

ARTICLE

NUCLEAR ENERGY AND PROLIFERATION: PROBLEMS, OBSERVATIONS, AND PROPOSALS

TAYLOR BURKE*

TABLE OF CONTENTS

I.	INTRODUCTION.....	
II.	NUCLEAR HISTORY IN THE UNITED STATES: BETWEEN THE MILITARY AND CIVILIAN USES OF NUCLEAR TECHNOLOGY.....	
	A. <i>Domestic Law and Policy</i>	
	1. The Atomic Energy Act.....	
	B. <i>Price Anderson Insurance</i>	
	C. <i>Nuclear Energy in the Courts</i>	
	D. <i>Analysis: Lessons of the Bureaucracy</i>	
III.	THE NUCLEAR ENERGY PROCESS AND MILITARY APPLICATIONS.....	
	A. <i>How Does Nuclear Energy Work?</i>	
	1. Generally.....	
	2. Nuclear Fuel.....	
	B. <i>Reactor Types</i>	
	1. Natural Uranium Reactors.....	
	2. Water Reactors.....	
	3. Liquid Metal Reactors.....	
	4. Integral Fast Reactors.....	
	5. Thorium Reactors.....	
	C. <i>How Can This Process Be Used to Develop Nuclear Weapons?</i>	
	1. Fuel Rod Theft and Reprocessing.....	
	2. Alternative Diffusion.....	
	3. Waste.....	
IV.	UNITED STATES POLICY ACTIONS IN RESPONSE TO THE THREAT OF REPROCESSING AND PROLIFERATION.....	
	A. <i>“Cooperative Threat Reduction”</i>	
	1. Policy.....	
	2. Technical Process.....	
	3. DOE and DOD Participation.....	
	4. Implementation and Difficulties.....	
	B. <i>The Nuclear Non-Proliferation Treaty</i>	
	C. <i>The International Atomic Energy Agency</i>	
	D. <i>Diversion Proof Fuel</i>	

E. *Export Controls*.....

F. *Direct Foreign Policy Measures*.....

V. ANALYSIS.....

A. *Should the United States Promote the Use of Nuclear Energy?*.....

B. *What Measures Can Be Taken to Ameliorate the Proliferation Risks Posed by Nuclear Energy?*.....

C. *Is the Present Division of Labor Within the Federal Government Appropriate to Address the Myriad Issues Created by the Unique Nature of Nuclear Technology?*.....

VI. CONCLUSION: TWO BROAD OBSERVATIONS ON NUCLEAR ENERGY AND NUCLEAR PROLIFERATION.....

I. INTRODUCTION

An aging nuclear reactor sits in Kinshasa, Congo.¹ It was developed in the 1950s, as part of the American effort to win over popular appeal during the Cold War.² Like all contemporary nuclear reactors in use, it is powered by materials that could, by remote possibility, be converted into a nuclear weapon.³ During some of the more difficult times in Congo's recent history, the reactor in Kinshasa has sat unmonitored by local and international authorities.⁴ This reactor has been cited as a potential source for black market smugglers interested in the sale of dangerous materials.⁵ The problems associated with such reactors, including the threat of black market smuggling, have motivated contemporary United States foreign policy.⁶ The implications

* J.D., University of Tulsa, 2006; B.A., Political Science and History, University of Tulsa, 2002.

¹ Paul Cullen, *A City Picked Bare . . . Even Nuclear Reactor Was Looted*, IRISH TIMES, July 28, 2005, available at 2005 WLNR 11812866; see also Douglas Pasternak & Eleni E. Dimmler, *A Home-Grown Nuclear Threat*, U.S. NEWS & WORLD REP., Sept. 23, 2002, at 40; Sara Daly, John Parachini & William Rosenau, *Aum Shinrikyo, Al Qaeda, and the Kinshasa Reactor: Implications of Three Case Studies for Combating Nuclear Terrorism*, RAND PROJECT AIR FORCE (2005), available at http://www.rand.org/pubs/documented_briefings/2005/RAND_DB458.pdf (last visited Feb. 13, 2006)

² Daly et al., *supra* note 1, at 54 (discussing the competition between the United States and the Soviet Union to draw less developed nations into their respective spheres of influence with nuclear technology).

³ Douglas Pasternak & Eleni E. Dimmler, *A Home-Grown Nuclear Threat*, U.S. NEWS & WORLD REP., Sept. 23, 2002, at 40; Daly et al., *supra* note 1, at 65.

⁴ See *id.*

⁵ *Id.*

⁶ Mitchell B. Reiss & Robert L. Gallucci, *Red-Handed*, FOREIGN AFFAIRS, (2005), available at <http://www.foreignaffairs.org/20050301faresponse84214/mitchell-b-reiss-robert-gallucci/red-handed.html> (last visited Mar. 30, 2006) (discussing the Clinton and Bush administrations' efforts to confront the North Korean nuclear enrichment program that

of such policy (or lack thereof) are the subject of this paper.

The evolution of nuclear technology has presented policy challenges to the United States, both domestically and abroad, in dealing with the problems of nuclear technology. Nuclear energy has clear advantages. It is relatively inexpensive for the amount of energy produced, which can be useful in relatively fossil-fuel-poor nations.⁷ Nuclear energy also does not emit carcinogenic air pollution or carbon dioxide, an important factor for any nation dealing with air pollution.⁸

Nuclear technology, however, also has obvious drawbacks. The nuclear fuel cycle generates extremely dangerous waste.⁹ Nuclear plants, even with the remote possibility of an accident or a terrorist attack, require a great deal of security and bureaucratic oversight, making their use very expensive.¹⁰

The relationship between civilian and military applications of nuclear technology poses a number of modern challenges to policymakers. This paper examines the relationship between military applications and civilian uses of nuclear technology and focuses on the methods taken by the United States to address this relationship. To understand the U.S. policies, it is necessary to analyze the history of nuclear technology, the aspects of nuclear technology that enable security threats, the history of the United States response to those threats, the current United States policy, and finally, the possible improvements to the policy.

Nuclear energy represents a necessary component of an international energy strategy that will address the world's increasing energy demand.¹¹ This paper will argue that the United States should only promote nuclear technology if it is willing to address the related risk of proliferation. The analysis concludes by examining three questions: 1) Should the United States promote the use of nuclear energy?; 2) What measures can be taken to ameliorate the proliferation risks posed by nuclear energy?; and 3) Is the present division of labor within the federal government appropriate to address the myriad issues that the unique nature of nuclear technology creates?

II. NUCLEAR HISTORY IN THE UNITED STATES: BETWEEN THE MILITARY AND

utilizes dual-use nuclear technology); *When the Soft Talk Has to Stop*, THE ECONOMIST, Jan. 14, 2006, at 29 (discussing international effort to confront Iran regarding its nuclear program).

⁷ SCOTT W. HEABERLIN, *A CASE FOR NUCLEAR-GENERATED ENERGY ELECTRICITY . . . OR WHY I THINK NUCLEAR POWER IS COOL AND WHY IT IS IMPORTANT THAT YOU THINK SO TOO* 236 (Battelle Press 2004).

⁸ MAX W. CARBON, *NUCLEAR POWER: VILLAIN OR VICTIM?* 87 (Pebble Beach Publishers 1997).

⁹ *Id.* at 59

¹⁰ See generally CARBON, *supra* note 8, at ch. 6.

¹¹ HEABERLIN, *supra* note 7.

CIVILIAN USES OF NUCLEAR TECHNOLOGY

The nuclear energy industry is the result of the efforts of United States military scientists during the 1930s and 1940s.¹² During this period, the United States explored military applications of nuclear energy, focusing on how splitting uranium atoms could create energy.¹³ To understand the current regulatory framework of nuclear energy, we must first understand the origins of the United States policy concerning this technology.

A. *Domestic Law and Policy*

The nuclear era literally began with a bang: the attacks on Hiroshima and Nagasaki during World War II.¹⁴ The technology and science that developed these weapons is, and will always be, fundamentally associated with the energy resource that followed it. After World War II, Congress passed the Atomic Energy Act of 1946 (“AEA”) to address the profound military and economic implications of this new technology on the United States.¹⁵ While unsure of the long-term implications of nuclear technology, Congress, in the AEA, expressed concern with the direction of the nuclear industry: “[S]ubject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace.”¹⁶ President Eisenhower followed suit in the 1954 with the “Atoms for Peace” Program, which encouraged peaceful use of nuclear technology and served the political aspirations of the United States during the Cold War.¹⁷ From the very beginning of the nuclear era, the federal government has been concerned with the implications of nuclear technology for security and foreign policy goals. As a result, the federal government has sought to shape the technology through a variety of legal and bureaucratic devices.

1. The Atomic Energy Act

Among the notable aspects of the AEA was the decision by Congress to make the nuclear industry a government monopoly that allowed for private

¹² See generally RICHARD L. GARWIN & GEORGES CHARPAK, MEGAWATTS AND MEGATONS: A TURNING POINT FOR THE NUCLEAR AGE? 31-106 (2001).

¹³ *Id.*

¹⁴ CARBON, *supra* note 8, at vi.

¹⁵ See Nuclear Regulatory Commission, Our Governing Legislation – Atomic Energy Act of 1954, available at <http://www.nrc.gov/who-we-are/governing-laws.html> (last visited Feb. 16, 2006) (discussing how the Act formed the legal foundation for military and civilian applications of nuclear energy technology).

¹⁶ 42 U.S.C. § 2011(a) (2000).

¹⁷ Daly et al., *supra* note 1, at 54.

groups to invest subject to a great deal of federal oversight.¹⁸ The AEA's purpose is to regulate the various materials involved in the nuclear process.¹⁹ Under the current law, the Department of Energy ("DOE"), through the Nuclear Regulatory Commission ("NRC"), has oversight of source materials,²⁰ special nuclear materials,²¹ and byproducts.²²

Congress had two main motivations in its initial attempts to regulate nuclear energy. First, it recognized the "need for atonement" after the attacks on Hiroshima and Nagasaki, which served as a major impetus for developing peaceful applications of nuclear energy.²³ Second, and very much ironically, Congress saw a need to pursue the technology for purposes of the Cold War, both in terms of technology and as part of a greater international agenda – the 1954 AEA also included the aforementioned "Atoms for Peace" Program.²⁴ This Program established a relationship between military and civilian developments in applications of nuclear technology. For example, the navy developed the light water reactor, a model frequently used in U.S. nuclear power plants, for use on submarines.²⁵

The AEA also created the Atomic Energy Commission ("AEC"), which was responsible for licensing and energy development functions.²⁶ The Energy Reorganization Act of 1974 split the AEC into the NRC and the Energy Research and Development Administration ("ERDA"), which eventually became the DOE.²⁷ Congress has charged the NRC with the health and safety aspects of the industry.²⁸

The original AEA said nothing about public safety, perhaps because safety is traditionally a state function. In 1959, Congress amended the AEA to allow nominal state involvement in the regulation of byproducts, source materials,

¹⁸ 42 U.S.C. § 2017.

¹⁹ *Id.* § 2013.

²⁰ "Source material" is uranium, thorium, or any other material deemed by the NRC to be source material and ores containing those materials. 42 U.S.C. § 2091 (2000).

²¹ "Special nuclear material" refers to plutonium, enriched uranium (isotope 233 or isotope 235). 42 U.S.C. § 2141 (2000).

²² "Byproducts" include any material made radioactive by exposure to radiation or other nuclear material. 42 U.S.C. § 2112 (2000).

²³ Diane Carter Maleson, *The Historical Roots of the Legal System's Response to Nuclear Power*, 55 S. CAL. L. REV. 597, 597-98 (1982).

²⁴ See Adam Tanner, *Nuclear power at a standstill*, PHILA. INQUIRER, Oct. 10, 2004, at A25, available at 2004 WLNR 3698836; see also Daly et al., *supra* note 1, at 54.

²⁵ CARBON, *supra* note 8, at 79.

²⁶ Office of History and Heritage Resources, Executive Secretariat Department of Energy, Department of Energy History: An Overview, available at <http://www.cfo.doe.gov/me70/history/overview.htm> (last visited Feb. 17, 2006).

²⁷ Energy Reorganization Act of 1974, 42 U.S.C. §§ 5801 et seq. (2000).

²⁸ *Id.* § 5841(a).

and small quantities of special nuclear materials.²⁹ The states and the NRC sign agreements related to these regulations after the NRC finds that a state's radiation control program coincides with federal intentions.³⁰ States must also regulate nuclear energy with regard to its energy production as part of a utility system.³¹

B. Price Anderson Insurance

Another important step in the process of creating a commercial nuclear industry was the Price Anderson³² “umbrella” for nuclear power operators. Given the unfathomable legal cost of a nuclear accident, Congress realized that the fledgling nuclear industry would be unable to pay the cost of insurance since the industry operated on small margins like other utility producers.³³ Over the past five decades, Congress has developed a system in which nuclear producers share a certain amount of the insurance cost for accidents, and Congress agrees to pay the rest in the event of a catastrophic accident.³⁴ This plan also enables the nuclear industry to survive and generate profits.³⁵ It is worth noting, however, that the federal government has never paid money for a claim under Price Anderson.³⁶

C. Nuclear Energy in the Courts

The legal system has had limited experience with the challenges of interpreting the AEA and the Price Anderson provisions. In *Northern States Power Co. v. Minnesota*,³⁷ the Eighth Circuit Court of Appeals ruled that the federal government preempted state authority to regulate nuclear power plant operation and construction, allowing the AEC to regulate release of radioactive effluents from nuclear plants.³⁸ *In re TMI Litigation Cases Consolidated IF*³⁹ discussed the history of federal regulation of nuclear energy in depth, describing the method used to allocate responsibility for nuclear energy, such as the Price Anderson system.⁴⁰

²⁹ *Id.* § 2021.

³⁰ *Id.* §§ 2021(b), (d).

³¹ *Id.* § 2021 (k).

³² *Id.* § 2210(c).

³³ *A Renaissance That May Not Come*, THE ECONOMIST, May 17, 2001, at http://www.economist.com/displaystory.cfm?story_id=623959.

³⁴ HEABERLIN, *supra* note 7, at 230.

³⁵ *A Renaissance That May Not Come*, *supra* note 33.

³⁶ HEABERLIN, *supra* note 7, at 230.

³⁷ 447 F.2d 1143 (8th Cir. 1971).

³⁸ *Id.* at 1154.

³⁹ 940 F.2d 832 (3d Cir. 1991).

⁴⁰ *Id.*

The overwhelming attitude of the courts concerning nuclear energy, however, has been one of deference.⁴¹ Diane Carter Maleson noted that American courts often adopt conservative positions when considering emerging technologies and social concerns. She compared the deference of the courts towards nuclear energy with the slow response of the courts in addressing the problems created by industrialization in the 1800s.⁴² Moreover, Carter noted that this deference was inspired by judicial trust in the technocratic regime, which she viewed as a policy choice in and of itself. Carter argued that courts, by deferring to administrative judgment, have changed nuclear energy from an “option” to a “mandate.”⁴³

D. Analysis: Lessons of the Bureaucracy

These cases illustrate a unique aspect of the American nuclear system vis-à-vis that of other nations: namely, the impact of the bureaucratic system that regulates all aspects of American nuclear technology. There are lessons to be learned from this system for comparative purposes. The United States has a comprehensive system of checks and balances to ensure an appropriate separation between the interests of industry and those of the government. The federal government defines policy areas (security, safety, and an energy supply) and the appropriate entities (the military, the various civilian government entities at the state and federal level, the entrepreneurs) to act in accordance with that policy.

This sort of system, however, does not exist in every nation around the world. In one way or another, some of the emerging nuclear states lack the technocratic structure to divide those responsibilities adequately.⁴⁴ In some instances, those shortcomings create potential security risks for the United States, like the problem in the Congo, which this analysis focuses on. The next section discusses how the technology creates those risks.

⁴¹ There are a few notable exceptions. See *Int'l Union of Elec., Radio and Mach. Workers v. U.S.*, 280 F.2d 645 (D.C. Cir. 1960) (overturning an AEC approval of a breeder reactor project because it did not meet the safety standards in the AEA). On appeal, the Supreme Court overturned the court of appeals' decision, again deferring to the AEC's authority. *Power Reactor Dev. Co. v. Int'l Union of Elec., Radio and Mach. Workers*, 367 U.S. 396 (1961). See also *Porter County Chapter of the Izaak Walton League of Am., Inc. v. Atomic Energy Comm'n*, 515 F.2d 513 (7th Cir. 1975) (holding that AEC grant of permit for plant violated its own citing regulations). The Supreme Court reversed. *N. Ind. Pub. Serv. Co. v. Porter County Chapter of the Izaak Walton League of Am., Inc.*, 423 U.S. 12 (1975).

⁴² Maleson, *supra* note 23, at 605.

⁴³ *Id.* at 639-640.

⁴⁴ E.g., The Congo. See generally Daly et al., *supra* note 1.

III. THE NUCLEAR ENERGY PROCESS AND MILITARY APPLICATIONS

Nuclear energy uses a relatively simple atomic reaction to generate steam that creates energy.⁴⁵ Several different technologies have been developed to utilize this science and each warrants specific explanation. These technologies can also be used in a number of ways to develop nuclear weapons.

A. *How Does Nuclear Energy Work?*

1. Generally

A nuclear reactor releases energy from uranium and plutonium and uses that energy to heat water and generate steam.⁴⁶ A nuclear reaction creates the energy that leads to electricity.⁴⁷ Any of several methods achieve this reaction, but there is one fundamental model.

Uranium has a very unstable nucleus, which readily breaks up or disintegrates.⁴⁸ When the neutrons within uranium atoms collide with the nuclei of other uranium atoms, two or three neutrons are released and the reaction creates energy.⁴⁹ This is called the “fissioning process.”⁵⁰ Isotopes of uranium, U-235 and U-238, have different properties from standard uranium.⁵¹ U-235 captures a neutron, fissions, and releases energy more easily than U-238.⁵² However, U-238 is important because it can absorb neutrons and form the element plutonium.⁵³ Plutonium fissions like uranium and is frequently used in commercial nuclear reactors.⁵⁴ About 40% of commercial electricity comes from plutonium.⁵⁵

A nuclear reactor usually has four parts: uranium (or a combination of uranium and plutonium), water, devices that control the rate of fission, and a radiation shield.⁵⁶ Uranium is usually shaped into small rods, called fuel rods, to improve efficiency. Fuel rods are normally one-half inch in diameter and several feet long.⁵⁷

⁴⁵ CARBON, *supra* note 8, at 1.

⁴⁶ *Id.* at 9.

⁴⁷ *Id.*

⁴⁸ *Id.* at 7.

⁴⁹ *Id.*

⁵⁰ *Id.*

⁵¹ CARBON, *supra* note 8, at 9.

⁵² *Id.*

⁵³ *Id.*

⁵⁴ *Id.*

⁵⁵ *Id.* at 9.

⁵⁶ *Id.* at 11.

⁵⁷ CARBON, *supra* note 8, at 12.

2. Nuclear Fuel

Nuclear reactors use several types of fuel. The most important ingredient for a nuclear reaction is uranium, a relatively rare element.⁵⁸ Uranium needs to be enriched for use in many civilian and military applications, uranium must be enriched.⁵⁹ “Yellow Cake” is processed uranium concentrate, containing 70-90% uranium oxide.⁶⁰ Crushed, or compressed, uranium is used in the enrichment process.⁶¹

Enriched uranium is given a higher U-235 content through a process called isotope separation.⁶² Several different methods, such as centrifugation and gas diffusion,⁶³ are used to bring the U-235 content in fuel rods from 3-5% (up from the natural content of .70%).⁶⁴ The higher content permits the fuel rods in a reactor to be closer together, which allows more fission to occur.⁶⁵

Plutonium, a fundamental ingredient in nuclear weapons,⁶⁶ is obtained through a number of processes, two of which warrant specific attention. Plutonium is a byproduct in all civilian reactors. Reprocessing plants, such as breeder reactors, create plutonium that can be re-used as fuel within the reactor.⁶⁷

⁵⁸ See World Uranium Resources, <http://www.wise-uranium.org/img/uresw.gif> (last visited Nov. 29, 2005) (showing locations of uranium worldwide).

⁵⁹ See BBC News, Nuclear Fuel Cycle, http://news.bbc.co.uk/2/hi/in_depth/world/2003/nuclear_fuel_cycle/reactor/default.stm (last visited Feb. 15, 2006) (discussing that uranium must be “super-critical” in order to “allow a self-sustaining chain reaction to occur.”).

⁶⁰ See BBC News, Nuclear Fuel Cycle, http://news.bbc.co.uk/2/hi/in_depth/world/2003/nuclear_fuel_cycle/conversion/default.stm (last visited Nov. 29, 2005) (explaining the yellow cake process and the uranium enrichment process).

⁶¹ *Id.*

⁶² See BBC News, Nuclear Fuel Cycle, http://news.bbc.co.uk/1/hi/in_depth/world/2003/nuclear_fuel_cycle/enrichment/default.stm (last visited Feb. 15, 2006).

⁶³ Gas diffusion is the most frequently used technique in American nuclear reactors. The history of these processes is important to the history of the industry as a whole. A substantial amount of the Manhattan Project was dedicated to researching such processes. See GARWIN & CHARPAK, *supra* note 12, at 49-50; see also BBC News, *supra* note 62 (illustrating the nuclear fuel cycle in some detail).

⁶⁴ GARWIN & CHARPAK, *supra* note 12, at 48.

⁶⁵ *Id.* at 46-47.

⁶⁶ For a nuclear weapon to work, an explosive chain reaction must take place. By enabling more neutrons to react, the material reacts and generates more and more neutrons to react in a microsecond. In a nuclear reactor, the energy process is designed to maintain a chain reaction by regulating the system of fissioning so that only one neutron reacts at a time in the fission, because control rods absorb the excess neutrons. GARWIN & CHARPAK, *supra* note 12, at 34-35.

⁶⁷ See A. David Rossin, *U.S. Policy on Spent Fuel Reprocessing*, (1998), <http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/rossin.html> (last visited

Mixed Oxide Fuel (“MOX”) accounts for between 2% and 33% of the nuclear fuel used today.⁶⁸ It is derived from reprocessed plutonium and is generally very costly to make.⁶⁹ A discussion of MOX will be important in the discussion of Cooperative Threat Reduction below.

B. Reactor Types

A number of processes have been developed to utilize the reactions of uranium. Each process has advantages and disadvantages.

1. Natural Uranium Reactors

Natural uranium reactors use natural uranium instead of an isotope. This operation requires a heavy-water moderator at atmospheric pressure, which limits the energy within fast fission neutrons, allowing the small proportion of U-235 nuclei within the material to be fissioned.⁷⁰ These reactors do not need the thick steel pressure vessels found in other reactors.⁷¹ These reactors also do not need the processing that other reactors do.⁷² On the other hand, they are not as efficient as the more advanced reactors because they do not use refined uranium.⁷³

2. Water Reactors

In a light water reactor, water becomes steam as it passes through the reactor.⁷⁴ Fuel rods are inserted into a reactor in a chamber filled with water.⁷⁵ Water slows the pace of the uranium neutrons because they lose energy as they uranium neutrons react with the hydrogen in the water.⁷⁶ The water is pumped away from the uranium rods to carry the heat out of the chamber and to create the steam that in turn generates electricity.⁷⁷ Control rods, normally made of boron, regulate the rate of fission.⁷⁸ Boron absorbs excess neutrons within the

Feb. 15, 2006) (advocating the benefits of reprocessing).

⁶⁸ Estimates over the amount used tend to vary, depending on who is writing the analysis. One estimate places it as 2%, but growing slowly. World Nuclear Ass’n, Mixed Oxide Fuel, <http://www.world-nuclear.org/info/inf29.htm> (last visited Nov. 29, 2005).

⁶⁹ GARWIN AND CHARPAK, *supra* note 12, at 327-329.

⁷⁰ *Id.* at 81.

⁷¹ *Id.*

⁷² *Id.*

⁷³ *Id.*

⁷⁴ CARBON, *supra* note 8, at 12.

⁷⁵ *Id.*

⁷⁶ *Id.*

⁷⁷ *Id.*

⁷⁸ *Id.*

reactor.⁷⁹ The steam created from the system spins a turbine and creates electricity.⁸⁰ Similarly, in a pressurized water reactor, water leaves the reactor and passes through tubes in a heat exchanger. Heat from that water leaves the system and boils a separate supply of water.⁸¹

This system safely creates energy much more efficiently than natural uranium reactors.⁸² Nuclear energy benefits from the relatively low cost of uranium for the amount of energy that it can generate.⁸³ With this benefit comes a major long term problem: the limited amount of uranium in the world.⁸⁴ Indeed, some estimates posit that the supply of “easy-to-reach” uranium material, given current demands, will only last another century.⁸⁵ Other drawbacks, which are common to most types of reactors, include highly dangerous nuclear waste and the remote possibility that the waste material may be reprocessed into a weapon.⁸⁶

3. Liquid Metal Reactors

A recent development in nuclear technology attempts to address the limited supply of uranium. Liquid metal reactors (“LMRs”), also called breeder reactors, consume less U-235 than plutonium they generate, producing a net increase in fissionable material.⁸⁷ This might trouble some readers, given the Second Law of Thermodynamics: “[I]n all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state.”⁸⁸ The simple answer to this challenge to the Second Law of Thermodynamics is that it does not create an unlimited amount of nuclear energy; fuel rods still must be replaced after some time.⁸⁹ Rather, the difference that accounts for the seeming violation of the Second Law is that breeder reactors reprocess the waste product of the fission reaction (plutonium) into fuel that other reactors cannot use.⁹⁰ The reactor can generate more plutonium than the traditional reactors because it uses metal sodium as a

⁷⁹ *Id.*

⁸⁰ *Id.* at 1.

⁸¹ *Id.* at 13.

⁸² GARWIN AND CHARPAK, *supra* note 12, at 51.

⁸³ *Id.* at 3.

⁸⁴ CARBON, *supra* note 8, at 78.

⁸⁵ *Id.* at 79.

⁸⁶ *See* Rossin, *supra* note 67 (advocating the benefits of reprocessing).

⁸⁷ CARBON, *supra* note 8, at 78.

⁸⁸ Second Law of Thermodynamics. *See also* Newman v. Quigg, 877 F.2d 1575, 1582 (Fed. Cir. 1989), *modified*, 886 F.2d 329 (Fed. Cir. 1989) (rejecting a patent application for a perpetual energy machine because it violated the Second Law of Thermodynamics).

⁸⁹ CARBON, *supra* note 8, at 78.

⁹⁰ *Id.*

coolant.⁹¹ Metal sodium has a higher melting point than water (208°F compared to 32°F).⁹² Metal sodium thus does not slow neutrons down as much as water does, making more neutrons available for the U-238 at the capture point, which creates more plutonium.⁹³

To separate the useable nuclear fuel from the waste, the spent fuel is chopped and dissolved in an acid bath process.⁹⁴ Uranium and plutonium are recovered and the remaining material is neutralized.⁹⁵ This portion of the “fuel cycle process” is very expensive, requiring a great deal of safety measures given the high radioactivity of some of the materials.⁹⁶

In the 1940s, some predicted that the first reactors would be liquid metal reactors.⁹⁷ The United States Navy developed water-cooled reactors with a great deal of success, and these systems were eventually adopted by the United States nuclear industry.⁹⁸ A number of other nations have also experimented with this technology – such as England, France, India, Japan, China, and Russia – but with little serious success, other than limited commercial use in Russia and Japan.⁹⁹ The Ford and Carter administrations stopped United States development of the technology, but the current Bush Administration has shown interest in it.¹⁰⁰

This process lowers the cost of producing nuclear energy while limiting the waste product of the reaction.¹⁰¹ This technology does require that the fuel rods be discharged periodically and chemically reprocessed.¹⁰² The problem, as noted by the Ford, Carter, and Clinton administrations, is that the breeder

⁹¹ *Id.*

⁹² *Id.*

⁹³ *Id.* at 78-79.

⁹⁴ PETER BECK, PROSPECTS AND STRATEGIES FOR NUCLEAR POWER: GLOBAL BOON OR DANGEROUS DIVERSION? 12 (Royal Inst. Int’l Aff. 1994).

⁹⁵ CARBON, *supra* note 8, at 78.

⁹⁶ *Id.*

⁹⁷ *Id.* at 78-79.

⁹⁸ *Id.*

⁹⁹ *Id.*

¹⁰⁰ The Ford and Carter administrations hoped to convince the rest of the world to reject the process as well. *See also* Henry Sokolski, *Taking Proliferation Seriously*, POLICY REVIEW 51, Oct. 1, 2003 (describing the current Bush Administration’s efforts to encourage breeder reactors in other nations and the administration’s consideration of repealing the ban on reprocessing within the United States).

¹⁰¹ *See* Rossin, *supra* note 67 (advocating the benefits of reprocessing). *See also* HEABERLIN, *supra* note 7, at 303; Spurgeon M. Kenney, Jr., *Plutonium Reprocessing: Twenty Years Experience (1977-1997)*, (1998), <http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/kenney.html> (last visited Nov. 30, 2004).

¹⁰² CARBON, *supra* note 8, at 80.

2006] *NUCLEAR ENERGY AND PROLIFERATION*

reactor creates a pure form of plutonium that can be harnessed for a weapon.¹⁰³

4. Integral Fast Reactors

One recent development, the Integral Fast Reactor (“IFR”), uses a different form of chemical processing and different form of fuel rod.¹⁰⁴ The process never creates pure plutonium. Instead, it uses mixed fragments within the fuel cycle process, both fission materials and transuranic elements, making diversion very difficult.¹⁰⁵ If the material is stolen, a bomb could not be made without further chemical separation.¹⁰⁶

5. Thorium Reactors

Another relatively recent technology is the Radkowsky Thorium Reactor, which uses thorium in the fuel rods in combination with other fissionable premade material to create a theoretically diversion proof reactor.¹⁰⁷ The process of using thorium is costly, however, and requires the use of premade fissionable material (which often *could* be reprocessed).¹⁰⁸ The Radkowsky reactor addresses this problem by separating the U-235 from the thorium in different processes, thus dividing the component into one that creates neutrons for energy and fuel management.¹⁰⁹

C. *How Can This Process Be Used to Develop Nuclear Weapons?*

1. Fuel Rod Theft and Reprocessing

The uranium used in fuel rods cannot be used to make a bomb.¹¹⁰ The U-235 content in “enriched uranium” is around 4-5%; a mixture of U-235 and U-

¹⁰³ *Id.* at 80-81.

¹⁰⁴ See Interview by *Frontline* with Dr. Charles Till, (1998), <http://www.pbs.org/wgbh/pages/frontline/shows/reaction/interviews/till.html> (last visited Nov. 30, 2004) (discussing IFR technologies and the political decision that ended the research program).

¹⁰⁵ CARBON, *supra* note 8, at 80.

¹⁰⁶ A demonstration reactor, using this technology, was developed and tested in Idaho in 1995, but the Clinton Administration discontinued the program. CARBON, *supra* note 8, at 80.

¹⁰⁷ See Paul R. Kasten, *Review of the Radkowsky Thorium Reactor Concept*, 7 SCI. & GLOBAL SECURITY 237, 237-269, (1998), available at http://www.princeton.edu/~globsec/publications/pdf/7_3kasten.pdf (discussing the technology and its feasibility).

¹⁰⁸ Seth Grae, *The Nuclear Non-Proliferation Treaty's Obligation to Transfer Peaceful Nuclear Technology: One Proposal of a Technology*, 19 FORDHAM INT'L L.J. 1985, 1994 (1996).

¹⁰⁹ *Id.*

¹¹⁰ CARBON *supra* note 8, at 63.

238 would at least have to be 20% U-235 to be explosive.¹¹¹ Similarly, the plutonium that might be in fuel rods would also be difficult to transform into a bomb.¹¹² Fresh fuel rods contain no plutonium, so terrorists would have to steal spent fuel.¹¹³ The spent fuel itself is stored in casks and usually surrounded with security.¹¹⁴ Even if terrorists obtained used fuel rods, it is extremely difficult to separate plutonium into the pure form needed to make a bomb.¹¹⁵ Terrorists would have to shield themselves from a high degree of radiation and possess the technology and knowledge to separate the materials.¹¹⁶ Additionally, unlike military reactors, which use fuel rods for only a month or so, commercial reactors use fuel rods for three or four years at a time because of their cost.¹¹⁷ This extended use leads to many impurities, making it difficult to develop used fuel rods from commercial reactors into a weapon.¹¹⁸

The more pertinent threat now comes from advanced nuclear reactors that create a type of plutonium through reprocessing that is more useful in weapon making.¹¹⁹ In certain Soviet-style reactors, like the graphite-water reactor used in Chernobyl, they tended to replace the fuel much more frequently than in normal reactors, since these reactors could generate a relatively large amount of plutonium for weapons while also providing energy.¹²⁰ Traditional reprocessing plants separate plutonium and uranium from the used fuel so those materials can be re-used. This means that a nation that can obtain a reprocessing facility has the capability of creating a great deal of plutonium in a short time.¹²¹

2. Alternative Diffusion

Commercial reactors are not a likely candidate for plutonium processing. Plutonium can be processed in a more covert non-commercial reactor.¹²² In North Korea, for example, rather than develop nuclear reactors for energy purposes, the regime has favored more covert military development.¹²³

¹¹¹ *Id.* at 64-65.

¹¹² *Id.* at 64.

¹¹³ *Id.*

¹¹⁴ *Id.*

¹¹⁵ *Id.*

¹¹⁶ *Id.* at 65.

¹¹⁷ *Id.* at 52, 65

¹¹⁸ *Id.* at 66.

¹¹⁹ *Id.* at 68.

¹²⁰ GARWIN AND CHARPAK, *supra* note 12, at 315.

¹²¹ BECK, *supra* note 94, at 12.

¹²² CARBON, *supra* note 8, at 69.

¹²³ *Id.*; HEABERLIN, *supra* note 7, at 171-172.

2006] *NUCLEAR ENERGY AND PROLIFERATION*

3. Waste

Finally, a fear developed in the popular media after September 11, 2001, that terrorists could somehow obtain other nuclear waste material for use in a “dirty bomb” that would use the radiological effects of the nuclear material.¹²⁴ A “dirty bomb” generally refers to nuclear material used in a crude, non-conventional form, such as a method to expose civilians to radiation without employing an active fissile reaction.¹²⁵ There is not a simple way for terrorists to use the material as a weapon, which makes it hard to assess the threat accurately.¹²⁶

Security analysts typically contemplate scenarios that deal with plausible hypotheticals. Some studies have calculated little risk in such accidents.¹²⁷ Other real life stories have demonstrated the power of used nuclear materials.¹²⁸ Whatever the risk, after September 11, the world is much more cognizant of the threats posed by terrorism.

IV. UNITED STATES POLICY ACTIONS IN RESPONSE TO THE THREAT OF REPROCESSING AND PROLIFERATION

The United States has developed a number of policies aimed at curbing the threats of proliferation, ranging from technological to diplomatic solutions. While the United States has had some success in the area of curbing proliferation, the United States could do much more to address the issue.

A. “Cooperative Threat Reduction”

As a result of the efforts of Senator Richard Lugar and former Senator Sam Nunn, the “Nunn-Lugar” Program, otherwise known as Cooperative Threat Reduction (“CTR”), attempts to address the uses of loose nuclear weapon materials in Russia and other nations.¹²⁹ The fear is that Russian nuclear weapon or reactor components could be bought or stolen from Russian

¹²⁴ *Weapons of Mass Dislocation*, THE ECONOMIST, June 13, 2002, available at http://economist.com/displaystory.cfm?story_id=1177133.

¹²⁵ *Id.*

¹²⁶ *Id.*

¹²⁷ See BERNARD L. COHEN, THE NUCLEAR ENERGY OPTION: AN ALTERNATIVE FOR THE 90S 221 (1990) (discussing a Sandia National Laboratory Study in which an experiment showed that exploding a truck filled with nuclear waste in Manhattan would have a twenty percent risk of killing *one* person).

¹²⁸ *Id.* at 222-223 (describing the Kyshtym incident, in which misuse of radioactive waste created a dangerous chemical explosion in the former Soviet Union around 1957-1958).

¹²⁹ See Cooperative Threat Reduction Program, available at <http://nunn-lugar.com> (last visited Feb. 17, 2006); GARWIN AND CHARPAK, *supra* note 12, at 325; see also Richard G. Lugar, *Nunn-Lugar in the Second Term*, 19 NOTRE DAME J.L. ETHICS & PUB. POL'Y 233 (2005).

facilities, given their lax security.¹³⁰ The task of dismantling these weapons has proven to be very difficult.¹³¹

1. Policy

While plutonium reprocessing is a much-publicized portion of the CTR program, the program is much bigger. It has four broad goals: (1) destroying nuclear, chemical, and other weapons of mass destruction; (2) safely transporting and storing these weapons and materials; (3) establishing verifiable safeguards for these weapons and material; and (4) preventing the diversion of scientific expertise in nuclear technology.¹³²

2. Technical Process

Generally, the CTR program consists of two major nuclear-related programs. One program buys the enriched uranium from Russian weapons and reprocesses it into nuclear fuel.¹³³ However, it costs substantially more to produce MOX fuel for sale than it does to buy the more conventional uranium fuel.¹³⁴ To encourage the use of MOX, the United States plans to sell the materials at a price equal to or less than the uranium fuel that domestic reactors typically use.¹³⁵

Another program deals with the plutonium from Russian weapons. Some plutonium is reprocessed into fuel within commercial reactors while the rest is treated in a process known as “vitrification,” where the material is dissolved within glass.¹³⁶ This glass material can be stored in a secure place, neutralizing the threat posed by the material.¹³⁷

3. DOE and DOD Participation

The DOE is primarily responsible for the technical processes involved with CTR.¹³⁸ The Department of Defense (“DOD”) shares some responsibility on

¹³⁰ See Lugar, *supra* note 129, at 235.

¹³¹ Each ton of plutonium is enough to make 200 nuclear weapons, and a ton of highly enriched uranium is enough for fifty nuclear weapons. Russia would provide enough plutonium for approximately 10,000 plutonium weapons and 60,000 uranium weapons. GARWIN AND CHARPAK, *supra* note 12, at 329.

¹³² Sharon Squassoni, GLOBALIZING COOPERATIVE THREAT REDUCTION: A SURVEY OF OPTIONS 14 (Cong. Res. Service Apr. 15, 2004), available at <http://fpc.state.gov/documents/organization/32006.pdf>.

¹³³ GARWIN AND CHARPAK, *supra* note 12, at 328.

¹³⁴ *Id.*

¹³⁵ *Id.* at 329.

¹³⁶ *Id.* at 329-330.

¹³⁷ *Id.*

¹³⁸ DTRA, *DTRA Fact Sheet: Cooperative Threat Reduction Program*, (Nov. 2005)

these technical issues, but appears to be more of an executive after the current Bush Administration made changes to the CTR program.¹³⁹ The Defense Threat Reduction Agency (“DTRA”), part of the DOD, is primarily responsible for the CTR program.¹⁴⁰

4. Implementation and Difficulties

The policy was implemented slowly.¹⁴¹ The DOD initially had considerable discretion with the program’s funds, with the majority of the funding going towards security measures for the transportation and storage of nuclear weapons in the United States.¹⁴² The Armed Service Procurement Regulations prevented the use of funding in the former Soviet Union.¹⁴³ After it became apparent that Russian nuclear technicians had no incentive to act in the best interests of Russia and the United States, the DOE initiated a program between weapon laboratories in the two nations.¹⁴⁴

There have been other failures in the years since the program’s inception. The Bush Administration has considered changes to the program, including abandoning the vitrification program.¹⁴⁵ The Bush Administration also considered cutting funding.¹⁴⁶ Even with the War on Terrorism, the Bush Administration has at times sought to divert funds for the initiative to other programs.¹⁴⁷ Finally, the program does not address the limitations of nuclear facilities in other nations with any degree of efficacy. For example, the CTR program does not address the problems with nuclear reactors in nations such as the Congo, Uzbekistan, and Ghana.¹⁴⁸

http://www.dtra.mil/press_resources/fact_sheets/display.cfm?fs=ctr.

¹³⁹ *Id.*

¹⁴⁰ *Id.*

¹⁴¹ GARWIN AND CHARPAK, *supra* note 12, at 325

¹⁴² *Id.*

¹⁴³ *Id.*

¹⁴⁴ *Id.*

¹⁴⁵ *Id.* at 330.

¹⁴⁶ *Survey: America’s World Role: New Friends, New Opportunities*, THE ECONOMIST, June 27, 2002, available at http://www.economist.com/displaystory.cfm?story_id=1188810 (discussing committee report to Bush Administration to consider cutting funding); GARWIN AND CHARPAK, *supra* note 12, at 327.

¹⁴⁷ Part of the delay was the result of a diplomatic dispute between Russian and U.S. authorities over a number of issues, notably the certification of compliance. Richard Lugar, *Cooperative Threat Reduction*, <http://lugar.senate.gov/nunnlugar.html> (last visited Dec. 1, 2004).

¹⁴⁸ Michael Crowley, *Old Guard: W. Forgets the Nuclear Threat*, THE NEW REPUBLIC, Sept. 9, 2002, at 18. In the Congo, the Kinshasa reactor is protected by a padlocked metal gate and has been missing a fuel rod since the 1980s. For a time after the 1997 coup in the Congo, the IAEA was unable to inspect the plant. *Id.* There is a bipartisan bill that was

B. The Nuclear Non-Proliferation Treaty

Under the Nuclear Non-Proliferation Treaty ("NPT"),¹⁴⁹ member states agreed to prevent the proliferation of nuclear weapons.¹⁵⁰ The NPT is largely a mixture of commitments regarding the oversight of member states (programs that have been in existence since the 1960s) and bolder guarantees (like the quixotic agreement that all members will eventually disarm their nuclear weapons in Article VI¹⁵¹).

The NPT underscores the relationship between commercial nuclear power and the security risks posed by nuclear technology. The NPT enables the International Atomic Energy Agency ("IAEA") to inspect the commercial power activities of member nations, and requires that all member nations be willing to share nuclear energy technology.¹⁵²

The NPT illustrates the interesting worldview of the 1960s. The United States and Soviet Union wanted to win over less developed nations that needed energy.¹⁵³ The United States and Soviet Union were willing to provide development assistance, such as helping with projects like the Aswan High Dam in Egypt.¹⁵⁴ With the United States' reactors supplying assistance to

recently introduced in Congress that would extend both the countries involved in Nunn-Lugar, as well as the type of weapons addressed to conventional weapons. See "Lugar-Obama Bill Introduced," at <http://lugar.senate.gov/nunnlugar.html> (last visited Feb. 19, 2006).

¹⁴⁹ Treaty for the Non-Proliferation of Nuclear Weapons, July 1, 1968, 21 U.S.T. 483, 729 U.N.T.S. 161, available at <http://www.state.gov/np/trty/16281.htm#treaty> [hereinafter *NPT*]. The NPT is up for review next spring. Steve Andreasen, *Bush Must Strengthen Nuclear Weapons Treaty*, BOSTON GLOBE, Nov. 20, 2004 at A19. See also Press Release, State Dep't, *U.S. Cites Response to NPT Noncompliance As Greatest Challenge* (May 10, 2004), available at 2004 WL 59152186 (discussing US view of central obligation of NPT, preventing the proliferation of nuclear weapons).

¹⁵⁰ "Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices." NPT, *supra* note 149.

¹⁵¹ "Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control." *Id.*

¹⁵² NPT, *supra* note 149, Art. IV, § 2.

¹⁵³ Daly et al., *supra* note 1, at 54

¹⁵⁴ Robert W. Rycroft and Joseph S. Syzliowicz, *The Technological Dimension of Decision Making: The Case of the Aswan High Dam*, 33 WORLD POLITICS: THE QUARTERLY JOURNAL OF INTERNATIONAL RELATIONS, Oct., 1980, at 36-61 (discussing the policy choices in promoting a project such as the Aswan High Dam in the broader scope of international

nations like the Congo and the Cold War powers' willingness to sign a treaty guaranteeing that interest, nuclear energy represented another bargaining chip in the efforts to obtain allies.¹⁵⁵

What happened to this enthusiasm for developing nuclear energy technology? The obvious answer is that the Cold War ended, and to a large degree, so did the United States' need to battle for the allegiance of developing countries. For the United States, the post-Cold War world was no longer bipolar but rather fraught with states like Iran, North Korea, and Iraq, who could develop reactors for military purposes.¹⁵⁶ This caused a shift from concerns over international goodwill to a concern over immediate security threats.¹⁵⁷ Additional causes were the loss of interest in nuclear energy in the United States, fears of accidents after Chernobyl, the media coverage of Three Mile Island, and the perceived risks of nuclear energy following September 11.¹⁵⁸

C. *The International Atomic Energy Agency*

The International Atomic Energy Agency ("IAEA") is a United Nations agency based in Vienna, Austria that came under fire in the months leading up to the 2003 invasion of Iraq.¹⁵⁹ The IAEA has three general duties: promoting safeguards and verification, promoting safety and security, and promoting science and technology.¹⁶⁰

The IAEA has two broad functions in promoting safeguards and verifications.¹⁶¹ It inspects the nuclear-related facilities of member states and, under the auspices of UN Security Council resolutions, has maintained a presence in Iraq to monitor nuclear-related events (although that function no

relations and power projection).

¹⁵⁵ Daly et al., *supra* note 1, at 54.

¹⁵⁶ In North Korea, for example, it would seem the end of the Cold War increased the need for security, with the perceived fear of threats to the regime. *A Bad Neighbor*, THE ECONOMIST, Apr. 17, 2003, available at http://www.economist.com/displaystory.cfm?story_id=1697795.

¹⁵⁷ Cf. Daly et al., *supra* note 1, at 54.

¹⁵⁸ HEABERLIN, *supra* note 7, at 4.

¹⁵⁹ Michael R. Gordon, *Threats and Responses: Nuclear Technology; Agency Challenges Evidence Against*, N.Y. TIMES, Jan. 10, 2003, available at 2003 WLNR 5239311 (quoting "a senior Bush Administration official" as saying, "I think the Iraqis are spinning the I.A.E.A. The majority of the intelligence community has the same view as before," when discussing IAEA statements about the likelihood of an Iraqi nuclear weapons program).

¹⁶⁰ IAEA, Our Work, <http://www.iaea.org/OurWork/index.html> (last visited Feb. 6, 2006) (describing the "three main pillars" of the IAEA).

¹⁶¹ IAEA, Our Work: Safeguards and Verification, <http://www.iaea.org/OurWork/SV/index.html> (last visited Nov. 29, 2004); IAEA, Our Work: Safety and Security, <http://www.iaea.org/OurWork/SS/index.html> (last visited Nov. 29, 2004).

longer exists).¹⁶² To promote safety, the IAEA oversees the nuclear equipment of the member states and sets safety standards for nuclear facilities.¹⁶³ To promote security, the IAEA attempts to ensure that nuclear materials within member states do not fall into the hands of terrorists and those who might obtain the technology for military applications.¹⁶⁴ Finally, the IAEA (following the philosophy of the NPT) promotes science and technology. It asserts, as part of its mission statement, that it will promote exchanges of knowledge about nuclear technology with developing nations (for energy and social benefits), and promote the research and development of technology related to corresponding nuclear technology issues (e.g., food, safety, and radiation exposure).¹⁶⁵

The IAEA faces several obstacles in carrying out these goals. The organization has severely limited funding. Its \$100 million budget compares with a midsize American city.¹⁶⁶ Moreover, the budget has seen no real growth in seventeen years, even as the IAEA's mission has seemingly grown more important in a post-Cold War world.¹⁶⁷ The buildup to the 2003 invasion of Iraq tarnished the IAEA's image, as the Bush Administration's public relations teams discredited Hans Blix and the international inspection methods used within Iraq.¹⁶⁸

D. Diversion-Proof Fuel

A recent proposal would focus on a method that would make nuclear power plants spend fuel useless for weapon purposes.¹⁶⁹ By putting an isotope of americium, Am-241, in all new fuel rods, neutrons can be captured while the rods are in the reactor.¹⁷⁰ This creates a curium isotope, Cm-242, which would eventually deteriorate into Pu-238.¹⁷¹ Theoretically, if this process is timed

¹⁶² IAEA, Our Work: Safeguards and Verification, <http://www.iaea.org/OurWork/SV/index.html> (last visited Nov. 29, 2004).

¹⁶³ IAEA, Our Work: Safety and Security, <http://www.iaea.org/OurWork/SS/index.html> (last visited Nov. 29, 2004).

¹⁶⁴ *Id.*

¹⁶⁵ IAEA, Our Work: Promoting Science and Technology, <http://www.iaea.org/OurWork/ST/index.html> (last visited Nov. 29, 2004).

¹⁶⁶ Crowley, *supra* note 148, at 15.

¹⁶⁷ *Id.*

¹⁶⁸ See, e.g., Gordon, *supra* note 159 (quoting a "senior Bush Administration official" as saying, "I think the Iraqis are spinning the I.A.E.A. The majority of the Intelligence community has the same view as before.")

¹⁶⁹ CARBON, *supra* note 8, at 71.

¹⁷⁰ *Id.*

¹⁷¹ *Id.*

appropriately, it would render spent fuel useless for weapons.¹⁷²

There are two policy issues related to such a solution. First, it would be necessary to create a system in which fuel fabrication systems were open to inspection. Second, there are very few fuel fabrication plants in the world, making the inspection easy to control, something that advocates of such a system often point out.¹⁷³

E. Export Controls

The DOE has oversight of the export of nuclear technology, including nuclear reactors.¹⁷⁴ Failure to comply with the export controls carries stiff penalties, such as jail time and fines.¹⁷⁵

F. Direct Foreign Policy Measures

The actions of the United States through international negotiations and other foreign policy are important to any discussion of proliferation. In the past, the United States has used a variety of different strategies. With Brazil and Argentina, the United States joined members of the international community to negotiate a series of agreements in which the two nations would join the NPT and agree to mutual verification measures.¹⁷⁶ In 1994, North Korea agreed to shut down a North Korean reprocessing plant in exchange for two light water reactors less suited for weapon making.¹⁷⁷ Since that time, the United States has used a less conciliatory method with North Korea, instead choosing implicitly to threaten military action.¹⁷⁸ Similarly, the United States took a more “hard line” approach towards Iraq’s efforts to develop nuclear technology.¹⁷⁹—

¹⁷² *Id.*

¹⁷³ *Id.*

¹⁷⁴ Atomic Energy Act, 68 Stat. 919 (1954). The specific regulations are governed by DOE regulations. Assistance to Foreign Atomic Energy Activities, 10 C.F.R. § 810 (2005).

¹⁷⁵ See CARBON, *supra* note 8, at 71.

¹⁷⁶ Recent developments deserve special attention as Brazil recently received authorization from the IAEA to enrich uranium. Raymond Colitt, *Brazil in Deal with Nuclear Watchdog*, FIN. TIMES, Nov. 26, 2004, at 7, available at 2004 WL 100695398.

¹⁷⁷ *Forget Atoms for Peace*, ENERGY, Sept. 22, 2000, at 2.

¹⁷⁸ *When Bluffs Turn Deadly*, THE ECONOMIST, May 1, 2003, available at http://www.economist.com/displaystory.cfm?story_id=1748566; see also *India, Oil and Nuclear Weapons*, N.Y. TIMES, Feb. 19, 2006, available at WK 11 (discussing the policy choices the United States faces regarding India’s participation in the IAEA vote against Iran vis-à-vis India’s participation in the NPT).

¹⁷⁹ *Dealing with Iraq and North Korea*, THE ECONOMIST, Oct. 14, 2002, available at http://www.economist.com/displaystory.cfm?story_id=E1_TQDPGQV&CFID=77109999&CFTOKEN=506255e-810f17ba-aa24-43ae-89f7-a98b61c9d2e0.

V. ANALYSIS

The following is a brief commentary of several major emerging issues related to nuclear energy, using the information presented above.

A. *Should the United States Promote the Use of Nuclear Energy?*

The answer to this question depends on whether one believes that a technologically feasible solution to the reprocessing problem exists. The Ford and Carter administrations concluded that there was no such solution and that the risks of plutonium proliferation outweighed the benefit of the technology.¹⁸⁰ Proliferation dealt a serious blow to the research and development of nuclear technology, in turn contributing to the change in United States policy regarding the promotion of the technology worldwide.¹⁸¹

Nuclear energy can provide relatively cheap and emission-free energy in places that lack sufficient natural resources to provide for their population.¹⁸² As international energy demand continues to rise, nuclear energy is a clear answer to offset the corresponding rise in cost. Furthermore, the promotion of such technology, while not serving an ideological interest as it did during the Cold War, could serve a more prophylactic measure in the future. Some of the potentially threatening nations in the world, such as North Korea, Belarus, and Afghanistan, have extremely limited energy infrastructures.¹⁸³ Even if they could grow, these nations likely lack the capability to develop the basic services, such as sufficient electric access, needed for successful development.¹⁸⁴ Proliferation-safe reactors, whether they be IFRs, thorium reactors, or simple light water reactors (which often make the cost of reprocessing too great), would offset some of these concerns.¹⁸⁵ In addition, better international monitoring could ease the concern of proliferation.

The United States should take a lead in promoting a diverse energy supply. As the growing international demand for fossil fuels increases, so will international tensions over fossil fuel access, as well as the continuing moral ambiguities policymakers face in dealing with a fungible energy source.¹⁸⁶ Nuclear energy is a component of a larger strategy to diversify the global energy supply, particularly because it can address the growing fossil fuel

¹⁸⁰ CARBON, *supra* note 8, at 79-80.

¹⁸¹ *Id.*; see also HEABERLIN, *supra* note 7, at 193 (implying that the decision was based more on politics than a substantive threat).

¹⁸² *Id.* at 282.

¹⁸³ *Id.* at 259-261.

¹⁸⁴ *Id.* at 236.

¹⁸⁵ *Id.* at 296-297.

¹⁸⁶ *Take Your Partners: China, India, and the Oil Market*, THE ECONOMIST, Jan. 19, 2006, available at http://www.economist.com/displaystory.cfm?story_id=5420659.

emission problems worldwide.¹⁸⁷ Of course, whatever policy is adopted will require some form of international oversight, such as by the IAEA.¹⁸⁸

B. What Measures Can Be Taken to Ameliorate the Proliferation Risks Posed by Nuclear Energy?

As noted above, proliferation-safe reactors, whether they be IFRs or simple light water reactors, would offset proliferation concerns.¹⁸⁹ United States policymakers should at least evaluate the possibilities of these technologies, rather than relegate them to the present status of Cold War relics.

Better international monitoring could also reduce the proliferation concern. At present, the IAEA is woefully under-funded given its responsibility of overseeing the safety of nuclear technology around the world.¹⁹⁰ Changes to the organization are necessary, whether through an increase in funding or a reassignment of the task to another organization. Of course, proliferation safe reactors, if actually technically viable, could make the IAEA's job much easier if the reactor vessel with all the dangerous nuclear gizzards is welded shut.¹⁹¹

Finally, the United States must choose whether it intends to enforce the NPT, an international agreement that sought to limit the military applications of nuclear technology. At times, the United States has failed to live up to other obligations of the agreement, such as the nuclear Comprehensive Test Ban Treaty ("CTBT").¹⁹² Some argue that this policy undermines the NPT from the standpoint that the NPT stands for the abolition of military applications of nuclear technology. The logic is that it is impossible to agree to that system without curbing nuclear weapon production.¹⁹³

¹⁸⁷ *The Nuclear Answer?*, THE ECONOMIST, July 7, 2005, available at http://www.economist.com/displaystory.cfm?story_id=4151435

¹⁸⁸ HEABERLIN, *supra* note 7, at 296-297.

¹⁸⁹ *Id.* at 295-297.

¹⁹⁰ Crowley, *supra* note 148, at 15; Press Release, International Atomic Energy Agency, IAEA Outlines Measures to Enhance Protection Against Nuclear Terrorism (2001), available at <http://www.iaea.org/NewsCenter/PressReleases/2001/prn0126.shtml>.

¹⁹¹ HEABERLIN, *supra* note 7, at 297.

¹⁹² Article VI of the CTBT explains: "Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control." The United States has failed to disarm, much less curb development of new weapons systems. Comprehensive Test Ban Treaty, Sept. 24, 1996, Art. VI., 35 I.L.M. 1439 (1996), available at: <http://pws.ctbto.org/> (last visited Feb. 17, 2006). The United States rejected the CTBT in the late 1990s. Eric Schmitt, *Senate Kills Test Ban Treaty in Crushing Loss for Clinton; Evokes Versailles Pact Defeat*, N.Y. TIMES, Oct. 14, 1999, at A1

¹⁹³ Winston P. Nagan and Craig Hammer, *The New Bush National Security Doctrine and the Rule of Law*, 22 BERKELEY J. INT'L L. 375, at 402 (2004).

The next issue is determining whether the United States can “go it alone” in its goal of curbing proliferation. There has been much debate on this issue since Congress rejected the CTBT in the late 1990’s. One side argues that United States’ unilateralism on these issues undermines the international nonproliferation effort when it rejects the very process it participated in for years.¹⁹⁴ At its root, this is a contract theory issue: if a party refuses to live up to an agreement, questions arise as to its basis for participating in the agreement long-term.¹⁹⁵

On the other hand, there is an argument that the CTBT does not effectively curb proliferation. Critics of the CTBT argue that the regime is ineffective towards the issues of national sovereignty that inevitably arise in its enforcement, where international monitors would be privy to sensitive state information and have some authority over a state’s national security strategy.¹⁹⁶ Moreover, critics often cite concerns that the CTBT’s goals are tangential from the goals of the NPT, which critics view as curbing nuclear proliferation instead of disarmament.¹⁹⁷

C. Is the Present Division of Labor Within the Federal Government Appropriate to Address the Myriad Issues Created by the Unique Nature of Nuclear Technology?

Given the analysis presented above, there should be little doubt that the federal government’s oversight of nuclear issues must be rethought, particularly in the realm of nuclear proliferation. The United States has failed to implement a clear strategy to prevent future abuses of nuclear technology.

One idea following September 11, was to create a separate White House post, overseeing the myriad DOE, DOD, and DOS programs related to the international trade of nuclear materials.¹⁹⁸ This “nuclear proliferation czar” would coordinate the respective efforts of the various foreign and domestic policymaking bodies involved with proliferation issues, with the overall goal

¹⁹⁴ *Id.*

¹⁹⁵ John Harrington, *Arms Control and National Security*, 38 INT’L LAW. 391, 396-397 (2004).

¹⁹⁶ Baker Spring, *Harnessing the Power of Nations for Arms Control: the Proliferation Security Initiative and the Coalition of the Willing*, The Heritage Foundation Backgrounder No. 1737, Mar. 18, 2004, available at <http://www.heritage.org/Research/NationalSecurity/bg1737.cfm>; see also Baker Spring, *The Comprehensive Test Ban Treaty and U.S. Nuclear Disarmament*, Heritage Foundation Backgrounder No. 1330, Oct. 6, 1999 (detailing how this process leads to nuclear disarmament).

¹⁹⁷ Baker Spring, *The Shalikhshvili Report on the Comprehensive Test Ban Treaty*, Heritage Foundation Backgrounder No. 1444, May 25, 2001, available at <http://www.heritage.org/Research/NationalSecurity/BG1444.cfm>.

¹⁹⁸ *Id.*

2006] *NUCLEAR ENERGY AND PROLIFERATION*

of developing a unified policy.¹⁹⁹

The Bush Administration has also proclaimed a “Global Threat Reduction Initiative,” which would expand the Nunn-Lugar Program.²⁰⁰ The program would compensate for the external limitations of the existing CTR program, expanding the DOE’s anti-proliferation efforts beyond Russia.²⁰¹ Whether this program will be successful remains to be seen.²⁰²

If the United States chooses to promote nuclear energy, it should be a leader in developing safer civilian applications of the technology and promoting the use of technology like integral fast reactors, thorium reactors, and diversion-proof fuel. Some have argued that sharing this technology is an obligation under the NPT.²⁰³

VI. CONCLUSION: TWO BROAD OBSERVATIONS ON NUCLEAR ENERGY AND NUCLEAR PROLIFERATION

This analysis also warrants two additional observations on nuclear energy. First, one striking aspect of the last two decades is the lack of legitimate research and development into nuclear energy. The United States has always been a world leader in technological development. Worldwide research and development into nuclear energy began to slow when the United States ended its research.²⁰⁴ Following the decision to ban reprocessing, the United States experimented with IFRs, but even that research has been dormant for over a decade.²⁰⁵ Given the public perception of nuclear energy in certain contexts, as well as the economic challenges of the nuclear energy business, the United States interest in nuclear energy has subsided as development has. There have been few new ideas and thus few new policies.²⁰⁶ If the argument that nuclear energy is a necessary step to offset the increased international demand is correct, then any policy that does not take those technological development issues into account is a mistake.

¹⁹⁹ *Id.*

²⁰⁰ D.O.E., *Global Threat Reduction Initiative Highlights*, http://www.energy.gov/engine/doe/files/dynamic/264200491138_Vienna_GTR_Fact%20Sheet_FINAL1_052604%20.pdf (last visited Dec. 1, 2004) (discussing the Bush Administration Global Threat Reduction Initiative).

²⁰¹ *Id.*

²⁰² *Id.*; see also Squassoni, *supra* note 132, at 14 (describing specific measures to expand CTR programs).

²⁰³ Grae, *supra* note 108, at 1998.

²⁰⁴ HEABERLIN, *supra* note 7, at 193-194.

²⁰⁵ CARBON, *supra* note 8, at 80.

²⁰⁶ See HEABERLIN, *supra* note 7, at 7-40 (discussing the policy implications in history where nations chose not to develop technology and applying that study to nuclear technology).

Second, the problems related to nuclear energy and proliferation will not go away under the current policy framework. Foreign nations will still need energy and, occasionally, a state will attempt to increase its power through the development of nuclear weapons.²⁰⁷ This reality demands vigilance regarding the problems of proliferation. One commentator, ranking nuclear proliferation as the most serious risk associated with nuclear energy, explained a method for evaluating the risk associated with nuclear proliferation:

[The] risk, in the formal sense, is the product of the probability of a harmful event times the consequences of the event if it takes place. Now, we do not know exactly how much the spread of nuclear power contributes to the probability of nuclear war, but it is certainly not inconceivable that the probability of nuclear war is already [one percent] per year and that the spread of nuclear power could double that figure in the short term . . . If nuclear power adds a probability of [one percent] per year to the chances of nuclear war, and recognizing that the consequences of nuclear war could include the deaths . . . of billions of people, then the “expected value” associated with that risk – that is, the probability times the consequences – is very large indeed.²⁰⁸

There is no clear way to evaluate the risk of a nuclear accident, much less the risk posed by nuclear proliferation. The lack of a tangible means of evaluating the probability of such incidents is not a reason to ignore the problem. If nuclear energy is a necessary step in addressing the rising energy demand worldwide, it will take an investment in the future to protect the world from dangers posed by nuclear proliferation. Allowing examples like the Kinshasa reactor to discourage a policy that pursues the safe development of nuclear energy is a mistake.

²⁰⁷ Recently, Iran again made the news with allegations from the U.S. State Department over its use of nuclear technology. The Bush Administration claimed that Iran was using its nuclear reactors for military purposes, and the international community has responded with a great deal of alarm. See *When the Soft Talk Has to Stop*, THE ECONOMIST, Jan. 14, 2006, at 29. The IAEA stepped in and felt comfortable with the result of its oversight. By early 2006, the IAEA voted to refer Iran to the UN Security Council as Iran continued efforts to enrich uranium. Richard Beeston, *Defiant Iran Steps Closer to the Brink as It Pulls Out of Inspection Deal*, LONDON TIMES, Feb. 6, 2006, available at: <http://www.timesonline.co.uk/article/0,,251-2026914,00.html>.

²⁰⁸ JOHN P. HOLDREN, PERSPECTIVES ON ENERGY 374 (Lon C. Ruedisili & Morris W. Firebaugh eds. 1982).