuel on the surface for hundreds of years may eventually increase the appeal of interim storage without reprocessing."[155]

## FINDING NO. 13

***Successful implementation of GNEP would require overcoming a number of significant political challenges.***

There appear to be at least five major political challenges that would have to be overcome in order for a successful implementation of GNEP:

1. The challenge to develop, build and operate the facilities needed for GNEP over a period that will span decades and, perhaps, centuries.

2. Lack of willingness of the American public to pay the hundreds of billions of incremental costs associated with GNEP.

3. Lack of willingness of the American public to support the siting of the many reprocessing facilities and ABRs that would be required under GNEP.

4. Lack of tolerance of the American public to allow the nation to become the "dumping ground" for radioactive wastes from other countries.

5. Lack of willingness of other countries to forego the development of their own nuclear fuel enrichment and reprocessing facilities and be dependent upon the United States and/or other current nuclear states for their reactor fuel supplies.

The 1996 National Academies study concluded that building a GNEP-like Separations and Transmutation system adequate to address existing and future LWR spent fuel would require a "long-term major national commitment with strong, stable, centralized government leadership and financing and operating within a favorable public perception of nuclear enterprises."[156] However, according to the study, "the last two decades of U.S. government-led nuclear programs provide little confidence that such conditions can be established and maintained."

***Successful implementation of GNEP will require coordinated actions by many successive Congresses and numerous Presidents, probably of different political parties.***

The study also concluded that "in the present context of institutional relationships in the United States, developing, siting and licensing an entire system of high-technology nuclear facilities, for which few precedents exist, are likely to take a very long time, cost a great deal, and continue to lack the assurance of eventual success. Any decision to build and operate a Separations and Transmutation system must take these constraints into account."[157] Thus, successful implementation of the administration's GNEP program will require coordinated actions by many successive Congresses and numerous Presidents, probably of different political parties. Maintaining the needed focus will be very difficult, if not impossible, in light of changing political circumstances and technological obstacles.

A representative from the DOE was asked at an international conference in 2006 whether GNEP is now national policy and can be relied on to remain stable. In response, the DOE representative conceded that a program that may take 20 years (based, it appears, on DOE's overly optimistic deployment schedule) would span ten Congresses and potentially five different presidents.[158]

The second political challenge facing GNEP is whether the American public will support the federal government expenditures that will be needed to research, develop, build, operate and eventually decommission the myriad of complex new technologies and facilities that would be needed. Over the past few decades, private markets have been, and continue to be, unwilling to invest capital in or insure new nuclear power plants. Given this reluctance, and the significant costs that can be expected for the research, development, construction and operation of closed fuel cycle facilities, it is likely that the burden of paying for GNEP will fall completely, or nearly completely, on the federal government and, consequently, taxpayers.

*Extensive federal subsidies, loan guarantees or direct federal funding are necessary if GNEP is to proceed beyond the current preliminary planning stage.*

Based on the history of the nuclear industry in the United States, private companies probably will be involved as contractors in GNEP, but they are unlikely to be willing to assume any significant ownership risks, at least until the new reprocessing and ABR facilities have been demonstrated to be commercially viable, assuming that they can be demonstrated to be commercially viable.

Nuclear utilities have made clear that they are not very interested in paying for the extra costs of a reprocessing plant or fast-neutron reactors.[159] In other words, the extra costs would have to be funded by the federal government.[160] Other assessments of GNEP have agreed about the necessity for extensive federal subsidies, loan guarantees or direct federal funding if GNEP is to proceed beyond the current preliminary planning stage.[161]

It is possible that the U.S. Congress might fund the launch of a federally funded reprocessing program plant, like GNEP, with appropriations of billions of dollars for research and development activities. However, those appropriations may well come at the expense of other programs seeking the building of new LWR reactors or development of the Yucca Mountain repository. As a result, there may be strong opposition from within the nuclear industry to diverting funding from these programs to GNEP. For example, Prof. Lester of MIT has observed that:

> The Bush administration is pushing for early selection of particular fuel cycle technologies and early commitment to large-scale multi-billion dollar demonstration projects. But these are neither necessary nor wise at this stage, and there is a real risk that they will siphon off financial resources and public support. It would be sad—and ironic—if this pronuclear administration, presiding over the most promising environment for renewed nuclear power growth in decades, ended up undermining the prospects for a nuclear revival.[162]

Prof. Bunn of Harvard has similarly written that:

> One of the remarkable aspects of the GNEP is its failure to address the US nuclear industry's three immediate needs relating to management of spent nuclear fuel. These are (1) the need to manage spent fuel building up at existing reactor sites as a result of the US government's failure to meet its obligation to begin taking it away in 1998; (2) the need to gain regulatory approval for construction and loading of a Yucca Mountain repository; and (3) the need to convince potential investors in new nuclear power plants that they will not be saddled with an indefinite liability for the spent fuel the plants generate. GNEP as currently conceived is too slow to have much of a benefit for any of these problems.
>
> It is clear…that GNEP as presently envisioned will not contribute anytime soon to addressing the problems posed by the build-up of spent fuel at reactor sites, or the growing government liability for its failure to meet its contractual obligations. Similarly, if Yucca Mountain is to be licensed any time in the next decade, it will have to be licensed without knowing whether GNEP will be workable and provide the kinds of reductions in the heat and radio toxicity of wastes that are currently envisioned. As for investors in new power plants, a mere possibility that the government may complete development of new technologies for spent fuel long in the future does not solve their problem—and as noted above, proposals whose financing would require massive government subsidies of uncertain sustainability or large increases in costs to the private sector are likely to increase, not decrease, investors' perception that spent fuel poses a large and uncertain liability.[163]

The third political challenge facing GNEP is whether the American public will support the siting of the large number of reprocessing facilities and ABRs that would be built at sites around the nation. A number of assessments have atributed the interest of DOE and some politicians to the LWR spent fuel waste reprocessing that would be undertaken as part of GNEP to a desire to postpone "a second U.S. waste repository indefinitely and thereby avoid another politically painful repository-siting process."[164] However, in place of siting a second repository, GNEP would require the siting of a substantial number of LWR reprocessing facilities and ABRs, with associated fuel fabrication and reprocessing facilities, at number of locations around the nation. Although some states and communities may welcome those facilities, many can be expected to oppose them.

*GNEP would require the siting of a substantial number of LWR reprocessing facilities and ABRs, with associated fuel fabrication and reprocessing facilities, at a number of locations around the nation. Although some states and communities may welcome those facilities, many can be expected to oppose them.*

In fact, it may not be easier to site 40 or more ABRs and numerous waste reprocessing facilities than a second geologic waste repository:

> The political calculus is somewhat analogous to the economic analysis. To an extent, reprocessing is an attempt to escape the political pain of finding a site for a second geologic repository. But this simply trades the well-known political problems of Yucca Mountain for the thus-far hypothetical, but most likely equally intense, local political resistance that can be expected from trying to site more than a dozen fast-neutron reactors, a couple of reprocessing centers, and the transportation of spent fuel.[165]

Indeed, in their dissent to the 2007 National Academies study, former NRC Commissioner Gilinsky and Dr. Macfarlane expressed the belief that GNEP's notion that siting reprocessing plants and fast reactors and surface storage for radioactive cesium and strontium would be easier is "fanciful."[166]

The fourth political challenge facing GNEP is whether the American public will accept having the spent reactor fuel from other nations brought here for reprocessing, burning in ABRs, and, ultimately disposal. Professor Bunn has commented that a U.S. offer to take in unlimited quantities of foreign spent nuclear fuel is simply not politically realistic—and that, indeed, few steps would be more likely to destroy renewed public support for nuclear energy in the United States than proposing to make the nation the "world's nuclear dumping ground," as antinuclear activists have labeled Russia.[167] Indeed, the international part of the GNEP plan appears to be in direct conflict with the announced desire to reduce waste storage requirements:

> The political debate has not yet come to grips with the conundrum that the international responsibilities implied by the GNEP are in conflict with the waste reduction goals. Recycling can reduce nuclear waste but if the rest of the world is shipping additional waste to the USA, any gain could be easily wiped out—and bringing radioactive waste into the country would be a political challenge.[168]

The fifth political challenge facing GNEP is whether other countries will be satisfied to participate as second class nuclear nations in a program through which their needs for reactor fuel will be dependent upon (1) a commitment not to seek fuel enrichment and reprocessing capability of their own and (2) their relationships with the United States, and perhaps, with other current nuclear powers and/or Japan. Given the current attitude of many nations in the world to the United States and the current administration it is hard to imagine any country being willing to rely on America for critical energy supplies. But this might change over time as new administrations work to rebuild the trust of the world in the United States.

But, on the other hand, this reluctance to rely on the United States for nuclear reactor fuel may not improve over time as countries remain concerned about being left out of the club of nuclear weapons states. In fact, an international panel of experts convened by the International Atomic Energy Agency (IAEA) found that "there is consistent opposition by many [non-nuclear weapon states] to accept additional restrictions on their development of peaceful nuclear technology without equivalent progress on disarmament."[169]

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**Risky Appropriations:**
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