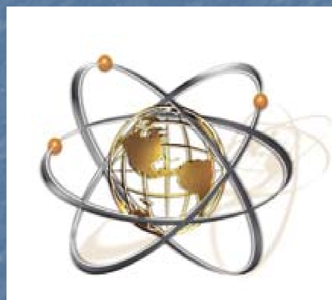
Nuclear Power in the Age of Global Warming:



New Solution or Same Old Threat?

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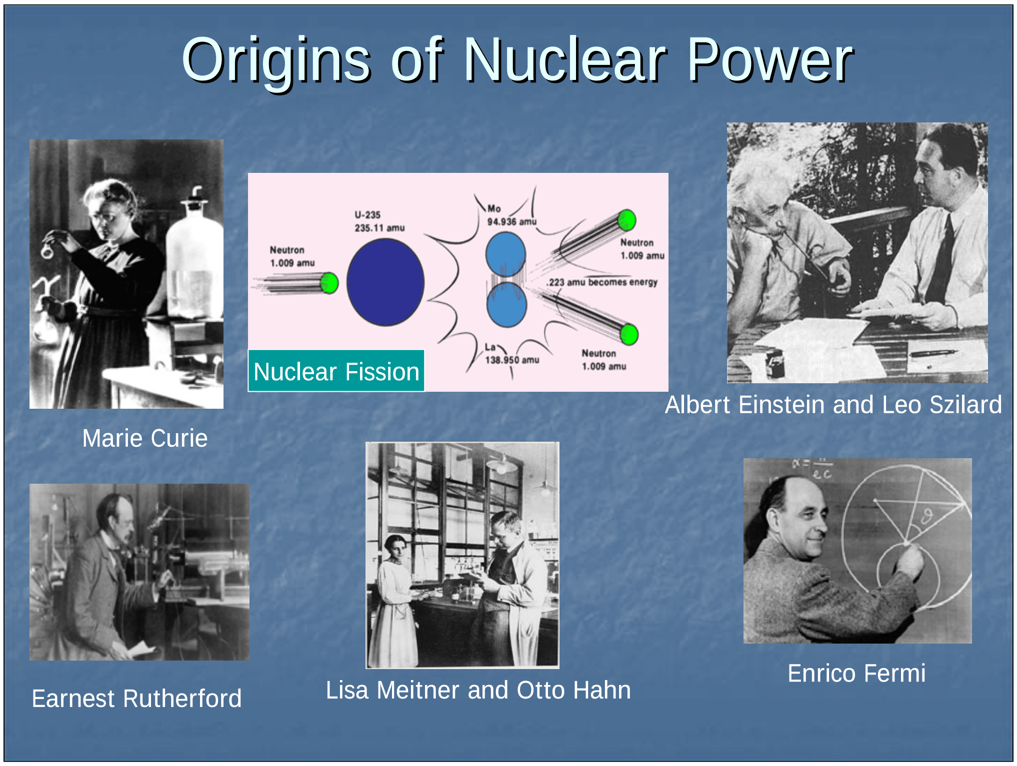
February 2008



Nuclear energy has its origins in the scientific discoveries of the early and mid 20th century. Pioneering scientists included:

- **Marie Curie, a physicist and chemist discovered radium, and advanced understanding of the properties of atomic radiation -- first discovered by Henri Becquerel in 1896.**

- **Albert Einstein described a phenomenon involving the interchangeability of matter and energy first described in 1905 by his Theory of Relativity. Einstein understood that small amounts of mass can be converted to very large amounts of energy--with the conversion ratio described by the very large number of the speed of light squared (E=mc2).**

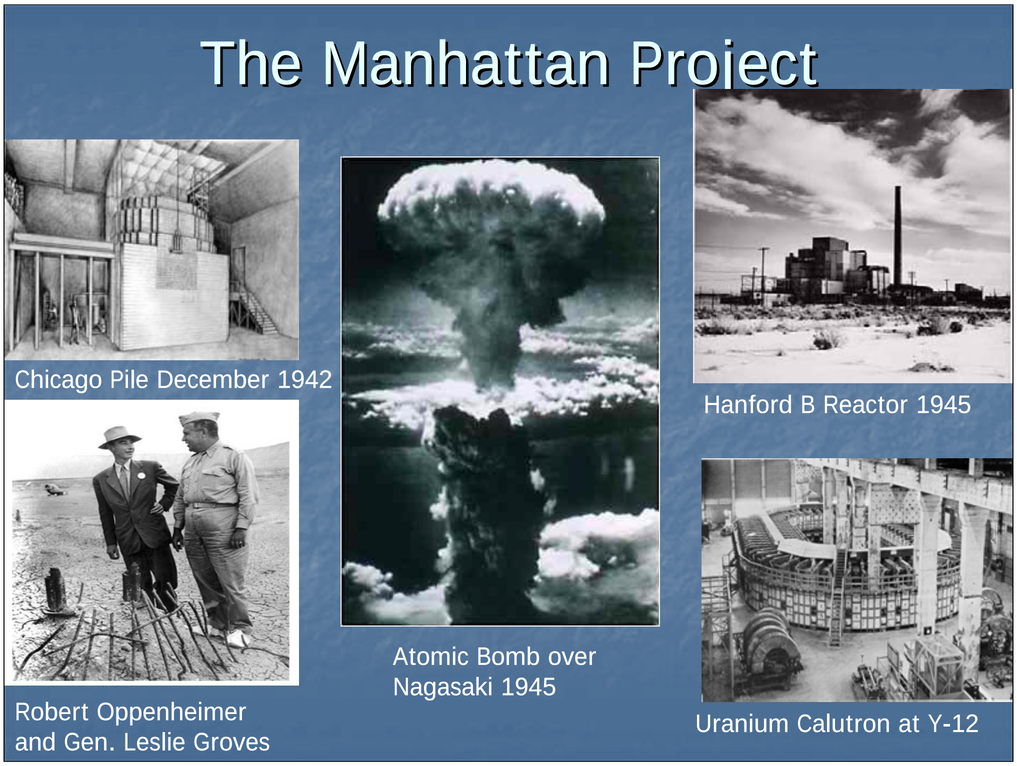
- **Ernest Rutherford developed the first model of the atom in 1909 having a very small positively-charged nucleus circled by electrons. Rutherford, Niels Bohr and Ernest Chadwick subsequently pointed to the existence of neutrons – subatomic particles with no electric charge.**

- **Leo Szilard, a physicist, conceived of the idea of a nuclear chain reaction in 1933 -- preceding the discovery of nuclear fission in which the atoms are split apart when struck by free neutrons. He realized that if the atoms of uranium were split by neutrons this would in turn turn generate more neutrons and great energy in a self-sustaining chain reaction .**

- **Lisa Meitner, a physicist, and her colleague Otto Hahn, a chemist, conducted a series of experiments in 1938 and 1939 that demonstrated that splitting uranium atoms was possible. Meitner and her nephew, Otto Frisch named the process "nuclear fission." Their discovery also led to the realization of the potentially tremendous explosive nature of fission.**

- **Enrico Fermi discovered new radioactive elements produced by neutrons and also showed that neutrons moving at slower speeds (thermal) created previously unknown nuclear reactions. In 1938 Fermi teamed up with Szilard in the United States to demonstrate that uranium could undergo a chain reaction – which under controlled conditions could produce energy, and if uncontrolled would produce a nuclear explosion.**

- **In 1939, alarmed by these findings, Szilard and Einstein wrote a letter to President Franklin D. Roosevelt warning of German efforts to make nuclear weapons and urging the United States to undertake its own nuclear arms effort. Shortly after the letter was sent, Roosevelt responded by organizing and sponsoring nuclear research. By December 1941 an unprecedented crash program to make the first nuclear weapons was launched known as the Manhattan Project.**



The Manhattan Project was an enormous engineering and construction effort that, within a period of three years, created one of the largest industrial enterprises in the United States. It would eventually employ more than 130,000 people and cost a total of nearly $2 billion ($23 billion in 2007 dollars). Project research took place at over thirty different sites spread across the United States, Canada, and the United Kingdom.

The military leader of the Project was General Leslie Groves. J. Robert Oppenheimer, a physicist from the University of California, was chosen to direct the scientific and engineering effort to design the first weapons at the Los Alamos Laboratory in New Mexico. They decided to pursue a two track approach to simultaneously develop atomic weapons fueled by uranium-235 and plutonium-239

Otto Frisch, an Austrian, and Rudolph Peierls, a German, working on Britain's nuclear program calculated in 1940 that a relatively small amount of U-235 was needed – indicating that a weapons could be made in a short amount of time. This led to the construction and operation of uranium enrichment plants in Oak Ridge, TN – which employed some 40,000 people to operate them.

Plutonium was first produced and isolated by Glenn Seaborg at the University of California in 1941. Plutonium had similar explosive properties as U-235, but could be made over a short time in reactors. The first reactor, known then as a "Pile" went into operation under the direction of Fermi in December 1942. This promptly led to the establishment of the Hanford site in eastern Washington, where the "B" reactor – the first large-scale reactor in the world went into operation to make plutonium for weapons.

The first nuclear weapon fueled by plutonium was successfully tested in Alamogordo, New Mexico on July 12, 1945. On August 6, 1945 a uranium weapon was dropped on Hiroshima Japan (It was not considered necessary to test uranium weapons before they were used). A plutonium weapon was dropped on Nagasaki Japan on August 9, 1945.

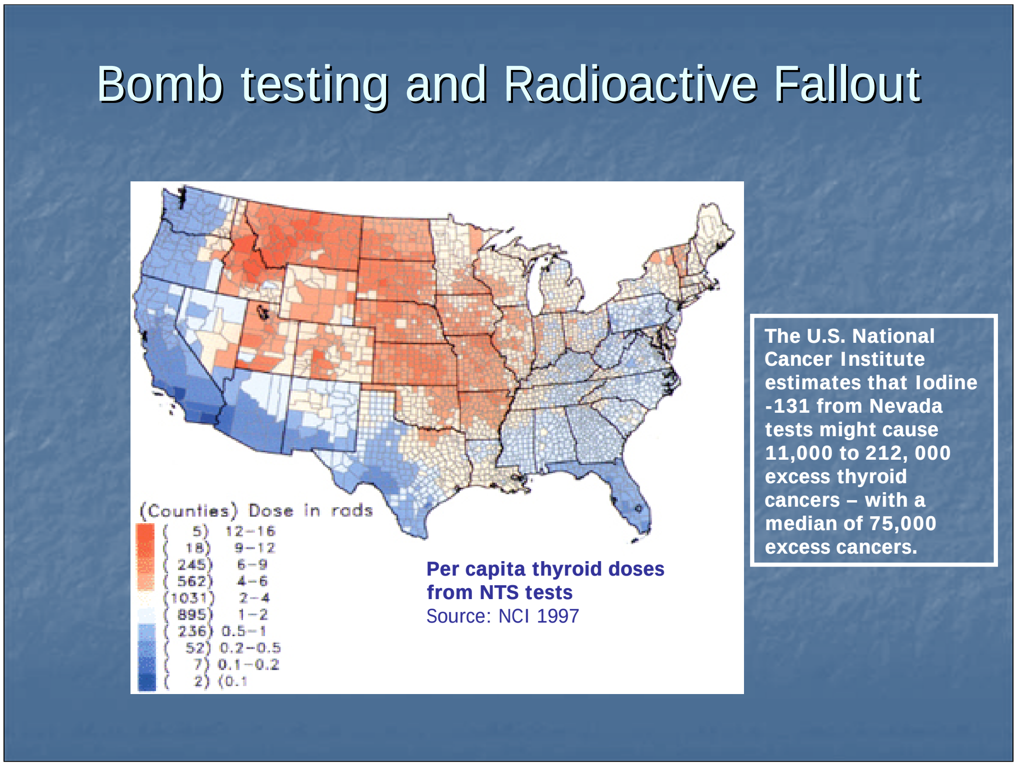
The basic foundation was now laid for the "nuclear age."

At the end of World War II, in 1945 the United States possessed no more than 6 nuclear weapons. One year later the United States and the Soviet Union entered into the Cold War – whose hallmark was an ever expanding nuclear arms race, threatening life on the planet.

In 1949, the Soviet Union exploded its first nuclear weapons – prompting the U.S. to launch a crash program to produce even more destructive thermonuclear weapons or hydrogen bombs. From the 1950's through the early 1960's, the U.S. and Soviet nuclear arms programs grew massively – churning out tens of thousands of warheads. This was also a period in which the U.S. and the Soviets exploded 193 and 142 nuclear weapons respectively in the atmosphere and underwater while the U.S. public was indoctrinated about the consequences of nuclear war. Hundreds of thousands of U.S. military personnel participated in these tests. There was widespread deployment of fallout shelters and nuclear war preparedness drills in U.S. public schools. "Duck and cover" became the watch words for millions of children.

Concerns over radioactive fallout from weapons testing intensified in 1954, after several Japanese Fishermen and dozens of people living on the South Pacific Island of Rongelap were severely overexposed from a U.S. thermonuclear test known as "bravo." By the late 1950's, a world-wide protest against nuclear testing –led by prominent scientists was growing. The U.S. Atomic Energy Commission (AEC) and its scientists vigorously defended the tests claiming they posed little if no harm.

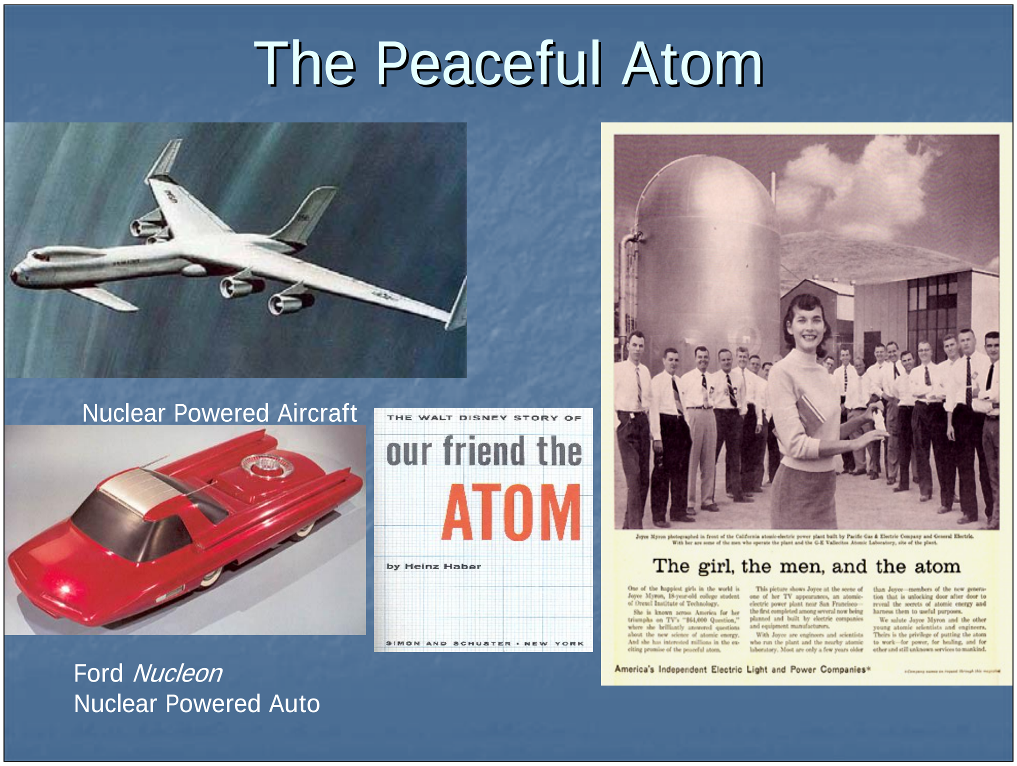
The AEC suffered a serious blow to its credibility in 1963, when the United States, Great Britain and the Soviet Union ratified the Limited Nuclear Test Ban Treaty (LNTBT), which prohibited atmospheric nuclear weapons tests. In retrospect, the Limited test Ban Treaty was in effect the first modern global environmental brought about in no small part by to the first modern global environmental movement. However, the end of atmospheric testing did not impact the nuclear arms race. Testing continued underground until 1990 in the Soviet Union and 1993 in the United States. Nuclear arms became even more deadly as missile accuracy improved.



Fears and concerns about radioactive fallout left a lasting impression on the American public. The deliberate efforts to mislead the public about fallout dangers instilled great distrust about nuclear energy that still remains a potent factor. Official repudiation of the U.S. Atomic Energy Commission's (AEC) claims about fallout came in 1997, when the National Cancer Institute (NCI) revealed that atmospheric nuclear weapons detonations at the Nevada Test Site resulted in significant radiological contamination of the nation's milk supplies. In 1998, NCI officials admitted that the study was completed in 1992 and not made public for five years.

The atmospheric explosions at the Nevada test Site released large amounts of radioactivity over the American landscape, In particular the NCI studied the impacts of Iodine-131. With a half-life of 8.5 days, this radioisotope rapidly contaminates air, vegetation and milk supplies. Because it is absorbed mostly in the body's thyroid, radioactive iodine has been linked to thyroid cancer and other types of thyroid damage in humans. It takes about 90 days for the radioactivity of I-131 to diminish to very small levels.

NCI researchers estimated that the tests released about 150 million curies of radioiodine. By comparison based on official estimates about 7.3 million curies of radioiodine was released over the ten day period of the reactor fire at Chernobyl in 1986.



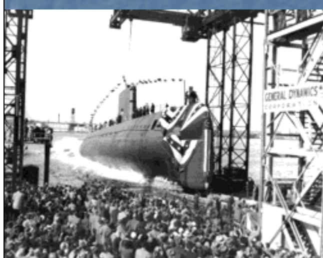
In December1953, President Eisenhower announced the "Atoms for Peace" initiative to the United Nations. Eisenhower was seeking to diffuse growing threats of the nuclear arms race by proposing to establish an international system of cooperation for the development of peaceful uses– such as nuclear research and power reactors, nuclear medicine applications and commercial uses of radioisotopes for activities such as food irradiation. The original vision in Atoms for Peace, would bring "abundant electrical energy in the power starved areas of the world".

The Atoms for Peace program gave rise to the International Atomic Energy Agency, which was mandated to both promote nuclear energy applications and to safeguard against weapons proliferation.

The program also spawned a national public relations campaign in the U.S., which pointed to the unlimited promises of nuclear energy – such as nuclear powered automobiles, home furnaces, and aircraft. Concerns such as crashes, what to do about the highly radioactive spent fuel and protecting passengers and crew from large doses of radiation were obscured, but eventually forced a halt to these speculative efforts. Despite these long-recognized obstacles the U.S. funded the nuclear powered aircraft program well into the 1960's.

Early Development of Nuclear Power Plants

America's First Power Reactor
EBR 1 Idaho 1955



U.S. S Nautilus 1954

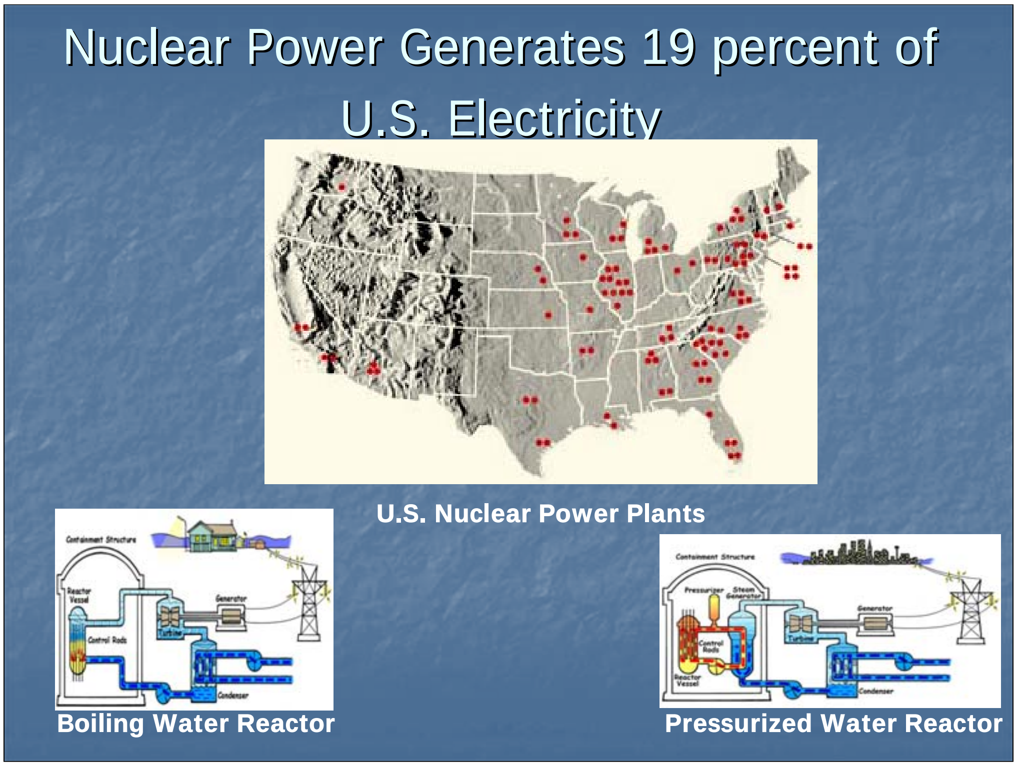
Shippingport: 1st Full scale
U.S. Nuclear Power Plant

Admiral Hyman Rickover

The Atoms for Peace program gave a major boost to the development of nuclear-generated electricity. While the Atomic Energy Commission worked to promote several different reactors, the light water reactor design first developed by the U.S. Navy to propel submarines that would be able to launch nuclear-tipped missiles became the mainstay for nuclear power in this country.

Until the late 1960's other nations, such as France, Britain and Russia based their designs on weapons material production reactors using graphite as a moderator.

Under the direction of Admiral Hyman Rickover, head of the U.S. nuclear navy, the first full scale nuclear power plant based on the pressurized light water reactor design (PWR) began operation at Shippingport,PA in 1957. It's capacity was 60 megawatts, and was originally designed to power a large aircraft carrier.



From 1959 to the early 1970's, nuclear power growth in the U.S. was large. During this period 112 reactors were constructed and operated.

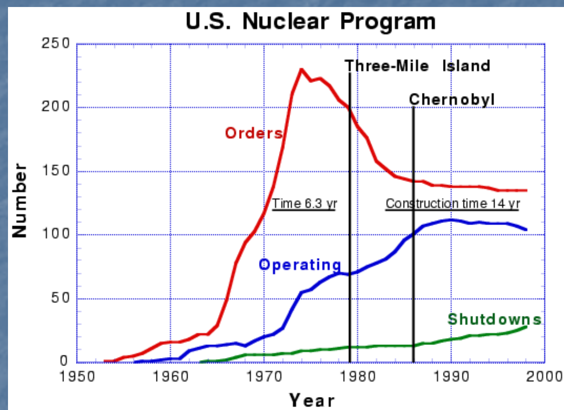
The light water reactor deployed in the U.S. is based on two types:

•The Boiling Water Reactor (BWR) has the same water loop serve as a moderator, coolant for the core, and steam source for the turbine. It is also described as a "single loop" System.

•The Pressurized Water Reactor (PWR) has water passing over the reactor core to act as moderator and coolant. It does not flow to the turbine, but is contained in a pressurized primary loop. The primary lop produces steam by heating the secondary loop

•As of 2001 there were 35 BWR's and 69 PWR's operating in the U.S.

Nuclear Power: 1970's- Present
What Happened?



Source: Ohio State University

New nuclear power plant orders dropped after in 1974. Dozens of partially constructed reactors were never completed.

Despite massive subsidies and R&D investments, there has not been an order for a new nuclear power plant in the U.S. for almost three decades. There are several reasons why Wall Street walked away from nuclear power.

•<u>Cost inflation</u> – On the average capital costs for nuclear power plants increased nearly 3-to 4 fold between the early 1970's and 1983.

•<u>Immaturity of the technology</u> – Even though, the first power reactors were first deployed in the late 1950's and early 1960's, key aspects of the technology required further research and development. This was especially the case for nuclear safety systems. Instead of addressing these emerging problems, the AEC ceased much of its R&D on light water reactors after the early 1960's and focused on the "next generation" of reactors that would use plutonium as fuel.

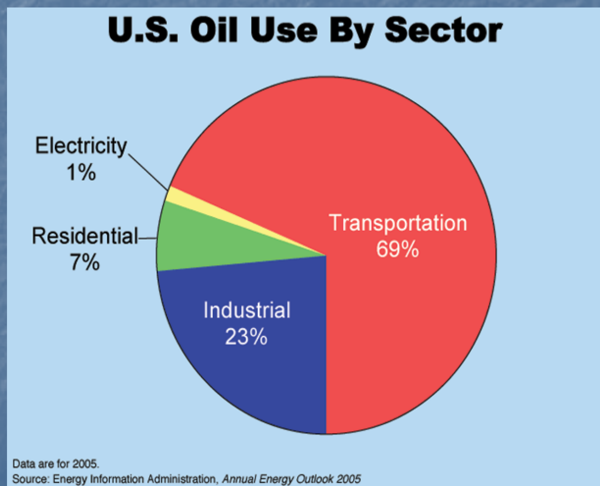
•<u>Failure to standardize</u> -- Despite generic design similarities the nation's existing nuclear power fleet is made up of one-of-kind facilities – with many different characteristics. This problem was synergistic with nuclear safety uncertainties associated with the immaturity of the technology. As a result, regulatory "ratcheting" was ongoing through design, construction and operation.

•<u>The Three Mile Island (TMI 2)Accident of 1979</u> – This accident dramatically demonstrated the financial risks of nuclear power. The costs for construction and cleanup of the accident was $2 billion -- the equivalent of over $10.6 million for every day TMI-2 produced electricity.

•<u>Nuclear Waste Uncertainties</u> – The inability to demonstrate a credible disposal path for spent power reactor fuel led to a ban on new reactor construction in California in 1976 – which reverberated throughout the country.

Meanwhile, the U.S. will have to "run faster on the treadmill" of impending nuclear power retirements. By 2056, if no reactors are constructed the 103 reactors in the U.S. fleet will cease operations. Based on past experience new reactor licensing and construction is likely to take about 15 years.

Nuclear Power:
Myth and Reality



- Myth – Nuclear power can reduce America's reliability on foreign oil.
- Reality – The great majority of oil is used for transportation
- *"A substantial growth in nuclear energy will not wean the United States off foreign sources of oil."*

  (Source: Council on Foreign Relations, April 2007)

This slide speaks for itself.

Accident Risks

Nuclear energy is high-risk technology with catastrophic potential.

In April 1986 the Chernobyl reactor exploded and caught fire. It severely contaminated about 93,200 square miles of the former Soviet Union, and required 700,000 emergency responders.

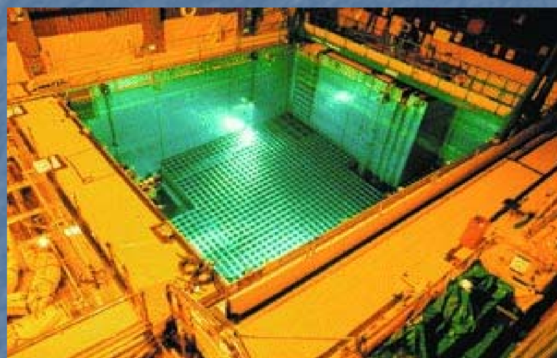
Because of enormous potential consequences, the U.S. Congress imposed a $9.5 billion limit on the total liability for a nuclear accident.

Nuclear accident costs are estimated to be 10 to 100 times greater than the statutory liability limit.

“ **Nuclear energy is perhaps the primary example of what are called ‘high-risk technologies’ with ‘catastrophic potential’; for such technologies, no matter how effective conventional safety devices are, there is a form of accident that is inevitable, and such accidents are a ‘normal’ consequence of the system. There is, in short, no escape from failures of the system. For those countries that have nuclear facilities but have not yet had a nuclear accident, it may only be a matter of time and luck. Continuing reliance on nuclear energy and building and operating more nuclear reactors only serves to increase the risk.”**

Source: Zia Mian and Alexander Glaser, Life in a Nuclear Powered Crowd, INESAP Information Bulletin No.26, June 2006

Spent Fuel and Terrorism



An almost full spent-fuel storage pool

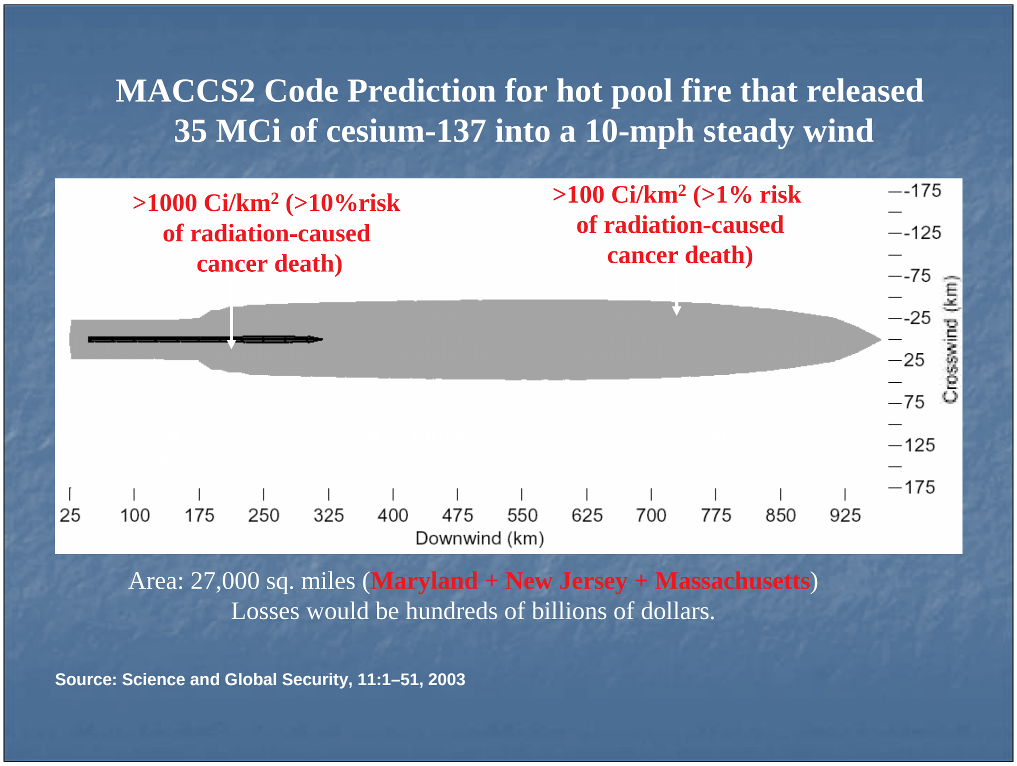
Dry Casks

> *“it is not prudent to dismiss nuclear plants, including spent fuel storage facilities as undesirable targets for terrorists…”*
>
> National Research Council, Committee on the Safety and Security of Commercial Spent Nuclear Fuel Storage(2005)

Until recently, concerns about attacks on commercial nuclear power plants focused mainly on the vulnerability of reactor containment buildings. But nuclear power plants may have a weaker link— spent fuel pools. Unlike reactors which are in steel vessels surrounded by thick concrete containment, spent fuel pools, containing some of the largest concentrations of radioactivity on the planet, can catch fire and are in much more vulnerable buildings.

The ponds, typically rectangular or L-shaped basins about 40 feet deep, are made of reinforced concrete walls four to five feet thick and stainless steel liners. Basins without steel liners are more susceptible to cracks and corrosion. Most of the spent fuel ponds at boiling water reactors are housed in reactor buildings several stories above ground. Pools at pressurized water reactors— representing about two-thirds of all ponds—are partially or fully embedded in the ground, sometimes above tunnels or underground rooms.

On average, spent fuel ponds hold five to 10 times more long-lived radioactivity than a reactor core. Particularly worrisome is the large amount of cesium 137 in fuel ponds, which contain anywhere from 20 to 50 million curies of this dangerous isotope. With a half-life of 30 years, cesium 137 gives off highly penetrating radiation and is absorbed in the food chain as if it were potassium. According to the NRC, as much as 100 percent of a pool’s cesium 137 would be released into the environment in a fire.



In 2003 I and my colleagues released a study which reviewed the past 25 years of nuclear safety research regarding spent fuel pools and analyzed what might happen if water were to be drained as a result of an act of malice. (Source: Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson, Frank N. von Hippel, Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States, Science and Global Security, 11:1–51, 2003.)

We estimated that a release of Cs-137 from a spent fuel fire could render an as much as a 27,000 square mile area uninhabitable from contamination. Our study was attacked by the nuclear industry and the NRC. Nonetheless, the controversy over our study prompted the U.S. Congress to ask the National Academy of Sciences to review this situation.

Nuclear Energy and Global Warming

In order to maintain global emissions of CO_2 at the year 2000 level:

- 1,000 to 3,000 power reactors would have to constructed by 2050.
- Each new reactor would have to come on line ranging from every week to twice a month for the next 40 years.
- Moody's Investor Service reported in October 2007 that capital costs for nuclear plants are likely to be twice as large as current market estimates.

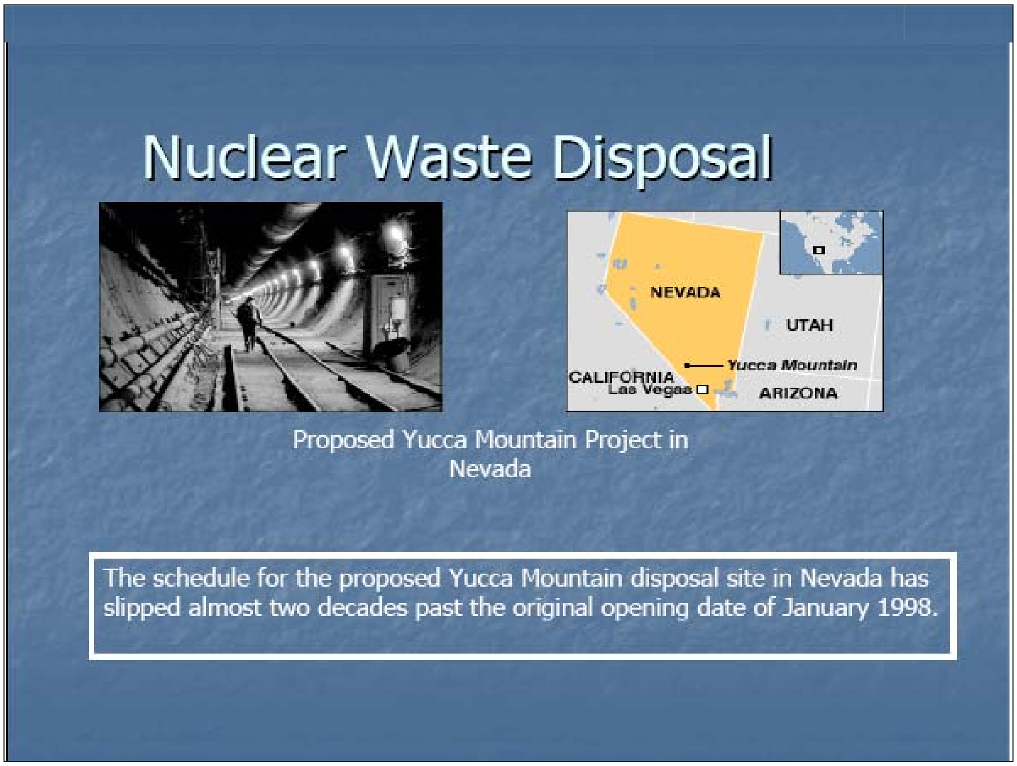
In the past few years several studies have examined the role nuclear power could play in mitigating the climate impacts of carbon emissions.

•In 2003 a study done at the Massachusetts Institute for Technology (MIT) indicated that if the base growth for nuclear power increased by 1000 reactors by the year 2050, the global share of nuclear energy would grow from 16 percent to 20 percent, based on projected electrical demands. This relatively small increase in nuclear power would not appreciably reduce global greenhouse gas emissions.

•A 2006 study by the Institute for Energy and Environmental Research estimates that in order to maintain CO2 emissions to the year 2000 level, this would require construction of 1,900 to 3,900 large reactors. This scenario would require a nuclear reactor to go online at a rate of less than one per week to the year 2050.

•Researchers at Princeton University reported in 2004 that in order to reduce CO2 emissions by 1 billion tons per year by 2050, about 700 large reactors would have to go on-line. This number goes up to 1,000 when replacement reactors are considered for those 103 reactors that will be shut down by the year 2056.

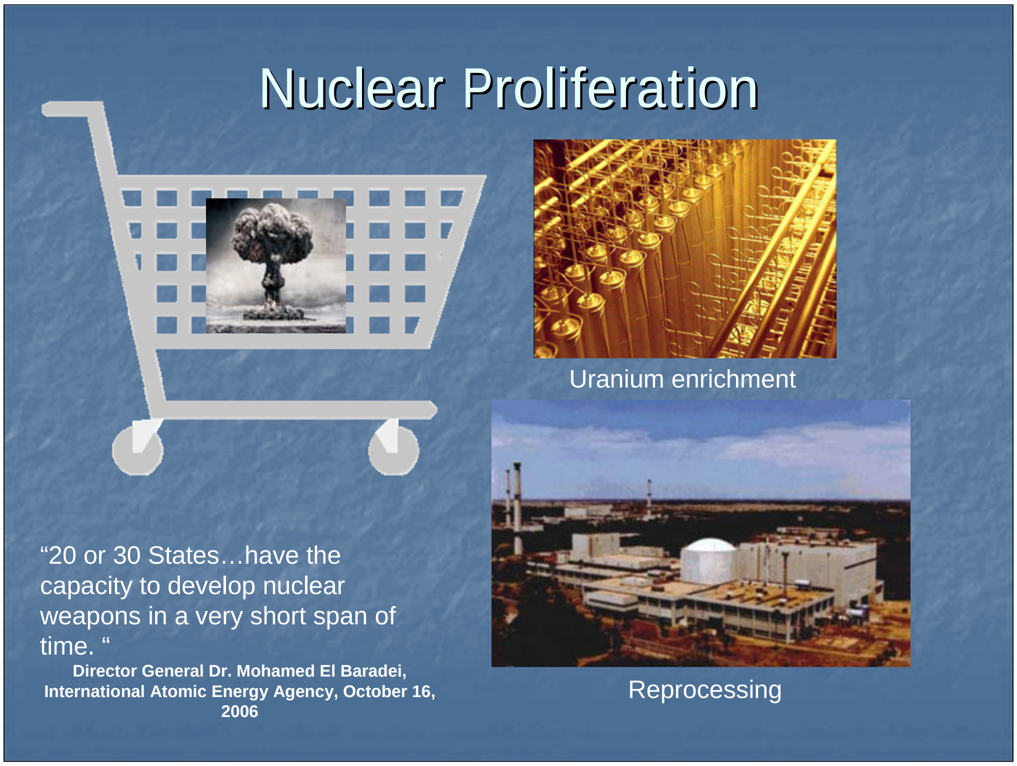
•Recently, a study done by the U.S. Council on Foreign Relations found that *" the rapid rate of nuclear reactor expansion required to make even a modest reduction in global warming would drive up construction costs and create shortages in building materials, trained personnel, and safety controls."* For these reasons the report concluded that "*nuclear energy is not a major part of the solution to U.S. energy insecurity for at least the next fifty years.*" (Source: Charles D. Ferguson, Nuclear Energy: Balancing Benefits and Risks , Council on Foreign Relations, April 2007.)



Recognizing the extraordinary hazards of high-level radioactive wastes, Congress passed the Nuclear Waste Policy Act in 1982 requiring they be disposed in deep geologic repositories so as to protect humans for at least hundreds of millennia. Since most of the nation's reactors are in the east and mid-west, the original law recognized the need for regional equity, and required disposal sites to also be sought in the regions receiving the benefits of nuclear power.

However, a year before 1988 elections, and after fierce opposition to disposal in areas of the country near reactors, the U.S. Congress eliminated the site selection process and picked the Yucca Mountain Site in Nevada. At the time Nevada had one electoral vote. Since then the government's nuclear waste disposal program is being impacted by legal challenges, technical problems, scandal and congressional funding cuts. The Department has recently stated that it will be able to submit a license application to the Nuclear Regulatory Commission in June 2008, as promised.

The DOE concluded in 2004 that 63,000 metric tons of nuclear spent fuel could be stored in the Yucca Mountain site, but continued operation of reactors would generate about 105,000 metric tons by 2030. In effect, by the time the Yucca Mountain Site would be full, nuclear power plants will have accumulated nearly the same amount of spent fuel stored at reactor sites today — requiring a second repository.



Nuclear reactors and the technologies that make nuclear fuel – such as uranium enrichment and reprocessing are the key for nuclear weapons production. Plutonium produced in nuclear power plants has been used in nuclear weapons in the U.S. and other countries.

To stem nuclear weapons proliferation the Nuclear Non-Proliferation Treaty (NPT) was enacted in 1969 and signed by 189 nations. The NPT is based on three pillars:

•to not transfer nuclear weapons technologies and information by the five original nuclear weapons states (U.S., U.K. France, Russia, and China);

•Achieving general and complete nuclear disarmament by the weapons states; and

•Allowing the use of nuclear power plants for energy generation.

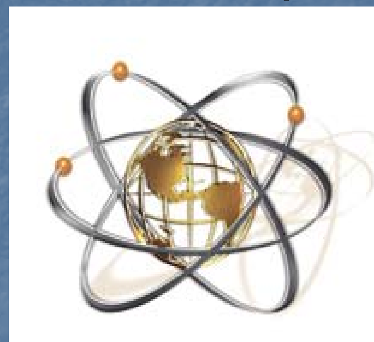
India, Pakistan and Israel did not sign the NPT and have developed nuclear arsenals. North Korea withdrew from the NPT in 2003 and detonated a nuclear device two years later. Iran is currently proceeding to develop a uranium enrichment capability that can make fuel for reactors and weapons.

The International Atomic Energy Agency in the United Nations is responsible for inspections and safeguards to ensure against weapons proliferation from the peaceful atom. Currently, the IAEA has found that several nations that have been reprocessing spent power fuel cannot account for significant amounts of plutonium -- enough to fuel several nuclear weapons. The IAEA safeguard system does not provide timely warning and is not adequately funded. It's annual budget is $100 million – comparable to the payroll of a U.S. professional football team.

A major expansion of nuclear power – such as 1,000 additional reactors proposed by experts, would require the establishing of a near-real time monitoring system and would require a major financial commitment by nuclear exporting and importing countries, far beyond what has been provided to the IAEA.

Moreover, current policy of the U.S. to produce new nuclear weapons for possible preemptive use, serves to encourage nations, particularly in the developing world to acquire nuclear arms as an "equalizer" and short-cut to regional security.

The Global Nuclear Energy Partnership



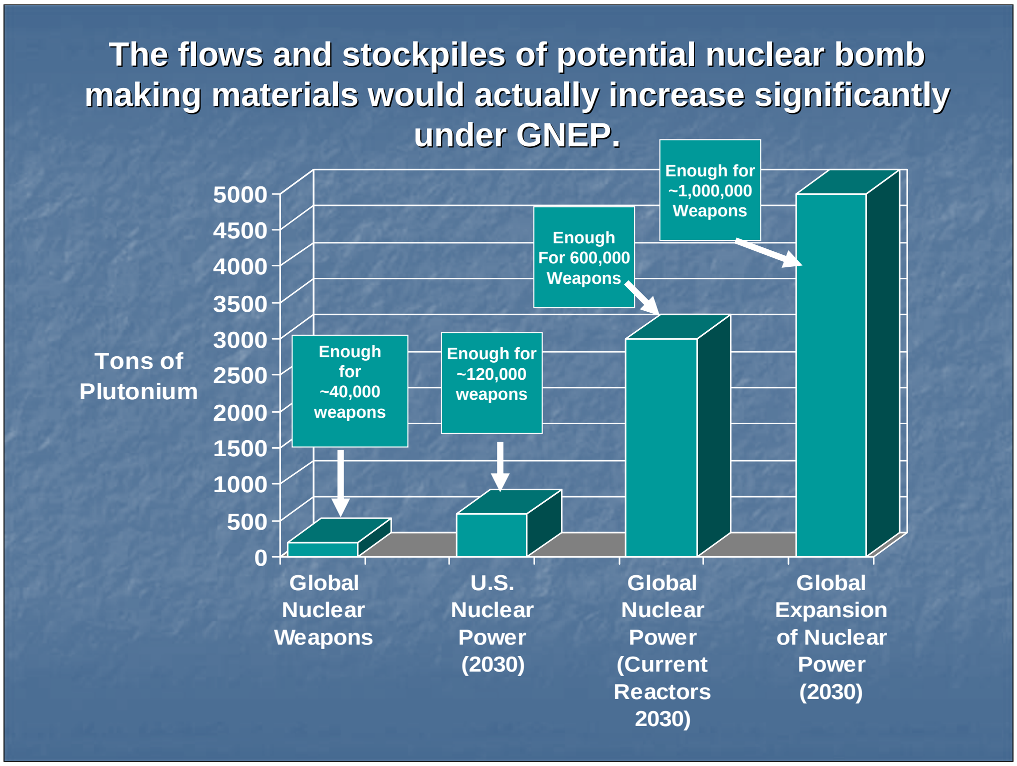
- Sell reactors to developing nations
- Take back reactor spent fuel to U.S.
- Reprocess foreign and U.S. spent fuel at a single site.
- Reduce disposal of high-level wastes and "burn up" plutonium

Under the president's plan, the United States and its nuclear partners would sell power reactors to developing nations that agree not to pursue technologies that would aid nuclear weapons production, notably reprocessing and uranium enrichment.

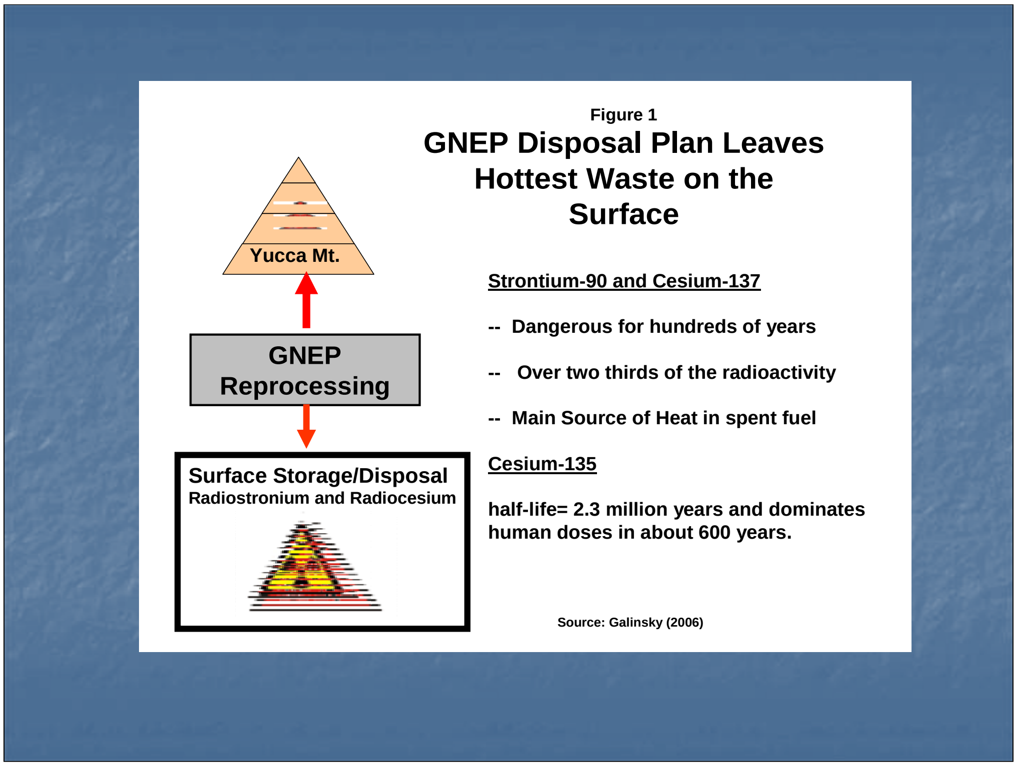
To sweeten the deal, the United States would take highly radioactive spent fuel rods to a recycling center in this country.

The foreign reactor wastes, along with spent fuel from the U.S. reactor fleet, would be reprocessed to reduce the amount that would go deep underground. Nuclear explosive materials, such as plutonium, would also be separated and converted to less troublesome isotopes in a new generation of reactors.

This discriminatory approach would divide nations into nuclear fuel suppliers and fuel dependant clients. It would also pose significant safety risks in the U.S. stemming from a greatly expanded nuclear waste processing and disposal infrastructure.

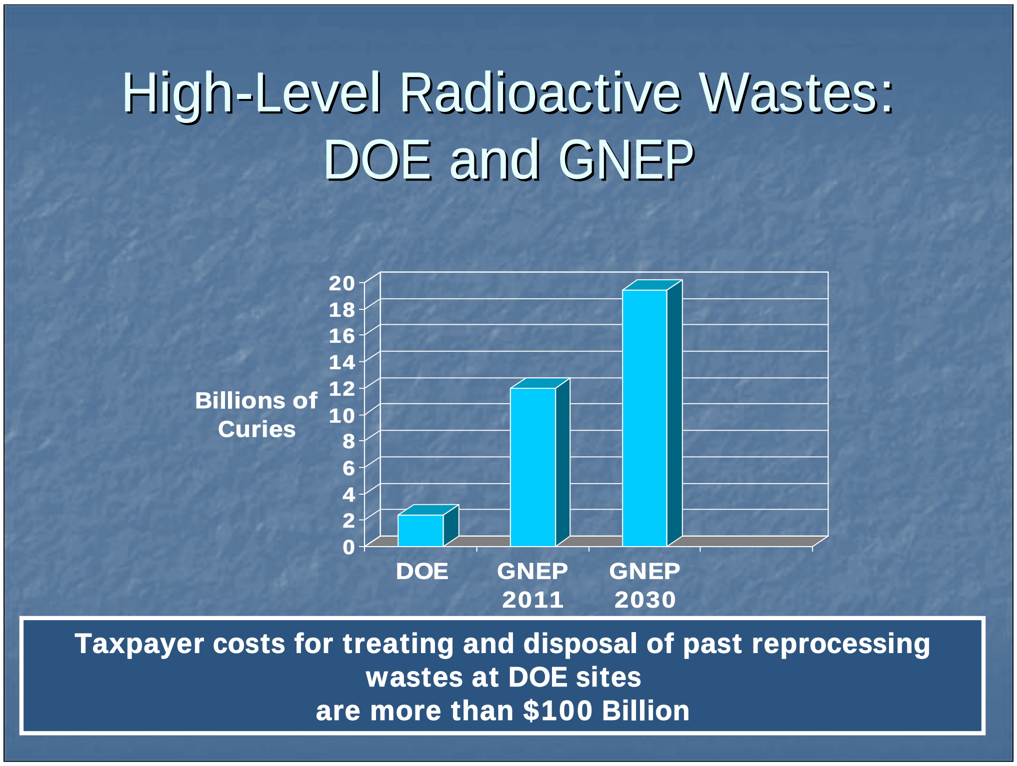


There is no evidence that GNEP actually would reduce the threat of proliferation of nuclear weapons and nuclear materials to other nations and terrorists. Indeed, the flows and stockpiles of potential nuclear bomb making materials would actually increase significantly under GNEP. Not only will more radioactive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



To reduce the amount of radioactive wastes slated for a deep geological repository, the DOE is seeking to store the vast majority of radioactive byproducts in shallow burial. Far from containing toxins, however, this proposal would pose threats to nearby water supplies. The site selected for the GNEP reprocessing facility would become a de-facto waste dump, creating unprecedented public health and security threats.

More than four thousand shipments of spent nuclear reactor fuel will be transported on rails and highways through cities and farmlands to the reprocessing site, posing unprecedented emergency response and security challenges. DOE plans to separate cesium and strontium for storage and disposal, after 300 years, in shallow land burial at the reprocessing site. This would result in the largest, lethal source of high-heat radioactivity in the United States and possibly the world. If placed in a crowded area, a few grams of radioactive cesium would deliver lethal doses in a matter of seconds. Concentrations of strontium and cesium could be so large that if they were disposed of in shallow land burial as low-level wastes, shortly after separation they would have to be diluted to a volume as large as 500 million cubic meters, enough to fill 500 Empire State Buildings.



The amount of radioactivity disposed of into the environment at a reprocessing site could be thousands of times greater than from nuclear weapons production. By contrast, much smaller amounts of similar radioactive materials from past reprocessing at DOE sites are to be geologically disposed because they are considered to pose significant risks to the human environment.

The amount of plutonium contained in separated transuranic materials proposed under GNEP could be as much as 638 metric tons – more than two and a half times the amount in world-wide nuclear arsenals. Waste created by separating transuranic materials could be far greater in concentration and volume that produced for nuclear weapons in the U.S.

Even though uranium constitutes more than 95 percent of the materials in spent nuclear fuel by weight, it will require costly treatment for reuse in reactors – estimated in the billions of dollars. As a result, DOE's plans include the landfill disposal of tens of thousands of tons of recovered uranium.

Conclusion

America is better off by investing in conservation, fuel efficiency, renewable energy and carbon capture technologies.