CHAPTER 7

INTERNATIONAL INITIATIVES AND IMPACTS OF THE PROGRAMMATIC ALTERNATIVES

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Chapter 7 describes the U.S. Department of Energy's (DOE)'s vision for two international elements of the Global Nuclear Energy Partnership initiative—Grid-Appropriate Reactors and Reliable Fuel Services. It also addresses how the selection of a domestic programmatic alternative (as discussed in Chapters 2 through 6 of this PEIS) could affect implementation of a Reliable Fuel Services Program.

7.1 INTRODUCTION AND BACKGROUND

At this time, the U.S. Department of Energy (DOE) has no specific proposals for the international component of the Global Nuclear Energy Partnership (GNEP). Rather, DOE is considering several potential international initiatives, none of which has risen to the level of a specific proposed action sufficiently advanced to require review in this programmatic environmental impact statement (PEIS). In this section, DOE describes the steps it has taken to initiate an international dialogue on GNEP principles and describes the various initiatives that it is considering. DOE also identifies the domestic resource areas that could be impacted by such international initiatives and discusses how such initiatives could also affect the global commons. As defined by Executive Order (EO) 12114, the term "global commons" refers to the environment outside the jurisdiction of any nation (e.g., the oceans or Antarctica) (EO 12114).

The international component of the GNEP Program is a cooperative program of those States that share the common vision of the necessity of the expansion of nuclear energy for peaceful purposes worldwide in a safe and secure manner. States participating in this cooperation do not give up any rights, and voluntarily engage to share the effort and gain the benefit of economical, peaceful nuclear energy. GNEP international engagement has built on existing U.S. Government programs in nonproliferation and international security, as well as advanced fuel cycle research and development (R&D). DOE envisions the international goals embodied within GNEP, as the potential means to accomplish the following objectives:

- Expand nuclear power to help meet growing energy demand in a safe and sustainable manner.
- Establish international supply frameworks to enhance reliable, cost-effective fuel supplies to the world market while reducing the risk of nuclear proliferation by creating a viable alternative to the acquisition of sensitive fuel cycle technologies.
- Develop, demonstrate, and in due course deploy advanced fast reactors that consume transuranic elements from recycled spent nuclear fuel (SNF).
- Develop and demonstrate advanced technologies for recycling SNF with a long-term goal of ceasing separation of plutonium and eventually eliminating stocks of separated civilian plutonium.
- Promote the development of advanced, more proliferation-resistant nuclear power reactors appropriate for the power grids of developing countries and regions.

- Continue, in cooperation with the International Atomic Energy Agency (IAEA), the development of enhanced nuclear safeguards and ensure nuclear energy systems are used only for peaceful purposes.

These objectives are laid out in a "Statement of Principles," which may be found by accessing the DOE GNEP website at: http://www.gnep.energy.gov/. As of June 2008, 21 nations have signed the Statement of Principles and agreed to be "partner nations." A partner nation is defined as a nation that has agreed to, and signed the GNEP Statement of Principles.

In support of the Statement of Principles, the United States has signed "Civil Nuclear Energy Bilateral Action Plans" with Japan, Russia, and China. One is currently pending with France and is expected to be signed by the end of 2008. These countries are referred to as "Fuel Cycle GNEP Partners." These Action Plans outline cooperative R&D on advanced reactors, exportable small and medium power reactors, nuclear fuel cycle technologies, and nonproliferation, with the focus on achieving the long-term GNEP vision of the expansion of nuclear power in a manner that reduces proliferation risks. The most significant agreed upon areas of international cooperation are:

- Development of technologies for recycling SNF that do not separate pure plutonium, and
- Development of advanced burner reactors.

Through the multi-lateral GNEP program (referring to all 21 partner nations), two international working groups have been established:

- Reliable Fuel Services Working Group, to investigate nuclear fuel supply and take-back schemes that would eliminate the need for countries to establish their own enrichment and reprocessing capability.
- Infrastructure Working Group, to assist in the development of the requisite infrastructure (regulatory, technical, and administrative) for developing countries (as they acquire responsibility for operating civil nuclear power stations safely, securely, and in compliance with international agreements).

Specific environmental impacts to the United States and the global commons would be addressed at such time as specific international proposals are brought forward. With respect to potential international initiatives, DOE would consider actions to promote safe, secure nuclear power reactors appropriate for developing countries and to support nuclear fuel services for countries that refrain from pursuing enrichment or reprocessing technologies. This, in turn, could affect the types of international programs that would develop and the associated environmental impacts within the United States and the global commons resulting from such programs. The private sector in the United States currently supplies nuclear fuel, both domestically and internationally. Those activities are outside of the alternatives considered by this PEIS and may continue in the future, independent of any Federal actions made as a result of decisions based on this PEIS.

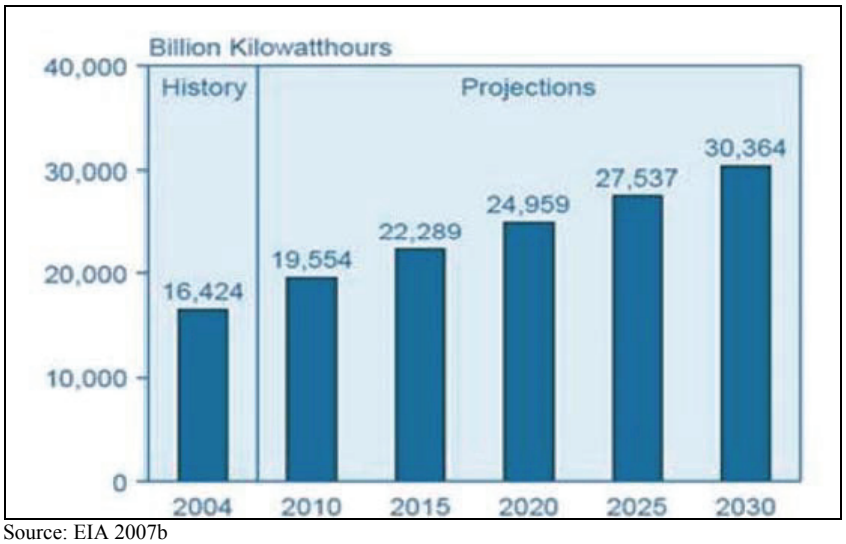
In support of international nonproliferation goals, the United States is considering a policy that promotes an alternative for countries that might otherwise consider developing uranium enrichment or SNF reprocessing capabilities, referred to in this PEIS as the Reliable Fuel

Services Program. The Reliable Fuel Services concept envisions a group of fuel cycle GNEP partner nations ("supplier nations") that would supply fresh nuclear fuel, either through a fuel lease or other arrangement for supply, to recipients ("user nations") that agree not to pursue their own indigenous enrichment and reprocessing capabilities. The Reliable Fuel Services concept also contemplates return of the spent fuel from the user nations to one of the supplier nations for reprocessing or disposal.

All international cooperation activities are and will be subject to established international standards for safety, safeguards, physical protection, and export control. The domestic programmatic alternatives in this PEIS could influence the types of future international actions that might affect either the international supply of nuclear fuel and/or the reactor technologies used to produce electricity. Either of these could have secondary impacts on the United States. As background, this chapter begins with a discussion of the international energy demands projected over the next several decades. It then looks at some hypothetical activities resulting from actions that could be taken based on this GNEP PEIS, and then gives the reader a perspective on the impacts such actions could have on the United States and the global commons.

7.1.1 International Energy Demand

The Energy Information Administration projects that world electricity generation will nearly double from 16,424 billion kilowatt-hours (KWh) in 2004, to more than 30,364 billion KWh in 2030 (See Figure 7.1.1-1).



Source: EIA 2007b

FIGURE 7.1.1-1—*World Electric Power Generation*

The Energy Information Administration projects that electricity generation from nuclear power will increase by around 40 percent, from 2,619 billion KWh in 2004 to 3,619 billion KWh in 2030. Higher fossil fuel prices, energy security concerns, improved reactor designs, and environmental considerations are expected to improve the prospects for new nuclear power plants in many parts of the world, and a number of countries are expected to build new nuclear power plants. In the International Energy Outlook 2007 reference case, the world's installed

nuclear capacity is projected to grow from 368 gigawatts electric (GWe) in 2004, to 481 GWe in 2030, a 31 percent increase (EIA 2007b). Declines in nuclear capacity are projected only among Organization for Economic Cooperation and Development[1] (OECD) European nations, where several countries (such as Germany and Belgium) have either plans or mandates to phase out nuclear power, and some older reactors are expected to be retired and not replaced (EIA 2007b).

From 2004 to 2030, nuclear power generation in non-OECD countries is projected to increase by 4 percent per year. The largest increase in installed nuclear generating capacity is expected for non-OECD Asia, where annual increases in nuclear capacity are projected to average 6.3 percent and account for 68 percent of the total projected increase in nuclear power capacity for the non-OECD region as a whole. Of the 58 GWe of additional installed nuclear generating capacity projected for non-OECD Asia between 2004 and 2030, 36 GWe is projected for China and 17 GWe for India. Russia is also expected to add substantial nuclear generating capacity over the mid-term, increasing capacity by 20 GWe by 2030 (EIA 2007b).

Even with these increases, nuclear energy will only fulfill a portion of the projected need for electrical power. Fossil fuels, especially coal, will continue to provide the largest portion of new electrical power supply. Accordingly, world carbon dioxide (CO_2) emissions are expected to grow. High growth is expected from the non-OECD nations, mainly China and India (EIA 2007b). As the United States and Fuel Cycle GNEP Partners develop the technologies to support a Reliable Fuel Services Program, the United States would work with those Fuel Cycle GNEP Partners to provide user nations with reactor technologies, reactor fuel, and potentially fuel recycling services. This assistance would support the expansion of nuclear energy among developing countries.

7.1.2 Grid-Appropriate Reactors

DOE supports the development of grid-appropriate reactors, which are well suited to the capabilities and needs of developing countries. These reactors would be designed to achieve high standards of safety and security and would be sized to suit those countries with smaller and less developed power grids. The successful deployment of these reactors, coupled with reliable fuel services, would provide an attractive energy solution to many countries and reduce the incentive for them to develop the more proliferation-vulnerable parts of the nuclear fuel cycle (e.g., uranium enrichment facilities).

Smaller power plants (less than 500 MWe) are particularly suitable for expansion into less developed countries because they would match grid capacities better, offer simplified operations with greater margins of safety, require less capital outlay, allow countries to add capacity in smaller increments to better match demand growth, and be better suited to provide important non-electrical products such as process heat and fresh water through desalination.

[1] The Organization for Economic Cooperation and Development (OECD), established in 1961, is an international organization composed of the industrialized market economy countries, as well as some developing countries, which provides a forum to establish and coordinate policies. The OECD's 30 members are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States (EIA 2007b).

Besides the United States, several countries, including France, Russia, Japan, South Korea, South Africa, India, and Argentina, have already recognized the global market need for smaller-sized nuclear power plants and are moving forward with the development of small and medium-sized reactors. Because it is ultimately the responsibility of private industry to develop and market commercial nuclear power plants, one role of DOE could be to assist U.S. industry efforts to standardize reactor design and obtain U.S. Nuclear Regulatory Commission (NRC) licensing of one or more new small- and medium-sized reactors for export. Two examples of grid-appropriate reactors are: 1) the International Reactor Innovative and Secure (IRIS): a smaller-scale advanced light water reactor, being developed for near-term deployment (within the next decade) and, 2) the Pebble Bed Modular Reactor (PBMR): a high temperature gas-cooled reactor (HTGR) with a closed-cycle, gas turbine power conversion system.

A GNEP international working group is developing a Grid-Appropriate Reactors Program. Such a program would facilitate the international development, demonstration, licensing, and deployment of these simpler nuclear technologies and would facilitate the introduction of nuclear electricity generation through numerous features such as smaller, modular-type designs, fuel designs that could last the entire life of the reactor, effective and inexpensive safeguard approaches, standardized modular designs, and fully passive safety systems. Such a program would not propose to build or operate such reactors for another country, but instead would assist in developing the technologies, develop construction and operational plan packages, and demonstrate how such grid-appropriate reactors could satisfy energy needs while reducing electricity generation costs, CO_2 emissions, and nuclear weapons proliferation concerns.

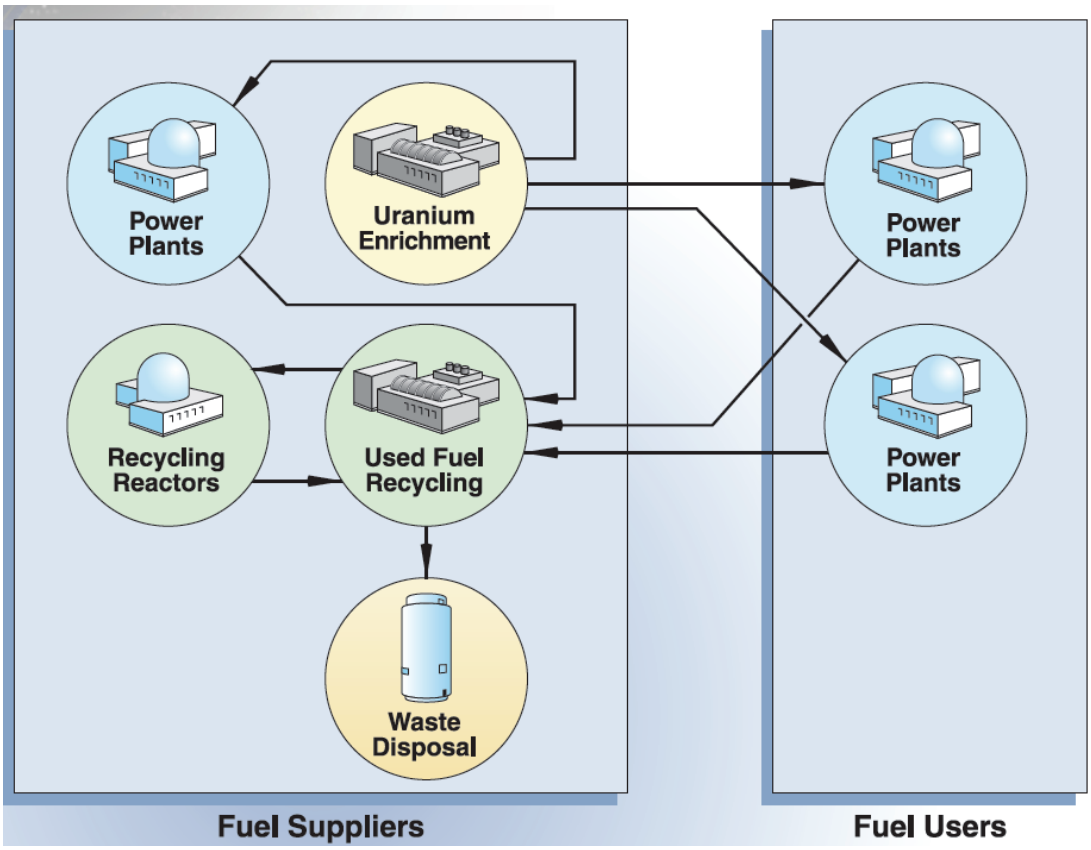
International safeguards are of paramount importance in developing new reactor technologies. The United States and other developed nations work closely with the IAEA in developing technologies that would help enable the IAEA to better assure nonproliferation compliance. Ensuring that such technologies are included in new reactor designs is a primary goal of the contemplated international Grid-Appropriate Reactors Program.

7.1.3 Reliable Fuel Services

The United States and other nuclear fuel supplier nations are cooperating to develop mechanisms to provide other countries pursuing nuclear power programs with an assured supply of fresh fuel for nuclear power plants. This effort builds on initiatives already underway to provide assurances of nuclear fuel supply, including the six-country proposal on Reliable Access to Nuclear Fuel at the IAEA and the established National Nuclear Security Administration program to blend down excess highly enriched uranium to create a fuel reserve to support a reliable fuel supply. In addition, a Reliable Fuel Services Program could help other countries manage the resulting SNF generated as described below.

The objective of a Reliable Fuel Services Program is to limit the spread of enrichment and reprocessing by offering countries an alternative to developing such facilities indigenously. Countries using such services would receive the benefit of having reliable access to nuclear fuel services without having to make the significant infrastructure investments required for enrichment and reprocessing. Figure 7.1.3-1 shows one potential concept for the Reliable Fuel Services Program. At this point in time, the Reliable Fuel Services Program is focused primarily

on fuel for light water reactors (LWRs); however, once the program has been implemented it could be expanded to other types of reactors.



Source: Derived from DOE 2008e

FIGURE 7.1.3-1—*One International Reliable Fuel Services Program Concept*

7.1.3.1 *Spent Nuclear Fuel Disposition*

Under a Reliable Fuel Services Program, SNF could be returned to the country that supplied it or to another supplier nation. If the supplier nation taking the SNF had a closed fuel cycle, and if the SNF was suitable for recycling, then it could recycle that SNF. Uranium and usable transuranics could be separated and used for additional fuel fabrication. Wastes resulting from the recycling of the SNF would be packaged for transport and disposal, as discussed below. If the country accepting the SNF had a once-through fuel cycle, or if the SNF was not suitable for recycling, then it could store the SNF pending disposal in a geologic repository.

7.1.3.2 *Wastes from Spent Nuclear Fuel Recycling and Disposition*

The recycling of foreign reactor SNF from a Reliable Fuel Services Program would generate the same types of waste as the recycling of domestic SNF and could include hazardous wastes, low-level radioactive waste (LLW), Greater-than-Class-C (GTCC) LLW, and high-level radioactive waste (HLW). Just as these wastes must be responsibly managed within the United States, it is equally important that these wastes be managed responsibly by other countries, in accordance with the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of*

Radioactive Waste Management (IAEA 2001a). The radioactive wastes from recycling would be stored or disposed of either by the supplier nation (the nation that provided the fresh fuel), returned to the user nation (the nation that generated the SNF), or sent to a third-party supplier nation (a nation that neither supplied the fresh fuel nor generated the SNF but has facilities to responsibly manage the SNF). Additional information on the wastes generated by SNF separation processes and the management of such wastes may be found in Section 7.2.1.8, Section 7.2.1.9, and Appendix A.

7.2 POTENTIAL ENVIRONMENTAL IMPACTS IN THE UNITED STATES AND GLOBAL COMMONS FROM INTERNATIONAL ACTIONS

DOE's underlying purpose and need is to support expansion of domestic and international nuclear energy production while reducing the risks of nuclear proliferation and to reduce the impacts associated with disposal of future SNF (e.g., by reducing the volume, thermal output, and/or radiotoxicity of waste requiring geologic disposal). The programmatic alternatives evaluated in this PEIS would have differing implications for the international initiatives of the GNEP Program. Since the international portion of the GNEP Program is still in its formative stage and no specific proposal exists, it is not possible to prepare a detailed analysis of the potential environmental consequences of each of these alternatives. Instead, this analysis is intended to provide a perspective of how each of the alternatives being considered by the GNEP PEIS could have implications for the international aspects of the GNEP Program which in turn could have environmental impacts within the United States or in the global commons.

Methodology and Assumptions

To standardize the impact of GNEP (relative to international nuclear power expansion), this chapter of the PEIS assesses the domestic environmental impacts and environmental impacts to the global commons associated with supporting SNF reprocessing, waste disposal requirements, and transportation requirements for 1 GWe of foreign nuclear power production. It is expected that more than 1 GWe would be supported by a Reliable Fuel Services Program. Impacts associated with additional production would be multiples of the impact estimates presented in this chapter. Once operational, these foreign reactors would need to be supplied with fuel on a regular basis.

7.2.1 Fast Reactor Recycle Alternative

The following analysis presents the environmental impacts in the United States and the global commons that could result from an international Reliable Fuel Services Program based on the Fast Reactor Recycle Alternative. For purposes of this analysis, a future Reliable Fuel Services Program would support the nuclear fuel requirements for 1 GWe foreign LWR production. Although these foreign reactors would likely be smaller, 1 GWe production provides a good scaling factor which may be used for comparing alternatives and for computing impacts associated with varying numbers of foreign reactors.

Supporting a 1 GWe LWR production would require sufficient fresh fuel for initial start-up and steady-state operations.[2] This could entail the manufacture of uranium-based reactor fuel in U.S. commercial fuel fabrication facilities. This fuel would be shipped to the foreign reactor where it would be used to power a LWR to generate electricity. The SNF resulting from reactor operations could then be returned to the United States or a partner nation, where it would be recycled in a nuclear fuel recycling center and separated into useful constituents and waste material. The useful constituents would be used again in the fuel fabrication process to provide fuel for advanced recycle reactors, and the waste material would be stabilized and packaged appropriately for storage or disposal.

Although fuel assemblies could be fabricated in any of the supplier nations, fuel fabrication is assumed to occur at any one or all of the U.S. commercial fuel fabrication facilities, since this analysis presents environmental impacts which could result within the United States or global commons. Once fabricated, the fuel assemblies would be placed into approved fuel shipping casks. For this analysis, several different NRC-certified and U.S. Department of Transportation (DOT) approved casks were analyzed, depending on the mode of transportation and the material being transported. These fuel assemblies would then be transported by truck to a U.S. port of exit. Information on U.S. fuel fabrication facilities may be found in Appendix A.

Previous environmental impact studies related to the global transportation of nuclear materials identified 10 ports in the United States with the capability and experience in handling the shipment of radioactive materials: Charleston, SC; Galveston, TX; Norfolk, VA; Jacksonville, FL; Military Ocean Terminal at Sunny Point, NC; Naval Weapon Station (NWS) at Concord, CA; Portland, OR; Savannah, GA; Tacoma, WA; and Wilmington, NC (DOE 1996c). In all likelihood, one of the east coast ports would be utilized for shipments to Europe, Central or South America, and Africa and one of the west coast ports utilized for shipments to Asia and the South Pacific.

Once the fuel assemblies expend their useful energy in the reactor (generally after about 3 years of full power operation), the SNF would be removed from the foreign reactor and stored for a period of time until cool enough to be placed in a specially designed container for shipment back to the United States or another supplier nation. For the receipt of the SNF returning to the United States from foreign reactors, the same ports used for shipment of the fresh fuel assemblies would probably be used as the ports of entry.

Although SNF could be transported to any supplier nation, it is assumed that the SNF would be returned to a U.S. port, since this analysis is intended to present the environmental impacts that could result within the United States or global commons. The SNF would then be loaded onto trucks, barges, or railcars and transported to a nuclear fuel recycling center. Here, the SNF would be recycled, the usable materials removed, and the waste products packaged and placed in the appropriate containers. The waste would either be retained by the United States, returned to the user nation, or be transported to a supplier nation for disposal or storage.

[2] DOE analyzed the steady-state impacts associated with annual operations; the initial start-up of a foreign reactor would require approximately 3-4 times as much start-up fuel as were analyzed for steady-state annual operations.

7.2.1.1 *Transportation of Reactor Fuel to and from Foreign Reactors*

Transportation of reactor fuel would involve the delivery by truck or barge from the fuel fabrication facility to a port of exit where the fuel assemblies, already packed in special NRC/DOT/IAEA-approved casks, would be loaded onto a ship for transport to a foreign port. Once in the foreign nation, the casks would be taken off of the ship and transported to a foreign reactor, where it would be placed into the reactor core.

Affected Environment

U.S. interstate highways, federal and state highways, local roads, rail routes, barge routes, U.S. ports, and both the Atlantic and Pacific Oceans, are areas that could potentially be impacted by the potential international initiatives being considered by DOE. Because specific foreign participants, sites of the recycling centers, and designated ports have not been identified, it is not possible, at this time, to perform site-specific analysis. Generic routing parameters were utilized consistent with the methodology described in Appendix E.

Domestic

Within the United States, the affected environment would be determined by the location of any fuel fabrication facility(ies), the specific port of exit for the uranium or fuel assemblies, the specific port of entry for the SNF, the location of the SNF recycling center utilized, any domestic storage or disposal facilities for the waste, and the specific port of exit for any waste returning to a user nation or a supplier nation. Once these facilities are identified, transportation routes between them could be determined and specific environmental impacts identified. Areas impacted would include these transportation routes, the ports, and the areas around these routes and ports.

Global Commons

The Atlantic Ocean is the second largest of the world's oceans. The surface of the Atlantic Ocean is usually covered with sea ice in Labrador Sea, Denmark Strait, and coastal portions of the Baltic Sea from October to June. The Atlantic Ocean exhibits a clockwise warm-water gyre (broad, circular system of currents) in the northern Atlantic, and a counterclockwise warm-water gyre in the southern Atlantic. The ocean floor is dominated by the Mid-Atlantic Ridge, a rugged north-south centerline for the entire length of the Atlantic basin (CIA 2008a). Figure 7.2.1.1-1 shows the location of the Atlantic Ocean.

Source: CIA 2008a

FIGURE 7.2.1.1-1—*The Atlantic Ocean*

The Pacific Ocean is the largest of the world's oceans. Surface currents in the northern Pacific are dominated by a clockwise, warm-water gyre (broad circular system of currents) and in the southern Pacific by a counterclockwise, cool-water gyre. In the northern Pacific, sea ice forms in the Bering Sea and Sea of Okhotsk in the winter. In the southern Pacific, sea ice from Antarctica reaches its northernmost extent in October. The ocean floor in the eastern Pacific is dominated by the East Pacific Rise, while the western Pacific is dissected by deep trenches, including the Mariana Trench, which is the world's deepest (CIA 2008b). Figure 7.2.1.1-2 shows the location of the Pacific Ocean.

Source: CIA 2008b

FIGURE 7.2.1.1-2—*The Pacific Ocean*

The North Atlantic Right Whale (*Eubalaena glacialis*) is on the Federal endangered species list and is also protected internationally under the Convention for the Regulation of Whaling. There are currently about 300 right whales in the North Atlantic, with ship strikes accounting for about 50 percent of their known deaths. Calving right whales usually winter in the waters between Savannah, GA, and West Palm Beach, FL, with an area of high density between Brunswick, GA, and St. Augustine, FL (NOAA 2008). The Maritime Safety Committee of the International Maritime Organization adopted a mandatory ship reporting system that became effective in 1999. This system requires ships to report whale sightings in the major shipping lanes from November 15 to April 15 off the southeastern coast of the United States so as to include the calving season for the right whales in this area, and operates throughout the year on the northeastern coast, where the whales have been sighted year-round. The sperm whale and all six species of sea turtles are on the Federal endangered species list and are found throughout the central and northern Pacific Ocean and the equatorial region of the Atlantic Ocean. Sperm whales migrate between mating and calving grounds near the equator and feeding areas in higher latitudes. Generally, however, females and their young stay in latitudes less than 40, and only the males venture into the polar waters. The total number of sperm whales in the world is not well known, with estimates ranging from 200,000 to 2,000,000. The sea turtle is found throughout both the Atlantic Ocean and the Pacific Ocean but is usually only vulnerable to harm on coastal shores. In the United States, it is most prevalent on and just off the central Florida coast (USFWS 2007a). Endangered marine species in the Pacific Ocean also include the dugong, sea lion, sea otter, and seals (CIA 2008b).

7.2.1.2 *Transportation of Reactor Fuel Assemblies*

Route options for ground transportation to the ports of exit for any reactor fuel going to foreign reactors would depend on the location of the fuel assembly fabrication facility and the marine port to be used. As described in 10 CFR 51.52, it was assumed that all fresh fuel shipments would be conducted via truck transport. For purposes of this analysis a distance of 500 miles (mi) (805 kilometers [km]) was assumed. Routing for shipments by truck would comply with all applicable DOT, NRC, and state regulatory requirements. The U.S. interstate highway system would be used to the extent possible, utilizing bypasses or beltways around cities. The selection of routes would be consistent with specific state requirements and declared preferences. All pre-shipment notifications and consultation requirements would also be met.

The analysis below addresses the shipment of 24 metric tons of heavy metal (MTHM) fresh fuel assemblies, which would be used to support the production of 1 GWe in LWRs annually. The 24 MTHM quantity represents the fewest number of full shipments (four shipments of 6 MTHM each) needed to provide 21.7 MTHM of fresh fuel annually for refueling. Shipment of these fresh fuel assemblies was analyzed as being shipped in a fuel cask capable of holding 12 assemblies, as described in NRC 2006c.

It is assumed that loading operations would be conducted by a crew of 13 persons during a 10-hour period. The external dose rate for the casks and containers containing the fresh fuel assemblies is assumed to be 0.1 millirem per hour (mrem/hr) at a distance of 3.3 feet (ft) (1 meter [m]) (NRC 2006c). Inspection would require one person at a distance of 6.6 ft (2 m) from the source for 1 hour (DOE 1996c). Table 7.2.1.2-1 shows the potential impacts from

loading and transporting 24 metric tons of heavy metal (MTHM) of fresh fuel assemblies by truck from a fuel fabrication facility to a port, as expressed in person-rem and latent cancer fatalities (LCFs).

TABLE 7.2.1.2-1—*Impacts of Shipping Fresh Fuel Assemblies from Manufacturer to a Port by Truck*

	Transportation Impacts for 24 MTHM Fresh Fuel via Truck Transport Fuel Fabrication Facility to Port (500 miles) (Note 1)	
	Person-rem	**LCFs**
Crew	1.24×10^{-4}	7.44×10^{-8}
Population	7.75×10^{-4}	4.65×10^{-7}
Stops	8.92×10^{-7}	5.35×10^{-10}
Loading	0.0900	5.40×10^{-5}
Inspection	0.0154	9.23×10^{-6}
Accident Risk[a]	--	--

Source: Tetra Tech 2008f

[a] Accident impacts are not provided for fresh fuel transportation, as information for nuclide inventory is not readily available. As stated in the *Environmental Impact Statement for an Early Site Permit (ESP) at the Exelon ESP Site* (NRC 2006c), potential impacts from the transportation of fresh fuels for contemporary reactor technologies tends to be orders of magnitude lower than the impacts provided for SNF in 10 CFR 51.52. Additionally, accident impacts would be bounded by the impacts presented in Table 7.2.1.7-1.

Note 1: No specific locations are assessed for the fuel fabrication facility or the port.

It is assumed that shipments by truck would require approximately one hour of stop time for rests and walk-around inspections per eight-hour driving shift. This assumption is more stringent than the Federal Motor Carrier Safety Administration requirement (49 CFR Part 395) and most state requirements. Transportation of fresh nuclear fuel across large distances by truck would result in greenhouse gas emissions that would have an impact on air quality. Though likely to be relatively small, the environmental impact of such emissions would be evaluated prior to making any decision on implementation of international elements of the GNEP Program.

7.2.1.3 *Marine Transport of Reactor Fuel Assemblies*

Information in this section was taken from the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel*, DOE/EIS-0218F (DOE 1996c). The information from that EIS is considered to be the best available information with respect to the marine transport of radiological materials. There are several types of ships that could be used to transport reactor fuel assemblies to foreign ports, as listed below.

Container vessels: These vessels are typically large ships specifically intended to transport containerized cargo. Some modern container ships can transport up to 5,000 containers, although a more typical capacity is in the range of from 800 to 1,000 containers. Container vessels usually transport containers between the larger, more widely-used ports of the world. Containers can be loaded or off-loaded from a container vessel at an average rate of about 45 containers per hour (DOE 1996c).

General cargo ships: General cargo ships are smaller vessels that typically transport cargo between the lesser used ports of the world. They usually have on-board cranes that can be used to

load or off-load the vessel, should the dock not have any cranes. Cargo is usually stowed in separate cargo hold compartments (DOE 1996c).

Purpose-built ships: Purpose-built ships are specially designed ships for the purposes of transporting reactor fuel assemblies or SNF. They are designed to hold casks below decks in specially designed hold compartments. These vessels have double bottoms and hulls and collision-damage-resisting structures built into the hull. The crews are specifically trained in the handling of the transport casks and in emergency response (DOE 1996c).

The fuel assemblies would be shipped by chartered and/or regularly scheduled commercial ships from U.S. ports to foreign ports. Chartered shipments would be on purpose-built ships or general purpose commercial cargo ships that meet all appropriate International Maritime Organization regulations. Regularly scheduled commercial shipments would be on general purpose commercial ships carrying other cargo at the same time. Marine transport, as well as ground transport, would be conducted in approved and certified nuclear fuel casks. One ship could easily accommodate 5 NLI-10/24, 11 GA-4/9 casks, or 4 fresh fuel casks needed to transport 21.7 MTHM of fuel. Vessels for charter are available from several steamship lines (DOE 1996c).

All ships entering U.S. territorial waters are required to comply with the U.S. Coast Guard safety regulations and are subject to U.S. Coast Guard inspection. In addition, international transportation of hazardous material is governed by the International Movement of Dangerous Goods Code, which is one of a series of safety codes associated with the International Maritime Organization (DOE 1996c). These requirements remain in effect today. As stated in Section 7.2.1, it is assumed that the reactor fuel could go to practically any country in the world. Once loaded, environmental impacts are a function of the miles traveled. For purposes of this analysis, a hypothetical maximal distance for a remote location was selected requiring a voyage duration of 31 days. A voyage of this duration would enable shipment between most foreign locations and U.S. ports.

The primary impact of incident-free marine transport of fuel assemblies is to the crew of the ships used to carry the casks. Due to the protective qualities of the transport cask, members of the general public and marine life would not receive any measurable dose from the fuel assemblies during incident-free marine transport. In addition to the protection provided by the transportation casks, further protection of the public and marine life would be provided by the ship's structure. Under incident-free conditions of transport, public exposure would be limited to the ship's crew, and their exposure would be limited to only those crew members exposed during the loading and off-loading of the casks and to crew members who, on a daily basis, are required to inspect cargo (to ensure secure stowage) and the vessel (DOE 1996c).

While loading the fuel assemblies onboard ships, inspectors, dockworkers, longshoremen, and crane operators would be exposed to radiation. This exposure would primarily be a function of the integrity of the regulatory design limits of the NRC/DOT-certified cask. It is assumed that loading operations would be conducted during an 8-hour period, and that five handlers would be involved in the loading operation at a distance of 16 ft (5 m) from the source. Four staging workers would be involved at a distance of 33 ft (10 m) from the source. One crane operator would be involved at a distance of 82 ft (25 m) from the source. After loading, it is assumed that

one inspector would be at a distance of 6 ft (2 m) for a period of 4 hours. In transit, it is assumed that inspections would be made daily, amounting to 6 total hours of exposure for a 31-day voyage at a distance of 6 ft (2 m). In addition, it is assumed that a chief mate would be at a distance of 82 ft (25 m) and a bosun (an assistant to the chief mate) at a distance of 33 ft (10 m) during the loading and for brief periods during each day of the voyage (DOE 1996c).

While the reactor fuel was onboard the ship, individuals coming into close proximity of the casks, such as sailors on watch or sailors performing routine inspections, would receive minimal doses of radiation. Since these individuals would be performing required routine functions, the doses they would receive would be a function of the time of transportation. The expected incident-free maritime transport impacts associated with loading the fuel casks onto a ship and the transport of the fuel assemblies to port requiring a voyage duration of 31 days are shown in Tables 7.2.1.3-1 and 7.2.1.3-2.

TABLE 7.2.1.3-1—*Impacts During Loading and Inspection at the Ports for 24 MTHM of Fresh Fuel*

	Person-rem	LCFs
Handler	0.00110	$6.6\text{x}10^{-7}$
Staging	4.32×10^{-5}	$2.6\text{x}10^{-8}$
Crane	2.70×10^{-6}	$1.6\text{x}10^{-9}$
Inspector	0.0154	9.2×10^{-6}

Source: Tetra Tech 2008f

TABLE 7.2.1.3-2—*Impacts During Voyage Between the Ports for 24 MTHM of Fresh Fuel—31-Day Voyage*

	Total Voyage (31 days)	
	Person-rem	LCFs
Crew	1.05×10^{-5}	6.3×10^{-9}
Population	0.00103	6.2×10^{-7}
Chief Mate	1.24×10^{-4}	7.4×10^{-8}
Bosun	7.75×10^{-4}	4.6×10^{-7}
Engineer	0.0192	1.2×10^{-5}
Accident Risk[a]	--	--

Source: Tetra Tech 2008f

[a] Accident impacts are not provided for fresh fuel transportation, as information for nuclide inventory is not readily available. As stated in the *Environmental Impact Statement for an Early Site Permit (ESP) at the Exelon ESP Site* (NRC 2006c), potential impacts from the transportation of fresh fuels for contemporary reactor technologies tends to be orders of magnitude lower than the impacts provided for SNF in 10 CFR 51.52, and shown in Table S.4-1. Additionally, accident impacts would be bounded by the impacts presented Table 7.2.1.7-1.

7.2.1.4 *Return of Spent Nuclear Fuel*

The production of 1 GWe in LWRs would generate approximately 21.7 MT of SNF annually. After removing the SNF from the reactor, it would be stored, onsite, until cool enough for shipment. This SNF would then be placed in certified transport casks and taken to a foreign port of exit where it would be shipped back to the United States or to a supplier nation. Because this analysis assesses the potential impacts on the United States and the global commons, it is

assumed these shipments would go to the United States. Once in the U.S. port of entry, the SNF would be off-loaded from the ship and placed on a truck, barge, or railcar for shipment to a recycling center. The fewest full cask loads for truck, barge, and rail shipments needed to transport 21.7 MTHM of spent fuel would represent 22 MTHM and 25 MTHM, respectively. The maritime shipment analysis assumed 22 MTHM, stored in 11 truck spent fuel casks (GA-4/9 casks).

7.2.1.5 *Marine Transport of Spent Nuclear Fuel*

The truck cask scenario was chosen to assess marine transport impacts because it represents the largest loading, unloading, and inspection impacts. The SNF would be shipped in the same types of ships as those that shipped the fuel assemblies to the foreign reactors, as detailed in Section 7.2.1.3. Once again, GA-4/9 and NLI-10/24 casks would be utilized for the SNF and 1 ship could easily accommodate the required truck casks and rail/barge casks. Although the composition of the SNF would be different from the fresh fuel, the volume of the fuel rod assemblies would remain the same and the same number of casks would be used for the return voyage. The external dose rate for the casks and containers containing the SNF is assumed to be 10 millirem per hour (mrem/hr) at a distance of 6.6 ft (2 m). While the SNF was onboard the ship, individuals coming into close proximity of the casks, such as sailors on watch or sailors performing routine inspections, would receive minimal doses of radiation. Exposure would be a function of the time of transport. Table 7.2.1.5-1 shows the impacts of transporting the SNF from a foreign nation back to a port in the United States.

TABLE 7.2.1.5-1—*Impacts of Transporting Spent Nuclear Fuel Casks from Foreign Nation Back to a United States Port—31-Day Voyage*

	Total Voyage (31 days)	
	Person-rem	**LCFs**
Crew[a]	0.00201	1.2×10^{-6}
Population[b]	0.198	1.2×10^{-4}
Chief Mate	0.0239	1.4×10^{-5}
Bosun	0.146	8.7×10^{-5}
Engineer	3.72	0.0022
Accident Risk	0.00225	1.4×10^{-6}

Source: Tetra Tech 2008f
[a] The values provided represent the daily and total voyage doses due to daily inspection processes.
[b] The accident risk is for the total voyage.

Transportation of SNF across large distances by ship would result in greenhouse gas emissions that would have an impact on air quality. Though likely to be relatively small, the environmental impact of such emissions would be evaluated before making any decision on implementation of international elements of the GNEP Program.

7.2.1.6 *United States Ports*

Once the returning ship carrying the SNF arrived at a United States port of entry, the SNF casks would be off-loaded onto the dock. While the casks were in port and during the time they were off-loaded, port workers would be exposed to small levels of radiation. Table 7.2.1.6-1 shows the impacts of off-loading the SNF at a United States port. Once the casks, containing the SNF, were

loaded onto a truck, barge, or railcar they would be shipped to a recycling center. No specific locations for a port or recycling center are assessed.

TABLE 7.2.1.6-1—*Impacts During Loading and Inspection at a United States Port for 22 MTHM of Spent Nuclear Fuel*

Off-loading Impacts of 22 MT SNF at United States Port of Entry		
	Person-rem	**LCFs**
Handler	0.605	$3.6x10^{-4}$
Staging	0.136	$8.2x10^{-5}$
Crane	0.00572	$3.4x10^{-6}$
Inspector	0.812	4.9×10^{-4}

Source: Tetra Tech 2008f

7.2.1.7 *Ground Transportation of Spent Nuclear Fuel*

The SNF would be loaded onto trucks, railcars, or barges, and transported to a SNF recycling center for processing. Once again, the GA-4/9 casks would be used for truck transport and the NLI-10/24 casks used for shipment by rail or barge. It is estimated that 11 truck shipments or 5 railcars (1 shipment with 5 freight cars and 4 spacer cars) would be required to transport the SNF. Route options for the potential ground transportation of the SNF would depend on the marine port to be used and the location of the yet-to-be proposed recycling center. For purposes of this analysis a distance of 500 miles was assumed.

Routing for shipments by truck would comply with all applicable DOT, NRC, and state regulatory requirements. The U.S. Interstate highway system would be used to the extent possible, utilizing bypasses or beltways around cities. The selection of routes would be consistent with specific state, local, and tribal requirements and declared preferences. All pre-shipment notifications and consultation requirements would be met. Table 7.2.1.7-1 shows the expected impacts of transporting the SNF from the U.S. port of entry to a recycling center by truck, barge, or rail.

TABLE 7.2.1.7-1—*Impacts of Shipping Spent Nuclear Fuel from a United States Port of Entry to a Recycling Center by Truck, Rail, or Barge*

Transportation Impacts: Spent Nuclear Fuel from United States Port of Entry to a Recycling Center (500 mi) (Note 1)						
	Truck (22 MTHM)		**Rail (25 MTHM)**		**Barge (25 MTHM)**	
	Person-rem	**LCFs**	**Person-rem**	**LCFs**	**Person-rem**	**LCFs**
Crew[a]	0.446	$2.7x10^{-4}$	0.0135	$8.1x10^{-6}$	0.00173	$1.0\ x10^{-6}$
Population[a]	2.23	0.0013	0.0421	$2.5x10^{-5}$	$1.38\ x10^{-4}$	$8.3\ x10^{-8}$
Stops	$1.12x10^{-5}$	$6.7x10^{-9}$	$1.78x10^{-5}$	$1.1x10^{-8}$	0	0
Loading	4.75	0.0028	3.32	0.0020	3.32	0.0020
Inspection	0.812	$4.9x10^{-4}$	0.0738	$4.4x10^{-5}$	0.0738	$4.4x10^{-5}$
Accident	$4.54x10^{-6}$	$2.7x10^{-8}$	$3.13x10^{-6}$	$1.9x10^{-9}$	$1.10x10^{-4}$	$6.6x10^{-8}$

Source: Tetra Tech 2008f

[a] The impacts to crew and general population are based on unit risk factors for barge transportation provided in Table J-28 of DOE 2002i.

Note 1: No specific locations are assessed for the port or recycling center.

Transportation of SNF across large distances by ship, truck, and/or rail would result in greenhouse gas emissions that would have an impact on air quality. Though likely to be relatively small, the environmental impact of such emissions would need to be evaluated before making any future decisions on implementation of international elements of the GNEP Program.

7.2.1.8 *Disposition of Reusable Materials from Spent Nuclear Fuel*

Once at a SNF recycling center, the SNF returned from the foreign reactor would be separated into reusable and non-reusable constituents. This process would separate the undesirable wastes from the material suitable for fabricating reactor fuel. Table 4.8-4 provides estimates of the wastes and products for the various programmatic alternatives (note: Table 4.8-4 is based on 100 GWe of production; for 1 GWe of production, the waste and product numbers in Table 4.8-4 need to be divided by 100). The reusable material would be packaged in the appropriate NRC/DOT casks and shipped by truck, barge, or rail to a fuel fabrication center, unless the facilities were colocated.

7.2.1.9 *Disposition of Waste*

The recycling process for the SNF received from production of 1 GWe in LWRs would be expected to generate the following annual wastes: 0.25–9.2 cubic meters (m^3) of HLW; 1.9–68.5 m^3 of GTCC LLW; and 0.6–382 m^3 of LLW. The HLW would produce 235 times less thermal load on a repository compared to spent fuel. The radiotoxicity of the HLW would decay to the radiotoxicity of natural uranium ore in 375 years (Wigeland 2008a). This waste would be processed and made ready for disposal. This waste could be returned to the user nation that generated the SNF, remain in the United States for storage or disposal, or be sent to a supplier nation. If this waste were to be returned to the country that generated the SNF or to a supplier nation, it would be placed in the appropriate NRC/DOT-approved casks and transported by rail or truck to a port. Here, it would be loaded onto a ship and transported back to the country of origin, or to another country, for storage or disposal. The international transport of the waste would utilize the appropriate NRC/DOT/IAEA-approved transport casks, transport routes, and undergo a similar handling and inspection regimen as the SNF shipments to the United States. Due to the integrity of the NRC/DOT/IAEA-approved casks (both the GA-4/9 and the NLI-10/24) and the reduced inventory of radionuclides in the materials being transported[3], emissions and corresponding environmental impacts from the international transport of waste returned to the user nation or to a supplier nation are expected to be similar to, or smaller than, the emissions and corresponding environmental impacts from the transport of the SNF, as discussed in Sections 7.2.1.5 through 7.2.1.7.

7.2.1.10 *Accidents*

7.2.1.10.1 *Ground Transportation Accident*

Vehicular, rail, and barge accident impact estimates are included in the impact table for ground transportation of SNF, only, as shown in Table 7.2.1.7-1. Accident impacts are not provided for fresh fuel transportation, as information for nuclide inventory is not readily available. As stated

[3] The removal of uranium and transuranic elements during recycling reduces the inventory of radionuclides requiring transport.

in the *Environmental Impact Statement for an Early Site Permit (ESP) at the Exelon ESP Site* (NRC 2006c), potential impacts from the transportation of fresh fuels for contemporary reactor technologies tend to be orders of magnitude lower than the impact estimates provided in 10 CFR 51.52. Additionally, accident impacts would be bounded by the impacts presented in Table 7.2.1.7-1. The transportation route between a U.S. port that handles radioactive materials and a SNF recycling center (yet to be proposed) was estimated to be a distance of 500 miles, for modeling purposes. The population densities used in this analysis are derived from the WebTRAGIS model (see Appendix E for a discussion of the population densities).

7.2.1.10.2 *Marine Accident*

Information in this section was taken from the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (DOE 1996c). The information from that EIS is considered to be the best available information with respect to accidents associated with the marine transport of radiological materials. The maximum reasonably foreseeable accident involving marine transportation of nuclear materials would involve the sinking of the ship with casks containing SNF. If the casks were to sink anywhere in U.S. coastal waters, under the provisions of the *Marine Protection, Research, and Sanctuaries Act*, Title I (MPRSA) they would be recovered, regardless of depth (33 U.S.C. 1401). U.S. coastal waters, in this case, refer to waters within the 12 mi (19 km) territorial limit. Elsewhere in the world, if the casks were to sink in coastal water (i.e., in water up to 660 ft. [201 m]), every effort would be made to recover them. In deeper waters, the recovery would be more problematic and recovery could not be guaranteed. The same casks loaded with about 5 MTHM of SNF were used for this analysis. The probability of a marine accident was estimated to be $5x10^{-10}$ (DOE 1996c). The consequence of this analysis is shown in Table 7.2.1.10.2-1. The analysis in Table 7.2.1.10.2-1 is based on the loss of a single cask. If more than one cask were lost at sea, the impacts would be expected to increase linearly as a function of the number of casks lost (i.e., loss of 2 casks would double the impacts). For the annual transport of 21.7 MTHM, a total loss of these casks at sea would be expected to increase the impacts shown in Table 7.2.1.10.2-1 by approximately five times.

TABLE 7.2.1.10.2-1—*Consequences Resulting from the Loss at Sea of a Rail Transportation Cask Containing Spent Nuclear Fuel*

	Coastal Waters		Deep Ocean
	Undamaged Cask	Damaged Cask	Damaged Cask
Peak Individual Dose (Man) rem/yr	0.0003	0.019	1.5×10^{-8}
Peak Biota Dose (Fish) rad/yr	0.0001	0.0008	0.9
Peak Biota Dose (Crustaceans) rad/yr	0.0001	0.0009	1.2
Peak Biota Dose (Mollusks) rad/yr	0.0003	0.019	41

Source: Tetra Tech 2008f

7.2.1.10.3 *Port Accident*

The only port accident considered is one in which the ship carrying the SNF is struck by another ship. For accidents where ships ram a fixed structure or another ship, the damage would be limited to the prow and to the forward-most hold, and the forces exerted on cargo in the forward hold would not be expected to be sufficient to damage the shipping cask. Such forces would be

substantially less than the forces exerted on cargo in the case where a striking ship impacts the cargo hold. For ships that might run aground in port, their keel structure is sufficient to limit damage to the cargo. Although a ship could sink, immersion to the depths of a harbor would not damage the integrity of the SNF cask or pose significant retrieval problems (DOE 1996c).

7.2.2 Other Domestic Programmatic Alternatives

This section discusses the potential environmental impacts in the United States and the global commons that could result from an international Reliable Fuel Services Program based on the domestic programmatic alternatives, other than the Fast Reactor Recycle Alternative. Under each of the domestic programmatic alternatives, an international Reliable Fuel Services Program would produce the following impacts:

- Transporting Fresh Fuel from the United States to a Foreign Reactor—these impacts would be the same as those presented in Sections 7.2.1.1, 7.2.1.2, and 7.2.1.3
- Transporting Spent Nuclear Fuel from a Foreign Reactor to a United States Port—these impacts would be the same as those presented in Sections 7.2.1.4, 7.2.1.5, and 7.2.1.6
- Potential Accidents—these potential impacts would be the same as those presented in Section 7.2.1.10

In addition, there are potential differences among the domestic programmatic alternatives for the impacts from disposition of foreign reactor SNF. These differences are shown in Table 7.2.2-1.

TABLE 7.2.2-1—*Potential Differences Among the Domestic Programmatic Alternatives Related to Disposition of Foreign Reactor Spent Nuclear Fuel*

	Disposition of Foreign Reactor SNF	Impacts of Foreign Reactor SNF Disposition
Fast Reactor Recycle Alternative	Recycle at recycling center	The recycling process for the SNF received from production of 1 GWe in LWRs would be expected to generate the following annual wastes: HLW: 0.25 – 9.2 m^3 GTCC LLW: 1.9 - 68.5 m^3 LLW: 0.6 – 382 m^3 The HLW would produce 235 times less thermal load on a repository compared to spent fuel. The radiotoxicity of the HLW would decay to the radiotoxicity of natural uranium ore in 375 years.
No Action Alternative	Disposal in geologic repository	Approximately 25 MT of SNF (annual maximum per 1 GWe) would require disposal in a geologic repository. Impacts from transporting the SNF to a geologic repository would depend upon the distance from the United States port to the geologic repository (note 1).
Thermal/Fast Reactor Recycle Alternative	Recycle at recycling center	The recycling process for the SNF received from production of 1 GWe in LWRs would be expected to generate the following annual wastes: HLW: 0.25 – 9.0 m^3 GTCC LLW: 1.9 - 66 m^3 LLW: 0.5 – 344 m^3 The HLW would produce 235 times less thermal load on a repository compared to spent fuel. The radiotoxicity of the HLW would decay to the radiotoxicity of natural uranium ore in 400 years.
Thermal Reactor Recycle Alternative (option 1)	Recycle at recycling center	The recycling process for the SNF received from production of 1 GWe fin LWRs would be expected to generate the following annual wastes: HLW: 0.3 – 17.4 m^3 GTCC LLW: 3.4 – 8.7 m^3 LLW: 0.2 – 260 m^3 The HLW would produce 1.8 times less thermal load on a repository compared to spent fuel. The radiotoxicity of the HLW would decay to the radiotoxicity of natural uranium ore in 55,000 years.
Thermal Reactor Recycle Alternative (option 2)	Recycle at recycling center	The recycling process for the SNF received from production of 1 GWe in LWRs would be expected to generate the following annual wastes: HLW: maximum of 8.0 m^3 GTCC LLW: minimum of 1.2 m^3 LLW: no data The HLW would produce 1.6 times less thermal load on a repository compared to spent fuel. The radiotoxicity of the HLW would decay to the radiotoxicity of natural uranium ore in an unknown period.
Thermal Reactor Recycle Alternative (option 3)	Recycle at recycling center	There are no data to estimate the quantities of wastes produced, the thermal load reduction, or the radiotoxicity reduction for this option.
Thorium Alternative	Disposal in geologic repository	Approximately 25 MT of SNF (annual maximum per 1 GWe) would require disposal in a geologic repository. Impacts from transporting the SNF to a geologic repository would depend upon the distance from the United States port to the geologic repository (note 1).
HWR/HTGR Alternative (option 1—All HWR)	Disposal in geologic repository	Approximately 25 MT of SNF (annual maximum per 1 GWe) would require disposal in a geologic repository. Impacts from transporting the SNF to a geologic repository would depend upon the distance from the United States port to the geologic repository (note 1).
HWR/HTGR Alternative (option 2—All HTGR)	Disposal in geologic repository	Approximately 25 MT of SNF (annual maximum per 1 GWe) would require disposal in a geologic repository. Impacts from transporting the SNF to a geologic repository would depend upon the distance from the United States port to the geologic repository (note 1).

Note 1: If a repository were 500 miles (804 km) away from the port (which was the distance assumed for transporting the SNF from port to a recycling center for the Fast Reactor Recycle Alternative), the impacts would be the same as those presented in Table 7.2.1.7-1. For other distances, the impacts would generally vary linearly with distance. That is, if the distance from a port to a geologic repository were 1,000 miles (1,608 km), the impacts would be twice as much as those presented in Table 7.2.1.7-1.

7.3 REFERENCES

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