The Nuclear Energy Future

Building the Nation's Nuclear Energy Laboratory

John F. Kotek, Deputy Manager
Idaho Operations Office
U.S. Department of Energy

June, 2004

Why Is Energy Important?

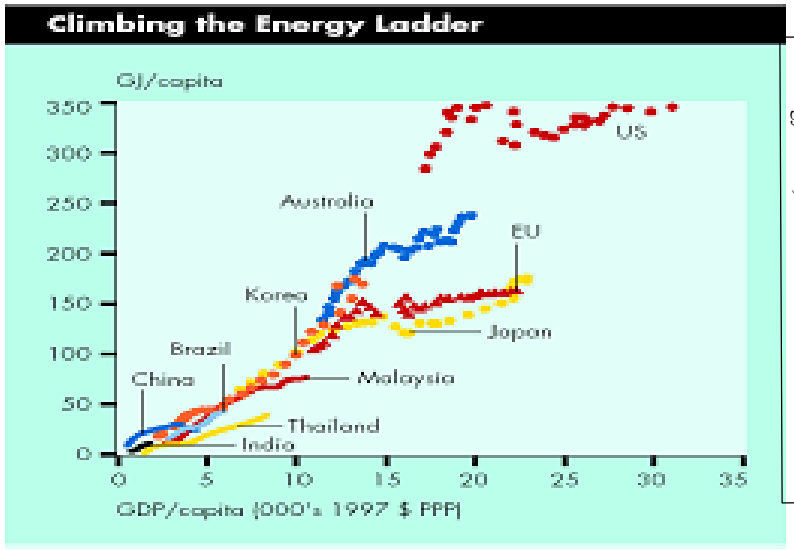
- "In traveling I have observed that in those parts where the inhabitants can have neither wood nor coal nor turf but at excessive prices, the working people live in miserable hovels, are ragged, and have nothing comfortable about them. But when fuel is cheap, they are well furnished with necessaries and have decent habitations."

  - Benjamin Franklin, 1786

Picture courtesy of ushistory.org

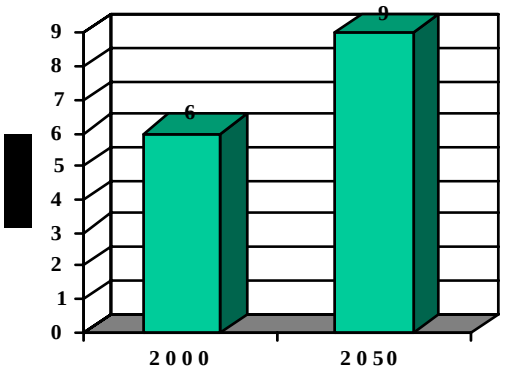
Why Is Energy Important?

- **Energy is vital to civilization.**
- **Our national security, economic prosperity, and global stability are closely tied to energy supplies.**

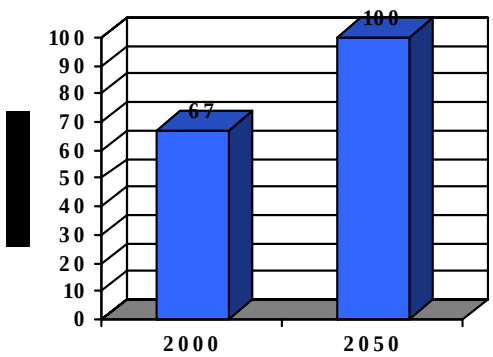


Source: Royal Dutch Shell, "Exploring the Future - Energy Needs, Choices and Possibilities

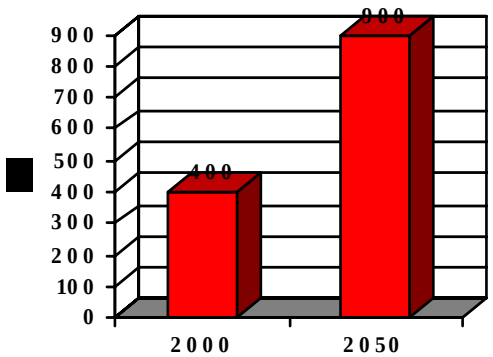
World Population



Per-Capita Energy Use



World Energy Demand

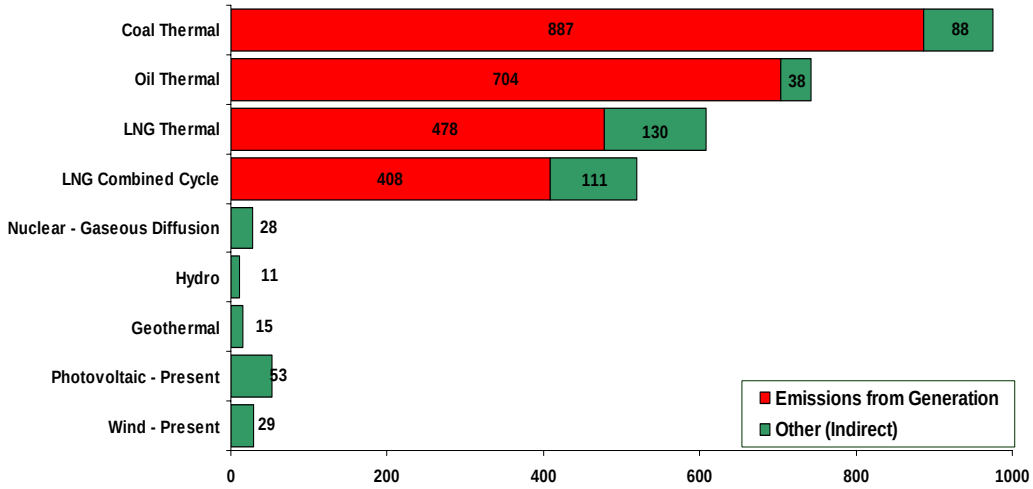


Where Do We Get Our Energy?

Source	% of U.S. Energy Supply	Pros	Cons
Fossil Fuels Oil Natural Gas Coal	84 39 23 22	Inexpensive to construct (gas) and operate Domestically available (coal) Flexible	Significant emissions Insecure supply (oil, gas?) Price volatility (oil, gas)
Nuclear	8	Essentially non-emitting Inexpensive to operate Domestically available	Radioactive waste Expensive to construct Safety concerns Proliferation concerns
Hydropower	4	Essentially non-emitting Inexpensive to operate Domestically available	Environmental concerns Few opportunities for domestic expansion
Biomass	3	Renewable Domestically available	Significant emissions Large land requirements
Other Renewables (e.g. solar, wind)	1	Essentially non-emitting Renewable Domestically available Inexpensive to operate	Expensive to construct Large land requirements Intermittent

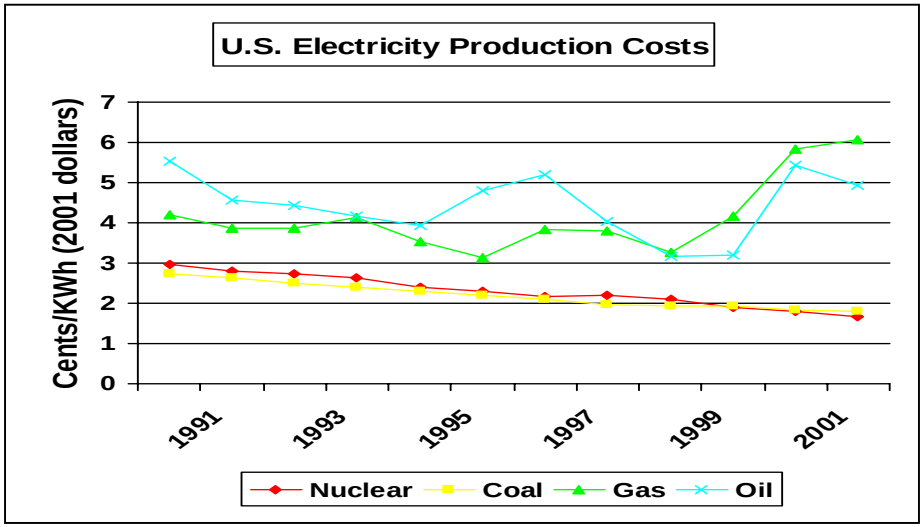
Why Is Nuclear Energy Important?

- **Nuclear energy enables:**
  - Air quality improvement
  - Carbon emission reduction
  - Waste reduction
  - Increased energy security



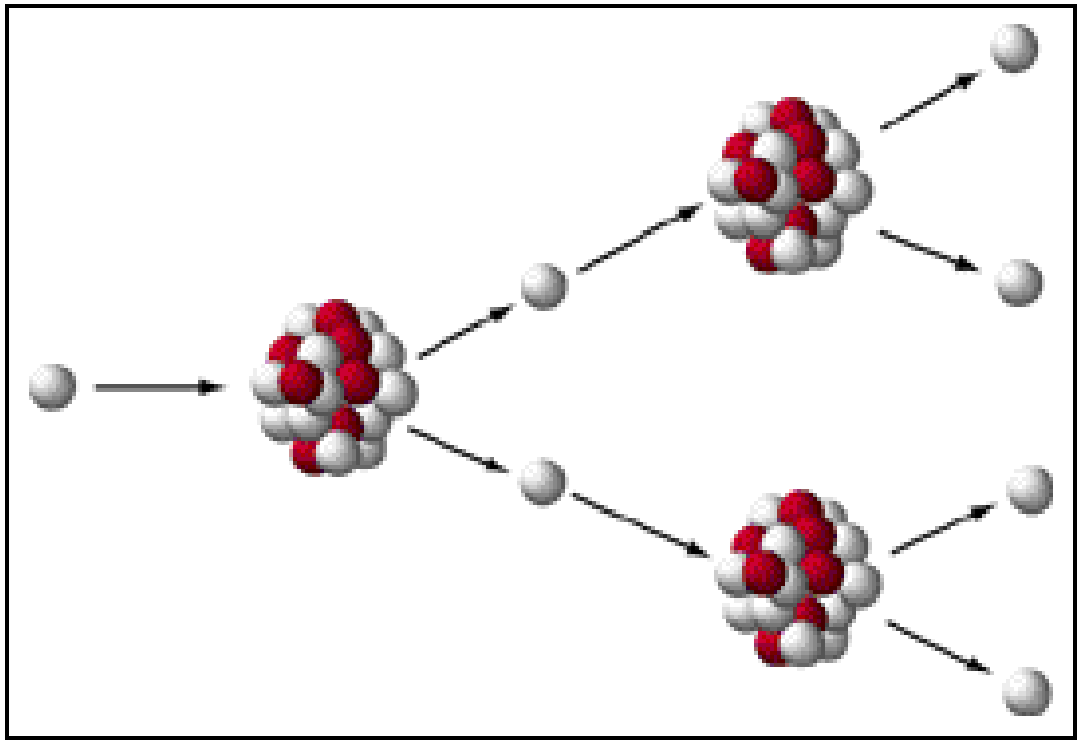
Source: Central Research Institute of Electric Power Industry, Japan 2000

- **Nuclear energy is affordable**
  - Currently operating U.S. nuclear power plants have achieved low operating costs and are attractive in today's market
  - The challenge is to design new plants that can be built faster and at less cost than today's reactors



How Does Nuclear Energy Work?

- **Nuclear energy works by capturing the energy released during the splitting, or "fission," of heavy elements like uranium and plutonium**
- **The neutrons released during fission can go on to cause other atoms to fission, resulting in a chain reaction**



The Nuclear Fuel Cycle

"Front-End"

Mining/Milling

Conversion

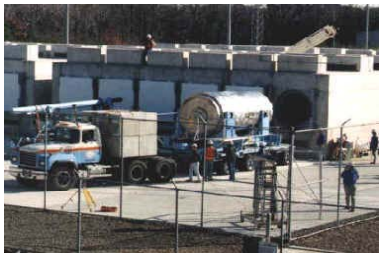
Enrichment

Fuel Fabrication

Irradiation

"Back-End"

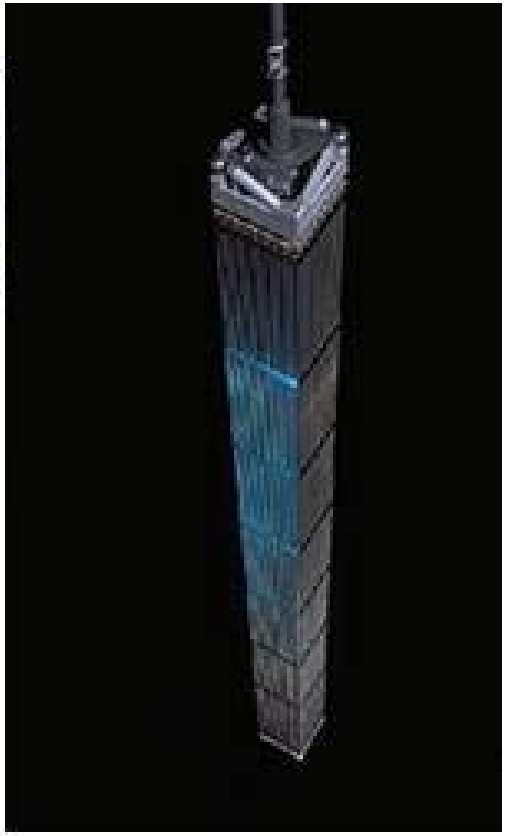
Reprocessing



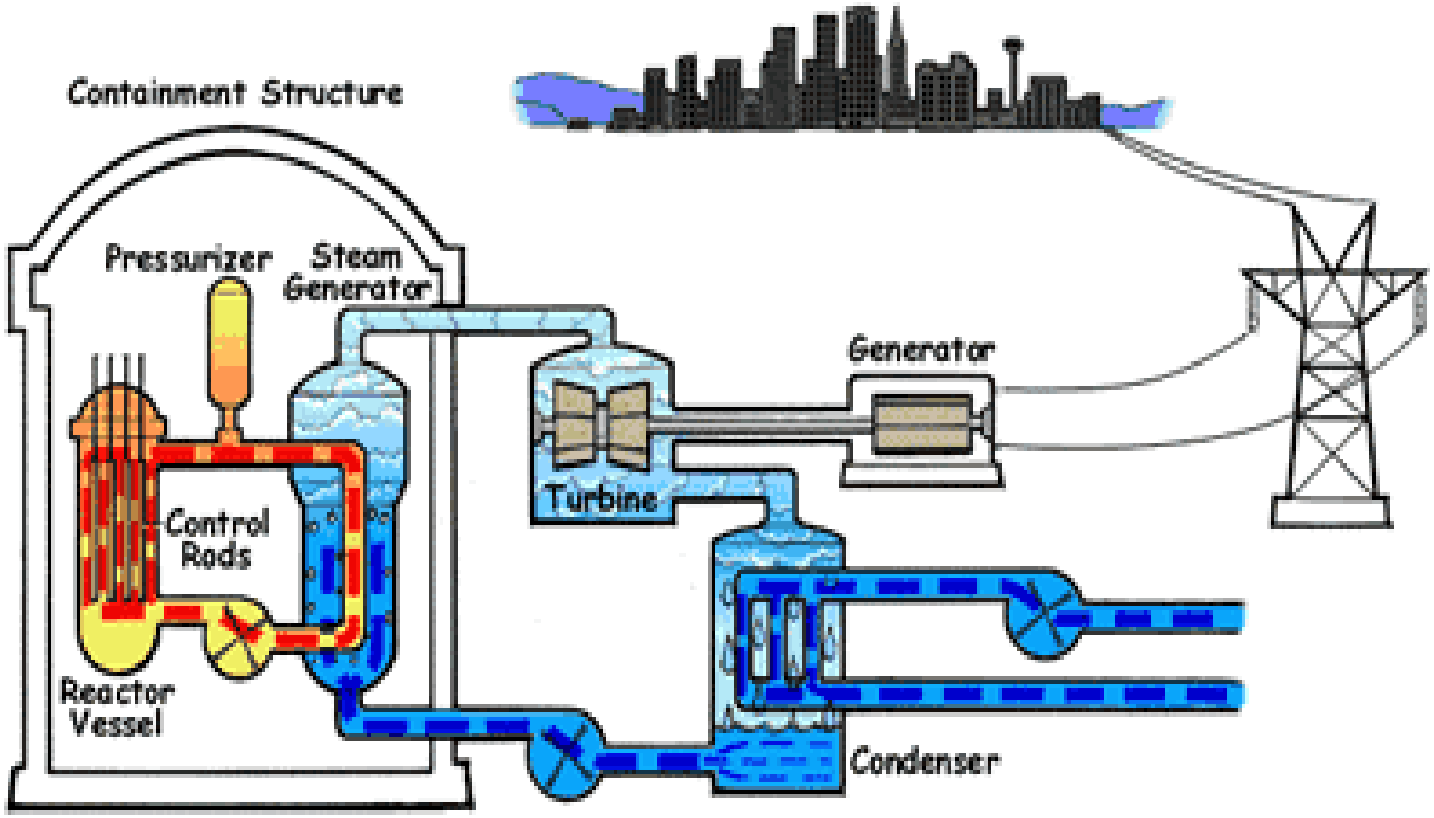
Storage/Disposal

Nuclear Fuel Assembly

- A typical fuel assembly contains about 450 kg of uranium in the form of UO_2
- At 3 cents/kWh (cheap) electricity and typical fuel in-reactor life, this assembly will generate about $6 million in electricity revenues, including $200,000 for the Nuclear Waste Fund



Pressurized Water Reactor

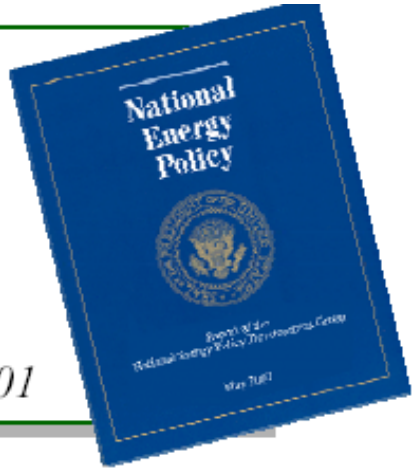


Courtesy of http://www.solcomhouse.com/nuclear.htm

The National Energy Policy

"The NEPD Group recommends that the President support the expansion of nuclear energy in the United States as a major component of our national energy policy."

Report of the National Energy Policy Development Group, May 2001



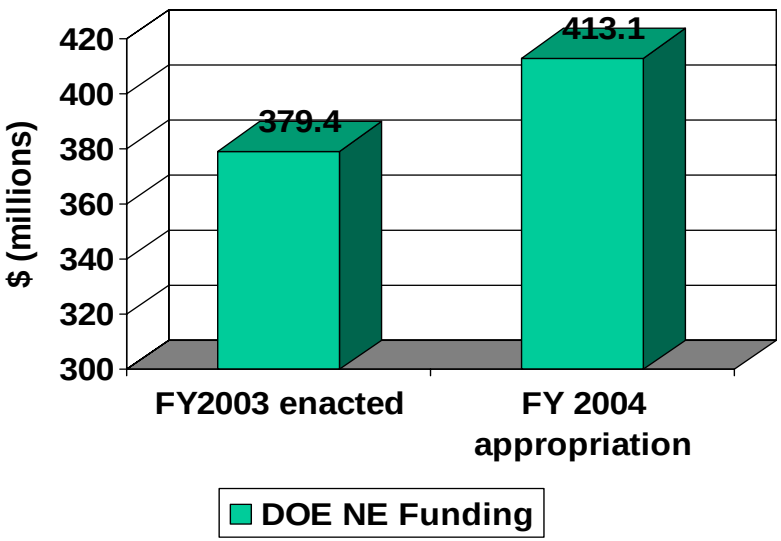
Test Reactor Area - Idaho

Recommendations:

- Support expansion of nuclear energy in the United States
- Develop advanced nuclear fuel cycles and next generation technologies
- Develop advanced reprocessing and fuel treatment technologies

What Is DOE Doing in the Area of Nuclear Energy R&D?

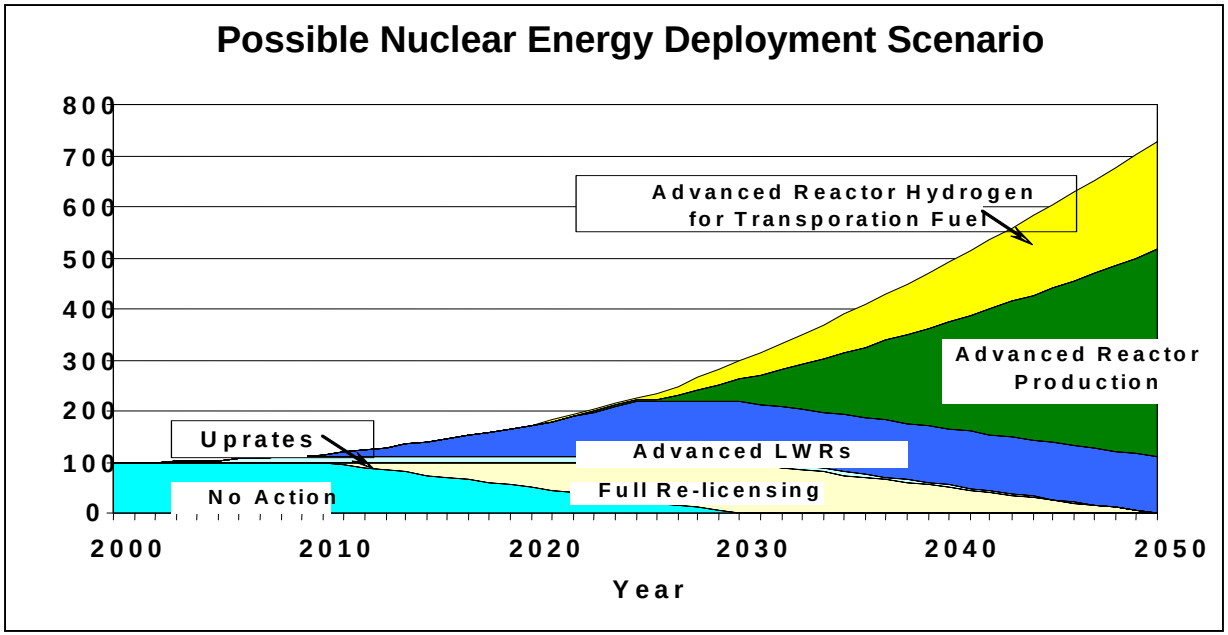
- **DOE has taken aggressive steps to ensure that nuclear energy plays a large role in our energy future.**
  - accelerating and enhancing nuclear energy, reactor waste, and nuclear materials management programs
  - working with industry to reduce regulatory barriers and financial risk to enable the construction of new nuclear power plants
  - planning new research, development, and demonstration facilities
  - attracting new scientists and engineers to the nuclear field



Spencer Abraham
Secretary of Energy

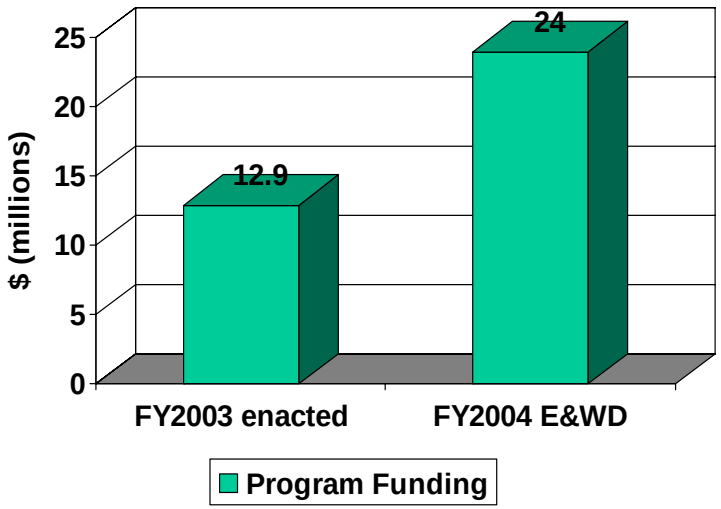
DOE Nuclear Energy Programs

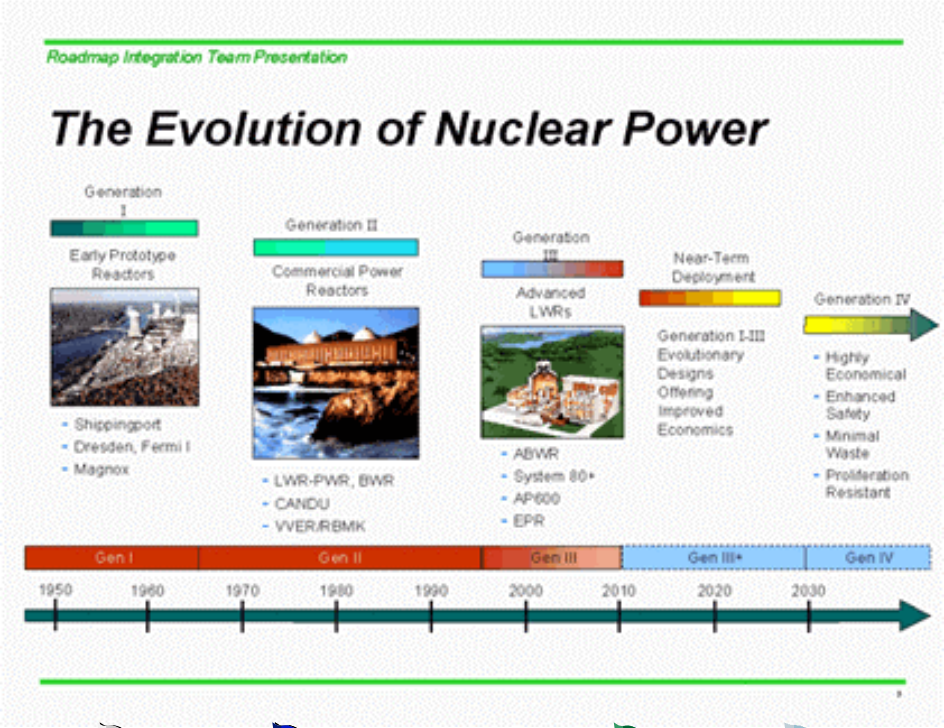
- **DOE's nuclear energy programs are focused on:**
  - Improving the efficiency of current reactor operations
  - Deploying new nuclear power plants in the next decade
  - Developing and demonstrating Generation IV reactor technologies
  - Developing advanced fuel cycle technology to reduce the waste burden
  - Ensuring a sufficient supply of trained nuclear professionals to carry out these missions



Generation IV Nuclear Energy Systems Initiative

- Supports the need to develop technologies that achieve safety performance, waste reduction, and proliferation resistance while providing the next-generation nuclear energy system that is economically competitive, reliable, sustainable, and ready for deployment before 2030.





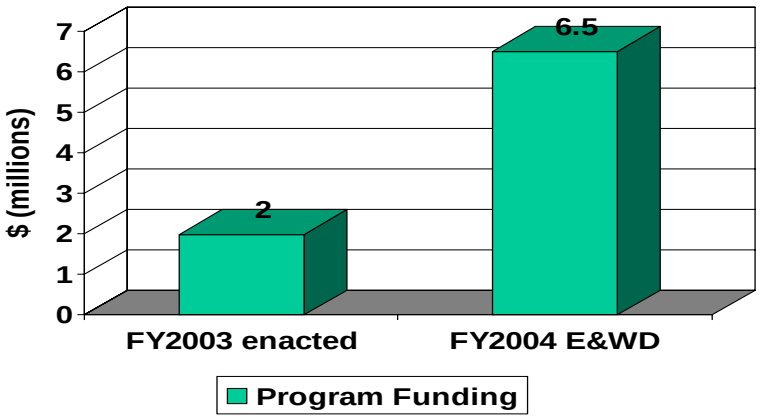
U.S.A. *United Kingdom* *Switzerland* *South Korea* *South Africa* *Japan* *France* *Canada* *Brazil* *Argentina*

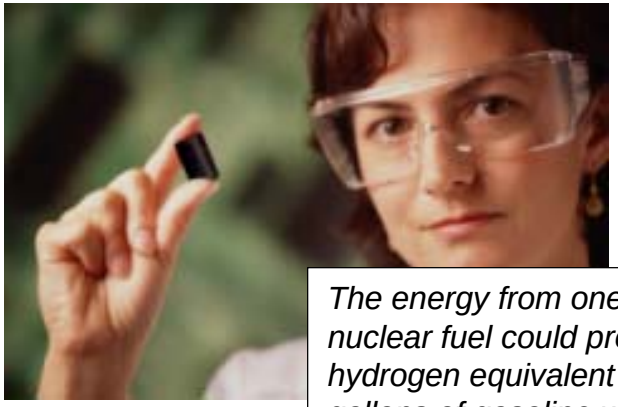
Nuclear Hydrogen Initiative

- **Established to identify and evaluate new and innovative concepts for producing hydrogen using nuclear reactors.**

- Conduct laboratory testing of candidate hydrogen production processes
- Complete design and initiate construction of two hydrogen production pilot plants - (200 kW) high temperature electrolysis plant and (500 kW) thermochemical plant
- Begin operation of the initial pilot plants
- Begin system optimization and scaling of thermochemical pilot plant
- Complete process improvements and scaling of thermochemical pilot plant to MW class
- Complete designs and start construction of engineering scale hydrogen production systems

2005 2006 2007 2008 2009 2010 2011 2012 2015

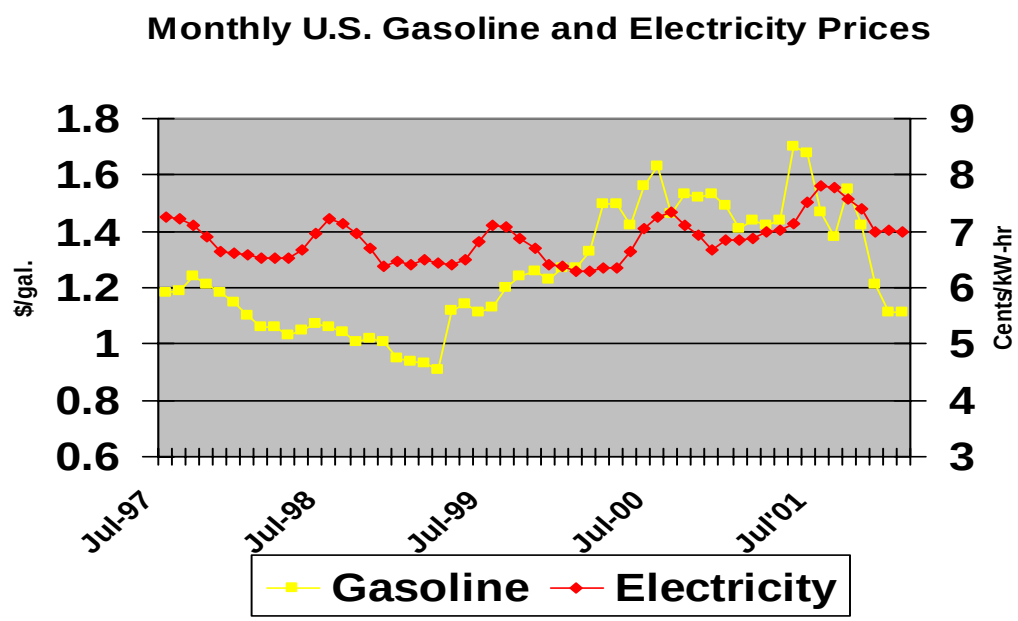




The energy from one pound of nuclear fuel could provide the hydrogen equivalent of 250,000 gallons of gasoline without any carbon emissions.

Why is the Administration Focused on Hydrogen?

- **Reduced reliance on foreign oil**
  - Hydrogen can be made from domestically-available energy resources
- **Cleaner air**
  - The use of hydrogen in fuel cells results in zero emissions
  - Hydrogen can be made using near-emissions-free energy technologies
- **Long-term sustainability**
  - Hydrogen can be made using a variety of energy resources, which can help ensure fuel supply diversity and price stability



Energy Source	% of U.S. Electricity Supply	% of Total U.S. Energy Supply
Oil	3	39
Natural Gas	15	23
Coal	51	22
Nuclear	20	8
Hydroelectric	8	4
Biomass	1	3
Other Renewables	1	1

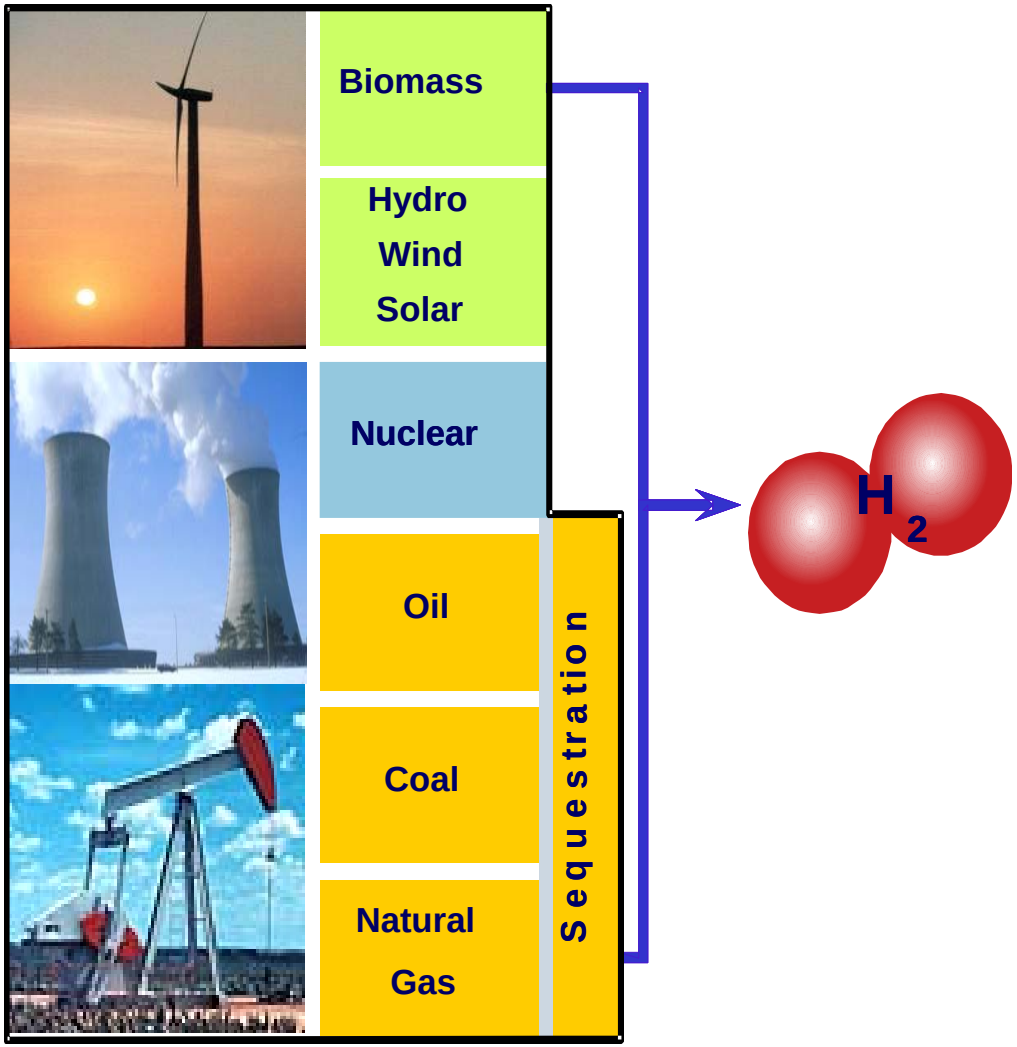
So where are we going to get the hydrogen?

- We can't mine it, we've got to make it
- We make about 20 million kg of H2 per day in the U.S., and use most of it in refineries and to make ammonia
- Almost all (>95%) of this H2 comes from the steam-reforming of natural gas
- The rest of our hydrogen is generated through electrolysis

So where are we going to get the hydrogen?

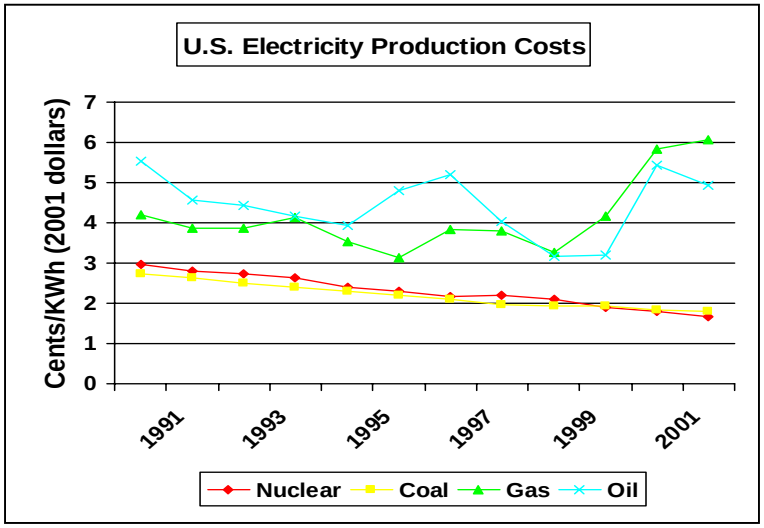
- **Several DOE offices are looking at ways of making hydrogen:**
  - EE – wind, solar, biomass, others
  - FE – fossil fuels with carbon sequestration
  - NE – high-temperature production cycles

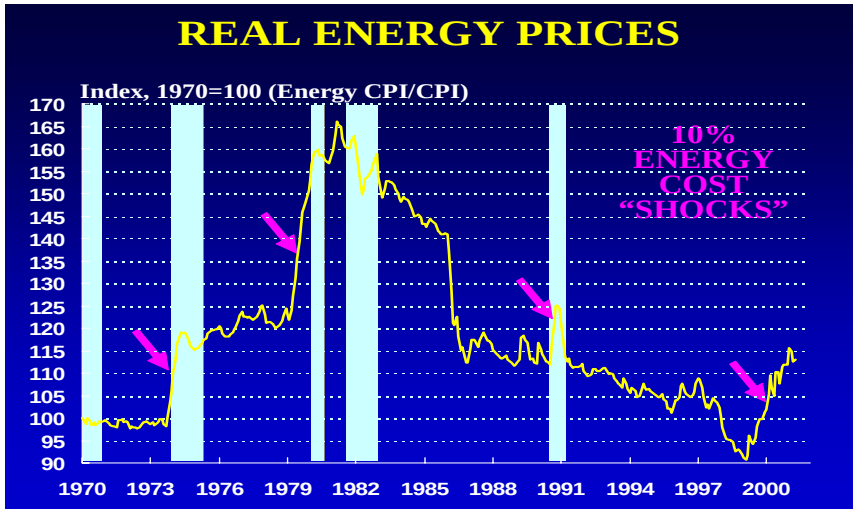
- **All of the production technologies under investigation offer certain challenges – it's way too early to pick winners, and several promising technologies will likely emerge**

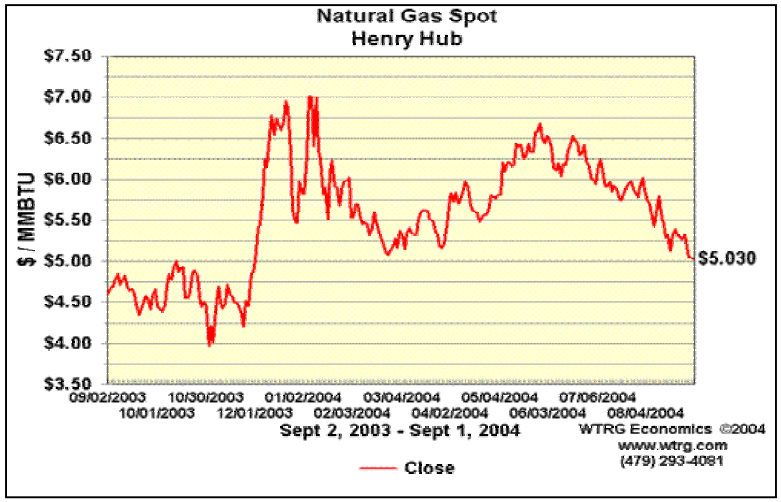


Why Nuclear for Hydrogen? – Energy Security and Price Stability Advantages

- The price of uranium is a very small percentage (<5%) of the cost of nuclear-generated electricity
- Nuclear is therefore immune from price spikes due to rising fuel costs
- The price of natural gas is a large fraction (~50%) of electricity price, so price spikes in gas price are reflected in electricity price

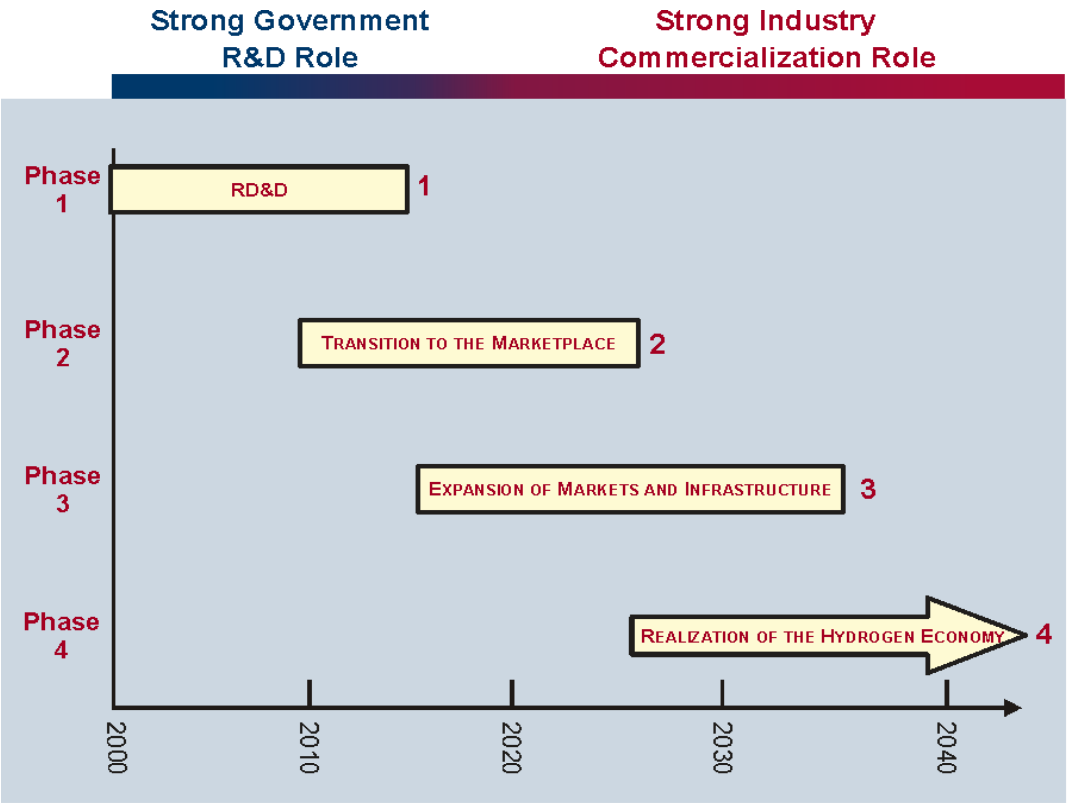






The path forward…

- **DOE has set the following schedule for commercialization of hydrogen vehicle and power technology**



Transitional Phases

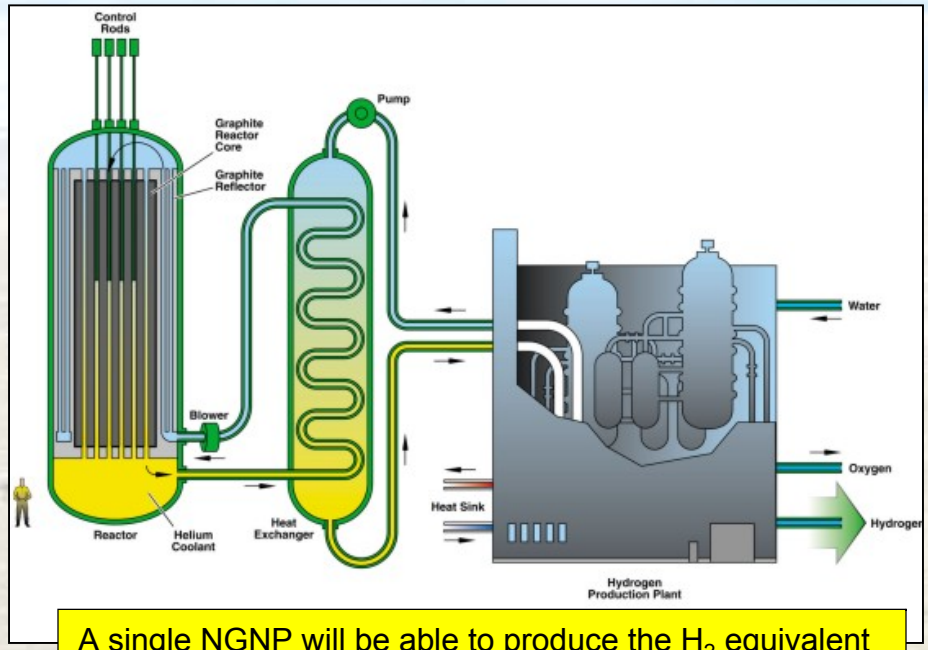
1. **Technology Development Phase**
   H_2 power and transport systems available in select locations; limited infrastructure
2. **Initial Market Penetration Phase**
   H_2 power and transport systems begin commercialization; infrastructure investment begins with governmental policies
3. **Infrastructure Investment Phase**
   H_2 power and transport systems commercially available; infrastructure business case realized
4. **Fully Developed Market and Infrastrucure Phase**
   H_2 power and transport systems commercially available in all regions; national infrastructure

- **We must find ways for nuclear-generated hydrogen to be available and competitive in this time-frame**

The Next Generation Nuclear Plant (NGNP)

What Does the NGNP Represent?

1. A very promising future option for economic, commercial-scale generation of hydrogen
2. A better, safer, more economic nuclear energy plant
3. The most important project under consideration for the new Idaho National Lab



A single NGNP will be able to produce the H_2 equivalent of 200,000 gallons of gasoline each day

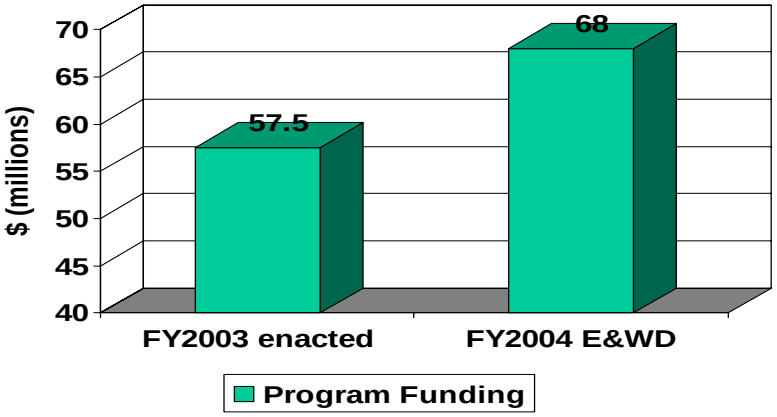
How Will We Get There?

1. DOE leadership and early investment in key materials, fuels, and H_2 production technology
2. Aggressive, well planned collaboration and cost-sharing with international partners and the private sector

Advanced Fuel Cycle Initiative

- The goal is to improve the understanding and performance of nuclear fuel and fuel cycles with respect to safety, waste production, proliferation resistance, and economics to enhance long-term viability of nuclear energy systems.

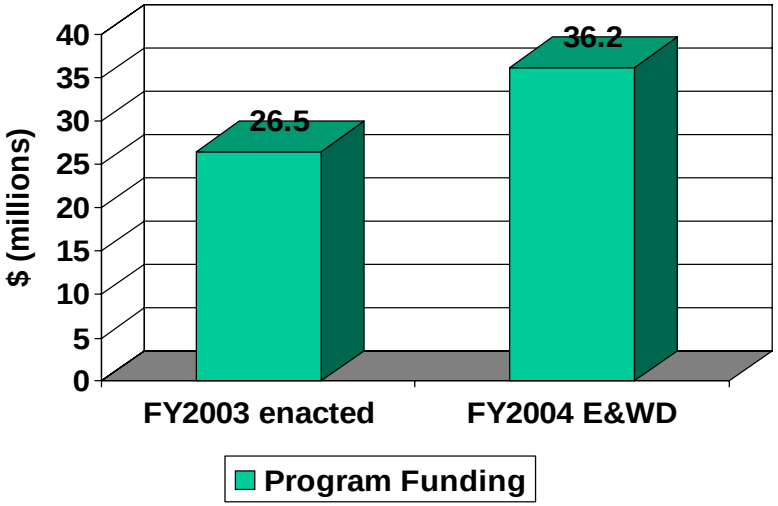
- Selected topics include:
  - Concepts for material preparation and fuel production
  - Inherently safe fuel designs and core response
  - Understanding life-limiting phenomena for high burnup fuels
  - High-temperature fuel and material performance
  - Critical safety and reactor physics data for advanced fuel designs, compositions and enrichments



January 2003

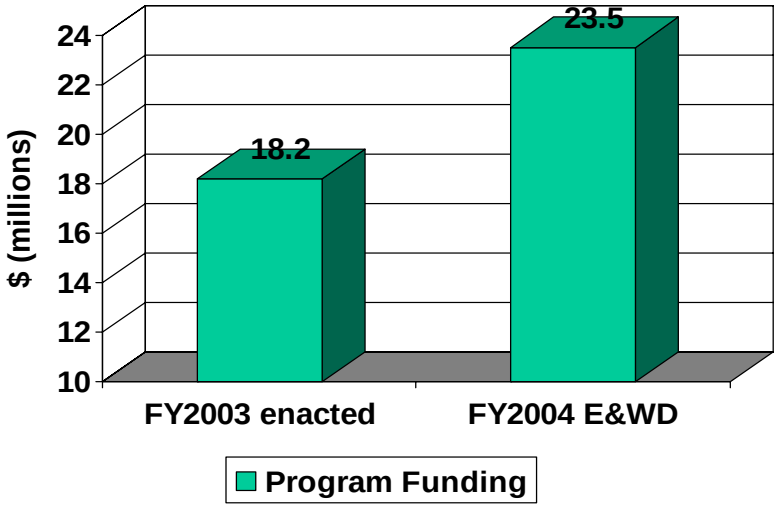
Space and Defense Radioisotope Thermoelectric Generator (RTG) Program

- **Provides support to NASA for radioisotope power source development, demonstration, and testing, to explore deep space and the surfaces of neighboring planets.**



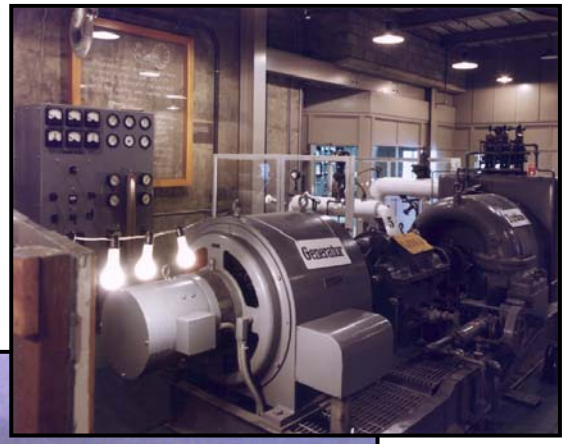
University Programs

- Established to help U.S. universities and colleges stay at the forefront of science education and research, the University Program assists universities in the operation of research reactors and in the performance of other educational activities. Direct support is provided to educational institutions in 27 states.



Idaho and Nuclear Energy

- **One role the US government has is to fund the development of long-term, high-risk technologies.**
- **Idaho has a proud heritage of nuclear excellence:**
  - World's First Generation of Electricity from Nuclear Power
  - First Materials Test Reactor
  - First Breeder Reactor
  - First Naval Propulsion Reactor
  - 52 Research, Development, Testing, and Demonstration Reactors
  - Worldwide Nuclear Safety Basis (LOFT/RELAP5)



The Idaho National Laboratory

"First, INEEL will be the central command center for the federal government's Generation IV nuclear systems research."

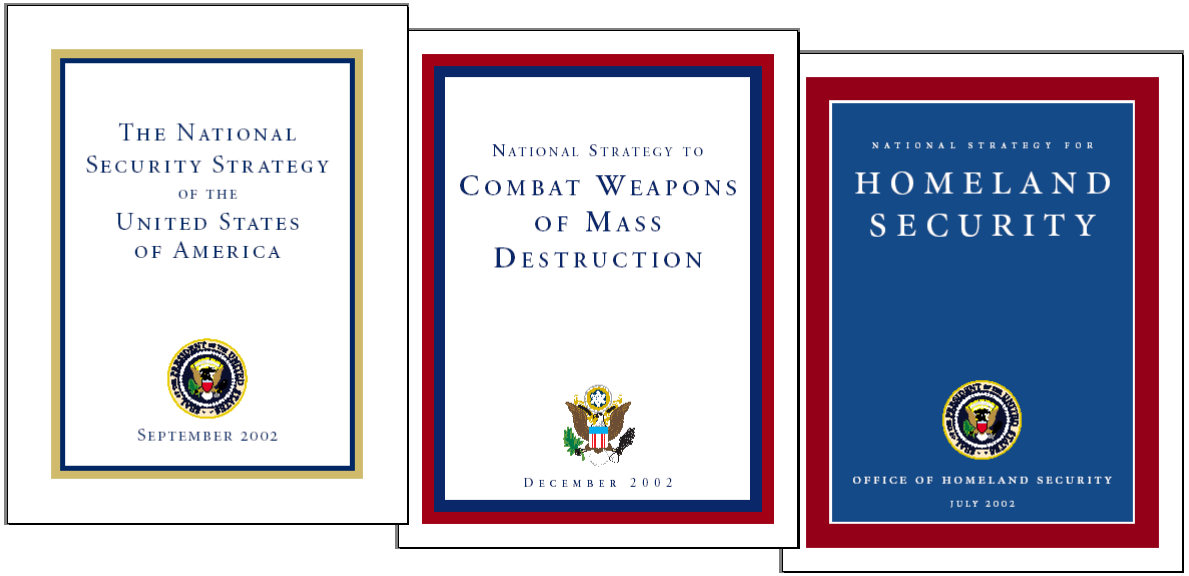
Second, an "Idaho Advanced Fuel Cycle Technology Initiative will be the focal point for developing and demonstrating separation technologies for treating and reducing spent nuclear fuel and high level waste."

– Spencer Abraham
July 15, 2002

National Security Programs

Mission Areas

- Homeland Security
- Nonproliferation and Nuclear Security
- Intelligence/Special Programs
- Combat Support



National Security Programs

Homeland Security

- Critical Infrastructure Assurance Test Range

Nonproliferation and Nuclear Security

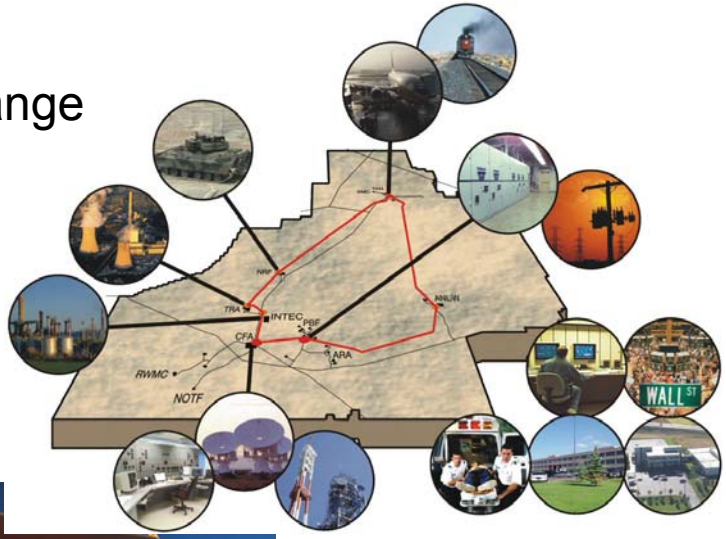
- Detection of Fissile Material in Cargo Containers

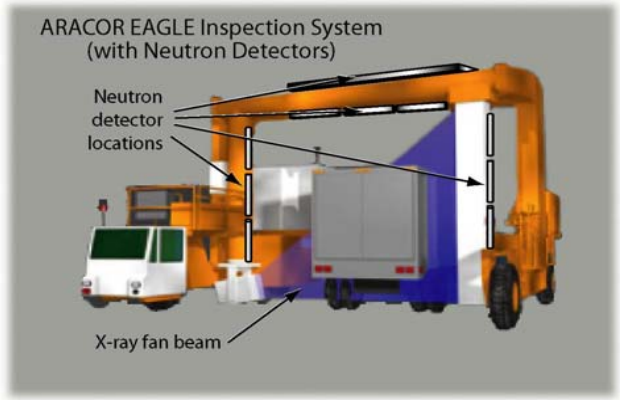
Intelligence/Special Programs

- Change Detection System

Combat Support

- Unmanned Aerial Vehicles





Change Detection System

Change Detection System

Change Detection System

Vision for the Idaho National Laboratory

- **From the Final RFP:**
  - The Department of Energy's (DOE's) vision is for the INL to enhance the Nation's energy security by becoming *the preeminent, internationally-recognized nuclear energy research, development, and demonstration laboratory within ten years.*
  - The INL will also establish itself as a *major center for national security technology development and demonstration*.
  - This requires that the INL be a *multi-program National Laboratory with world-class nuclear capabilities*.
  - The INL will foster *new academic, industry, government, and international collaborations* to produce the investment, programs and expertise that assure this vision is realized.

INL Focus Areas

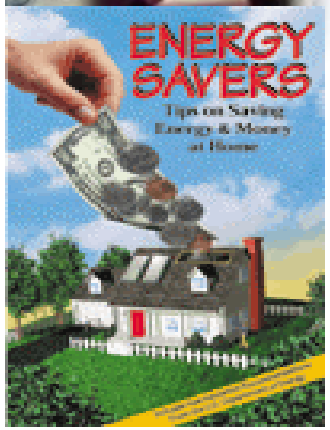
- **Nuclear Energy:**
  - Generation IV and Nuclear Hydrogen Initiative
  - Next-Generation Nuclear Plant (NGNP)
  - Advanced Fuel Cycle Initiative (AFCI)
  - Space Heat and Power Systems
  - Nuclear Engineering Education
- **National Security**
  - Nonproliferation and counterproliferation
  - Technology and systems testing
  - Specific Manufacturing Capability
- **Science and Technology**

What Does Formation of the INL Mean for Idaho?

- Enhances Idaho's already significant high technology sector
- Gives Idahoans another exciting place to work
- Helps establish Idaho as a world center for nuclear technology education
- Requires the new INL contractor to maximize opportunities for small and regional businesses

The Smart Energy Campaign

- Last Summer, Secretary Abraham unveiled the Smart Energy Use Education Campaign.
- Focused on educating consumers, homeowners and business owners on smart energy use including ways to cut their energy bills.
- "Individuals can play an important role in reducing energy use. Conserving energy in the home saves consumers money today while also helping ensure abundant energy supplies in the future."
- The Energysavers.gov website educates consumers on energy conservation and offers tips on how to conserve energy and save money.



Energy Conservation Facts

- **Did you know that the typical U.S. family spends close to $1,300 a year on their home's utility bills? Unfortunately, a lot of that energy is wasted. The amount of energy wasted just through poorly insulated windows and doors is about as much energy as we get from the Alaskan pipeline each year.**
- **If every U.S. household replaced just one incandescent bulb with a compact fluorescent, we'd save the energy equivalent of one large power plant running all year, or the equivalent of removing 1.7 million cars from the road.**
- **Appliances that are not in use, but plugged in, still use energy. Unplug that extra refrigerator in your basement and save 448 pounds of CO2 per year.**
- **If every commuter vehicle in the U.S. carried just one more person, we'd save 600,000 gallons of gas and 12 million pounds of CO2 *every day*.**
- **Washing clothes in cold water reduces your washer's energy use by 75% and saves almost 500 pounds of CO2 per year.**

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