Achieving the Vision of the Global Nuclear Energy Partnership – Greater Energy Security in a Safer, Cleaner World

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ABSTRACT

This paper describes the strategy that the U.S. Department of Energy (DOE) is pursuing to transform the vision of the Global Nuclear Energy Partnership (GNEP) into reality. GNEP will promote the use of clean, safe nuclear power through the use of advanced reactors and new methods to recycle spent nuclear fuel. By shifting from a once through fuel cycle to a closed fuel cycle, we can extract more energy from the nuclear fuel and dramatically reduce the amount of nuclear waste. By incorporating enhanced safeguards and material accountability we can further reduce the risk of nuclear proliferation.

While the benefits of achieving this vision are clearly profound, based on the sheer scope and magnitude of the GNEP, there will undoubtedly be challenges along the way. This endeavor will require careful planning and effective management to assure our long-term success. Moving forward, GNEP will be thoroughly engaged with our stakeholder community. By effectively leveraging the talents of DOE, the National Laboratories, Universities, private industry, the regulatory community and our international partners these challenges will become opportunities for success.

INTRODUCTION

On January 31, 2006, President Bush announced the Advanced Energy Initiative during the State of the Union Address. The Advanced Energy Initiative (AEI) seeks to promote reliable, affordable and clean energy sources which will help to ensure future United States competitiveness and continued prosperity. Through advanced technology and innovation, we can fundamentally change the way Americans power their vehicles, homes and businesses.

A key component of the AEI is the new Global Nuclear Energy Partnership (GNEP). Under GNEP, the U.S. will work with other nations that have advanced civilian nuclear energy programs to develop and deploy new technologies and methods to recycle spent nuclear fuel. Achieving the GNEP vision will:

- expand the use of nuclear energy both domestically and internationally,
- address the nuclear waste management issue, and
- reduce the risk of nuclear proliferation worldwide.

Domestic and world-wide energy demand continues to grow, driven by economic growth, especially in the developing nations. According to the most recent forecasts issued by the Energy Information Administration:

- Total world consumption of marketed energy will increase from 421 quadrillion British thermal units (Btu) in 2003 to 721 quadrillion Btu in 2030 [1], a 71-percent increase.

- Total U.S. electricity consumption is projected to grow from 3,729 billion kilowatthours in 2004 to 5,208 billion kilowatthours in 2025 [2], an increase of nearly 40-percent.

Clearly, nuclear energy can and must play a significant role in meeting the growing base load electricity demands in a way that does not contribute to the growing concerns over greenhouse gas emissions and global warming.

The Department of Energy (DOE) will lead the GNEP on behalf of the Administration, in cooperation with other federal agencies. The President's budget request for Fiscal Year 2007, which was submitted to Congress in February 2006, includes $250 million for DOE to begin to implement GNEP. As of this writing, Fiscal Year 2007 appropriations have not been passed and many federal programs are operating under the prospects of a long-term continuing resolution. While this has limited the pace of early GNEP activities, sufficient resources are expected to be included in the President's Fiscal Year 2008 budget request to address the near term priorities.

DOE is developing a comprehensive approach to create an advanced fuel recycling program that will ultimately:
- increase the supply of clean, safe nuclear power to meet growing energy demand;
- extract the energy content from spent nuclear fuel while reducing the amount of nuclear waste destined for disposal in a geologic repository; and
- reduce the risk of nuclear proliferation through enhanced nuclear safeguards and reducing the accumulation of civilian plutonium.

GNEP PROGRAM ELEMENTS

The closed fuel cycle envisioned by GNEP requires the ability to separate commercial light water reactor (LWR) spent nuclear fuel (SNF) into its usable and waste components; fabricate and recycle fast reactor fuel containing transuranic elements; and convert transuranics into shorter-lived radioisotopes while producing electricity. This process is illustrated in Figure 1.

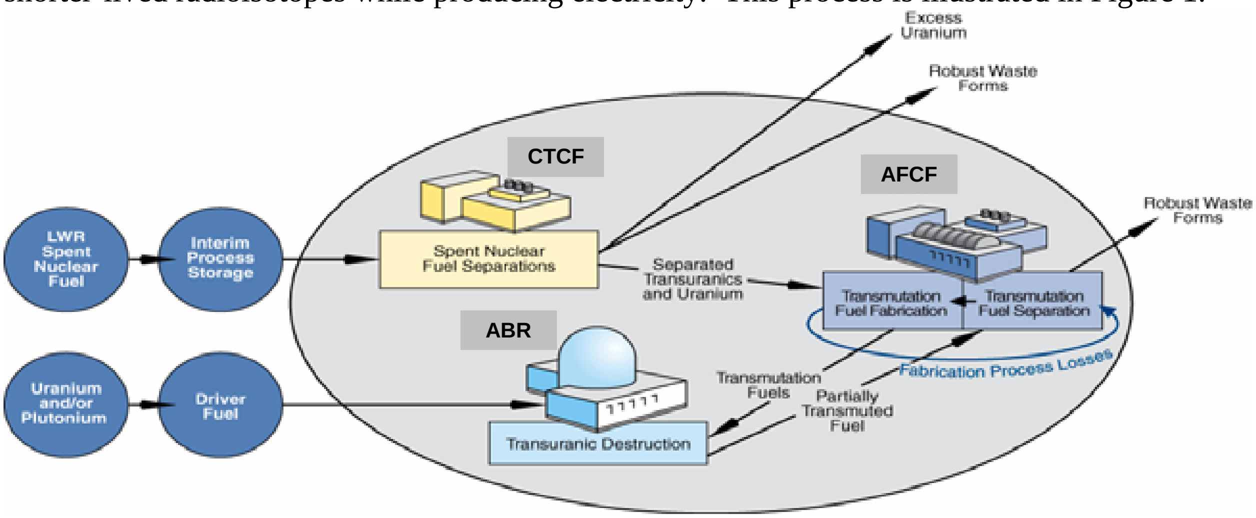

Fig. 1. GNEP advanced fuel cycle concept.

The GNEP program will develop the technologies that demonstrate an advanced proliferation-resistant closed nuclear fuel cycle enabling the recycle and consumption of the highly radioactive actinides contained in SNF. New facilities will be required to reprocess and recycle spent nuclear fuel and fast reactors to consume the transuranics and produce electricity. These facilities must not be "one of a kind" government research facilities. They must have true commercial value and ultimately demonstrate technologies which are reliable, efficient and sufficiently cost-effective to support future broad scale commercial deployment by industry.

Fuel Cycle Facilities

Subject to a decision by the Secretary of Energy, DOE proposes to build a nuclear fuel recycling center (the Consolidated Fuel Treatment Center (CFTC) project) and advanced recycling reactor (the Advanced Burner Reactor (ABR) project). The nuclear fuel recycling center will demonstrate key elements of a nonproliferation-based (i.e., without the separation of pure plutonium) fuel recycling program – initially, the separation of spent nuclear fuel from the existing light water reactor fleet into its usable and waste components, and ultimately, the fabrication of transmutation fuel from those components. Transmutation fuel contains plutonium and minor actinides. The advanced recycling reactor is a fast spectrum reactor that will consume (or transmute) the transuranic elements from spent light water reactor fuel and spent fast reactor fuel while producing electricity. The transmutation occurs from either neutron capture or fission. The advanced recycling reactor is expected to operate using conventional fast reactor fuel during the initial phase of reactor operations prior to the qualification of and transition to transmutation fuel. The production and recycling of fast reactor transmutation fuel may include the construction of a separate transmutation fuel separations and fabrication facility. Both the nuclear fuel recycling center and advanced recycling reactor will incorporate the latest safeguards and security features into the facility's design. These two facilities may be built at either government or private site(s).

DOE also proposes to build the Advanced Fuel Cycle Facility (AFCF) at a government site to serve as an R&D center of excellence for developing transmutation fuels and improving fuel cycle technology. The AFCF is envisioned to be the world's foremost facility for nuclear fuel cycle research and technology development. In addition to supporting the development of the transmutation fuel, the AFCF will work on advanced separations techniques and improved nuclear material accountability and control.

Reliable Fuel Services

Developing nations are expected to experience the greatest increase in energy demand, consistent with the growth of their economies. All nations should be able to enjoy the benefits of nuclear energy, without the substantial cost of developing their own enrichment and reprocessing capabilities. The global partnership aspect of GNEP envisions an international nuclear fuel supply strategy between existing nuclear fuel production states and those states that do not produce their own fuel that will ensure a secure international fuel supply while reducing the risk of nuclear proliferation. This concept is illustrated in Figure 2. Through the development of international fuel supply and leasing arrangements, the potential for terrorist access to sensitive nuclear technologies or materials is further reduced.

Many countries have an interest in utilizing nuclear technology but require a smaller scale than currently in use at existing nuclear states. Developing nations or regions with less developed transportation and industrial infrastructures can also benefit from nuclear power. Future activities under GNEP include the development of reactor concepts that are appropriately sized to provide electricity to developing nations, remote regions or for other applications, such as water desalination or process heat.

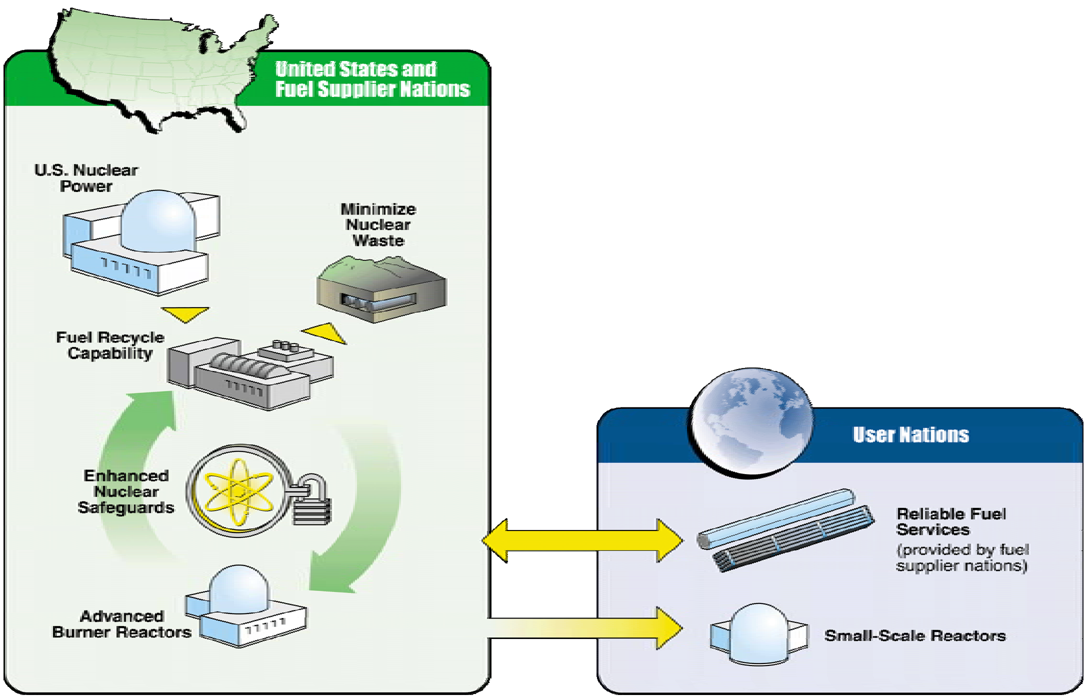

Fig. 2. GNEP reliable fuel services model

GNEP CHALLENGES

The world-wide expansion of nuclear power in a safe, environmentally responsible manner that does not contribute to the spread of nuclear weapons technology is a formidable, yet worthwhile initiative with enormous societal benefits. U.S. leadership in nuclear technology has eroded along with the domestic infrastructure needed to support the nuclear renaissance. It will take time and a substantial investment in the human resources, technology and industrial capacity to reverse several decades of neglect. It will also take a compelling vision, and a lasting commitment to regain U.S. technical leadership and assure U.S. economic competitiveness.

Technology Development

Viable technologies currently exist for many of the GNEP applications, including spent fuel reprocessing and sodium-cooled fast reactors (SFR). The SFR concept is the reference reactor technology for the advanced recycling reactor because of its technical maturity and U.S. and international experience in operating sodium-cooled fast reactors. Sodium-cooled fast reactors have been built and successfully operated in the United States, Russia, France, Japan and other countries. The principle challenge with the advanced recycling reactor will be to demonstrate adequate cost competitiveness with other reactor technologies.

Fabricating, testing, and qualifying fast reactor fuel containing transuranic elements (i.e., transmutation fuel), is a challenge with respect to being a "first of a kind" technology. The transmutation fuel will require remote fabrication techniques and there is relatively little experimental data on fuel performance. Similarly, the advanced chemical separation techniques envisioned by GNEP require additional technology development, particularly the group separation of actinides and the development of robust waste forms.

The potential benefits of this approach are significant. The disposal capacity of the Yucca Mountain geologic repository is affected by waste volume, temperature limits and the calculated dose rate. Processing the spent fuel to remove the actinides (plutonium, neptunium, americium and curium) and fission products (cesium and strontium) can substantially reduce the volume and decay heat, providing an opportunity for a much more compact waste loading in the repository. Figure 3 shows the relative increase in drift loading that can be achieved by reducing the heat load through reprocessing as a function of various removal/separation efficiencies [3]. As illustrated below, with 99.9% separation of these elements, the resulting waste can theoretically be loaded at a factor of 225 times greater than the original spent fuel. However, in addition to thermal issues, the repository is also limited by the peak dose rate. With 99.9% separations efficiency, repository loading may be limited to a factor of about 100 times greater, (rather than 225) due to elements such as technetium and iodine that have not been removed through reprocessing.

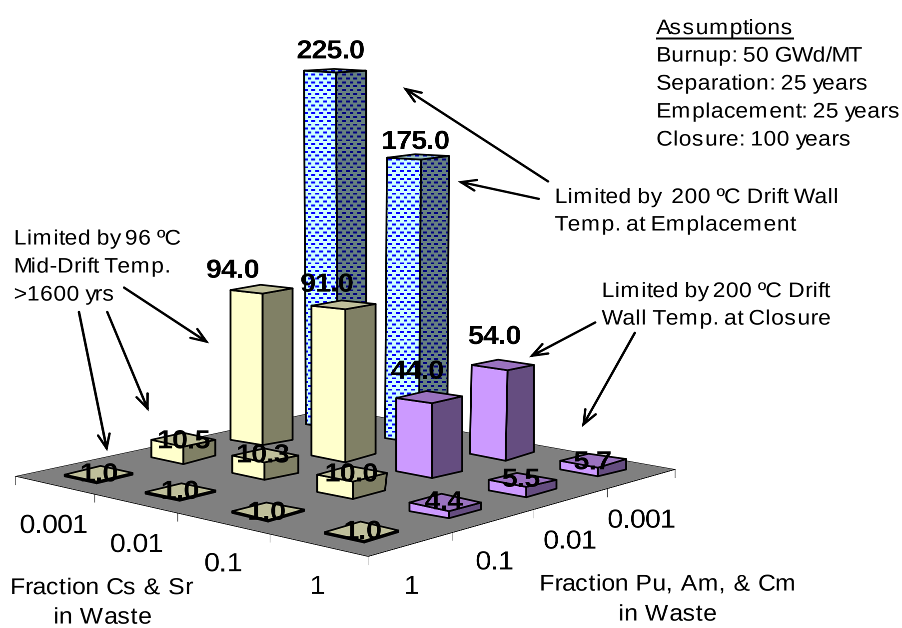

Fig. 3. Relative increase in repository capacity by recycling to reduce thermal load. [3]

Domestic Infrastructure

The U.S. has not begun construction on a new domestic commercial nuclear plant in the past 30 years. With the shutdown of the Fast Flux Test Facility and Experimental Breeder Reactor-II in the 1990s, there are no U.S. fast spectrum reactors currently operating. U.S. leadership in reactor and enrichment technology has eroded over time. Other nations have developed fuel reprocessing technologies as we were idle and our schedule to open a high level waste repository has continued to slip. The pool of human resources with experience designing, building or operating fuel cycle facilities continues to dwindle, along with the industrial base to manufacture equipment and components. For example, currently there are only about 50 domestic American Society of Mechanical Engineers (ASME) N-stamp suppliers, down from more than 600 suppliers at the peak. While the prospect for new reactor starts is promising, as is the introduction of new uranium enrichment capacity, the U.S. nuclear infrastructure as a whole must rebound from several decades of neglect.

Policy and Management

The sheer scope and magnitude of GNEP necessitates a new management approach. A "business as usual" approach with government fully funding and building expensive research and development facilities is unlikely to produce the desired results in the long-term. GNEP's success can only be realized if commercial industry adopts and deploys the fuel cycle technologies--and this private sector investment will only occur if there is a compelling business case. Developing a suitable government-private partnership is essential to reducing costs and accelerating commercialization. Implementing GNEP's international framework will require extensive collaboration and diplomacy. The GNEP program itself can not be managed and implemented as a "stand alone" component within the DOE, but must be fully integrated and aligned with other energy, science, environment and national security initiatives. Perhaps most importantly, a broad political constituency must be established, based on a sound and compelling vision, to assure that adequate resources are available and sustainable over the decades (and political Administrations) ahead.

PATH FORWARD

The Department's initial approach involved technology demonstration projects at the engineering scale, prior to a second phase of commercialization [4]. Based on input from foreign governments and private industry, DOE issued Requests for Expressions of Interest (REOI) to determine the feasibility of accelerating the development and deployment of advanced recycling technologies that would enable commercial scale demonstrations of the CFTC and ABR. Recently, the Department released the Global Nuclear Energy Partnership Strategic Plan [5]. This plan provides the implementation strategy and proposed actions that will take place over the next two years to achieve the GNEP vision.

The responses to the REOI confirmed that there is considerable international and industry support for GNEP and that it is feasible to deploy commercial scale prototype fuel cycle facilities. The response also demonstrated a potential willingness to invest substantial sums of private capital to build and operate GNEP facilities. In considering this input, DOE proposes to proceed in parallel to: (1) deploy nuclear fuel recycling center and advanced recycling reactor facilities using the latest commercial technology available, and (2) continue an aggressive research and development program focused on those areas with the highest technical risk and uncertainty (e.g., group separation of actinides and separation of the lanthanide fission products from the transuranics; remote fabrication and qualification of transmutation fuels). These two activities will be fully integrated between government and industry through a technology roadmap. Other priority items for ongoing research and technology development include the Removing the cesium and strontium from the SNF waste stream and converting it into a suitable waste form for decay storage. The capture and immobilization of technetium would help to limit the potential for migration.

Industry, as the end-user, must play a principal role in establishing the design and operating parameters for the nuclear fuel recycling center and advanced recycling reactor facilities. The ultimate commercial deployment of these technologies will require safe, reliable facilities that are economical to build, operate and maintain. DOE intends to engage with industry to begin design of the nuclear fuel recycling center and advanced recycling reactor. In addition, government and industry must reach consensus on an appropriate business model that will support GNEP implementation.

The DOE National Laboratories, in collaboration with Universities and international research organizations, will address the near-term technology development needs and perform the research needed to address the outstanding technical issues. A detailed technology roadmap will be prepared to support industry’s development of the nuclear fuel recycling center and advanced recycling reactor. International collaboration will be performed through existing Generation IV International Forum (GIF) and International Nuclear Energy Research Initiative (I-NERI) agreements, or new bi-lateral/multi-lateral agreements as appropriate.

DOE will work with the Nuclear Regulatory Commission (and our industry partners) to evaluate potential modifications to the existing regulatory framework which may be required to accommodate GNEP technologies. For example the current nuclear reactor regulations are based upon light water reactor technology and the regulations for commercial spent fuel reprocessing are dated. A Programmatic Environmental Impact Statement will be prepared in accordance with the requirements of the National Environmental Policy Act (NEPA) to evaluate the potential environmental impacts associated with the GNEP program and facilities.

Leveraging Analytical Capabilities

The GNEP program elements and facilities must be designed to effectively function as part of an integrated system. GNEP will use systems engineering and analysis methods to ensure that the various alternatives are evaluated at each level of the enterprise (deployment system, facility, technology) and that the various components are integrated. Evaluation tools will assess and guide program activities and investigate the optimal systems architecture (e.g., the best mix of facilities and systems) to meet the GNEP advanced fuel cycle objectives. In addition, DOE will utilize its substantial capabilities in science and high performance computer simulations in support of GNEP. This effort will leverage computational and experimental assets, resources, capabilities and experience throughout the Department and offers the potential to transform the way nuclear safety and design are performed though the development and deployment of high performance codes. Project teams will focus on priority areas including fast reactor design, safety and accident analysis; chemical separations and process chemistry optimization; and actinide fuel development and qualification.

Governance Model

The Office of Nuclear Energy has the lead responsibility within DOE for implementing GNEP and the Assistant Secretary for Nuclear Energy (NE-1), Dennis Spurgeon, serves as the GNEP Program Manager. Recognizing the need to draw upon the capabilities and resources across the entire Department in a sustained and integrated manner, the Deputy Secretary of Energy has established a GNEP Governance Board. The Board is comprised of the three Under Secretaries (Energy, Science and Nuclear Security) and is chaired by the Deputy Secretary. The Board will make policy decisions, monitor implementation and evaluate budget requirements.

Mr. Spurgeon will chair a GNEP Steering Group, comprised of relevant Program Secretarial Officers to assist in the management and implementation of GNEP. Subordinate “Integration Groups” with representation from across the Department’s elements will be formed to address specific GNEP program areas.

CONCLUSION

By June 2008, the Secretary of Energy will be asked to approve the path forward for GNEP. His decision to proceed will be predicated on a clear and credible technical pathway; an appropriate business plan with mutual contributions and benefits between government and industry; and an assessment of the environmental impacts under NEPA. In the interim, industry will provide substantial information on the technical approach, cost and schedule to help inform this decision.

Clearly, nuclear power can help to meet growing worldwide energy demand. GNEP offers the potential to achieve this goal while producing more energy and less waste. By significantly expanding the capacity of Yucca Mountain we can eliminate the need for additional repositories during this century. The current cost estimate for the nation’s first geologic repository is over $70 billion (in 2000 dollars). Over the next 100 years, assuming an expansion of nuclear energy in the United States, avoiding the need for additional repositories could translate to a government cost savings of at least $100 Billion.

Clearly, nuclear power is safe. GNEP offers the potential to make nuclear technology even safer. A proliferation-resistant alternative to the PUREX technology can reduce the world’s inventory of plutonium and enhanced nuclear safeguards would allow the safe expansion of nuclear power throughout the world. Improved process design and safeguards technologies can offer real-time material control and accountability with fewer potential pathways for the theft or diversion of fissile materials.

Clearly, GNEP is a U.S. Presidential initiative. GNEP requires sustained U.S. leadership and commitment to regain technical expertise and address the deteriorating domestic nuclear infrastructure. Only through leadership can the U.S. help influence the world’s “fuel cycle nations” to adopt a more proliferation-resistant fuel cycle technology. But leadership does not mean “going it alone”. The GNEP vision can only be fully attained through collaboration with our international partners on mutually agreeable goals. Effective international collaboration not only provides a means to off-set development costs (e.g., fuel irradiation and qualification testing in foreign fast reactors), but actually accelerates development time by sharing of knowledge and experimental data.

GNEP provides the opportunity to regain world leadership in nuclear energy development, improve our energy security and improve our global economic competitiveness…but more importantly, GNEP provides a unique opportunity to make the world a better place. All that is required is the willingness to take the bold actions necessary to make this vision a reality.

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