Changing the World:
The DOE Vision for the Next Nuclear Era

Workshop for
Graduate Students
for the
Big 10 Nuclear Engineering Department

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U.S. Department of Energy

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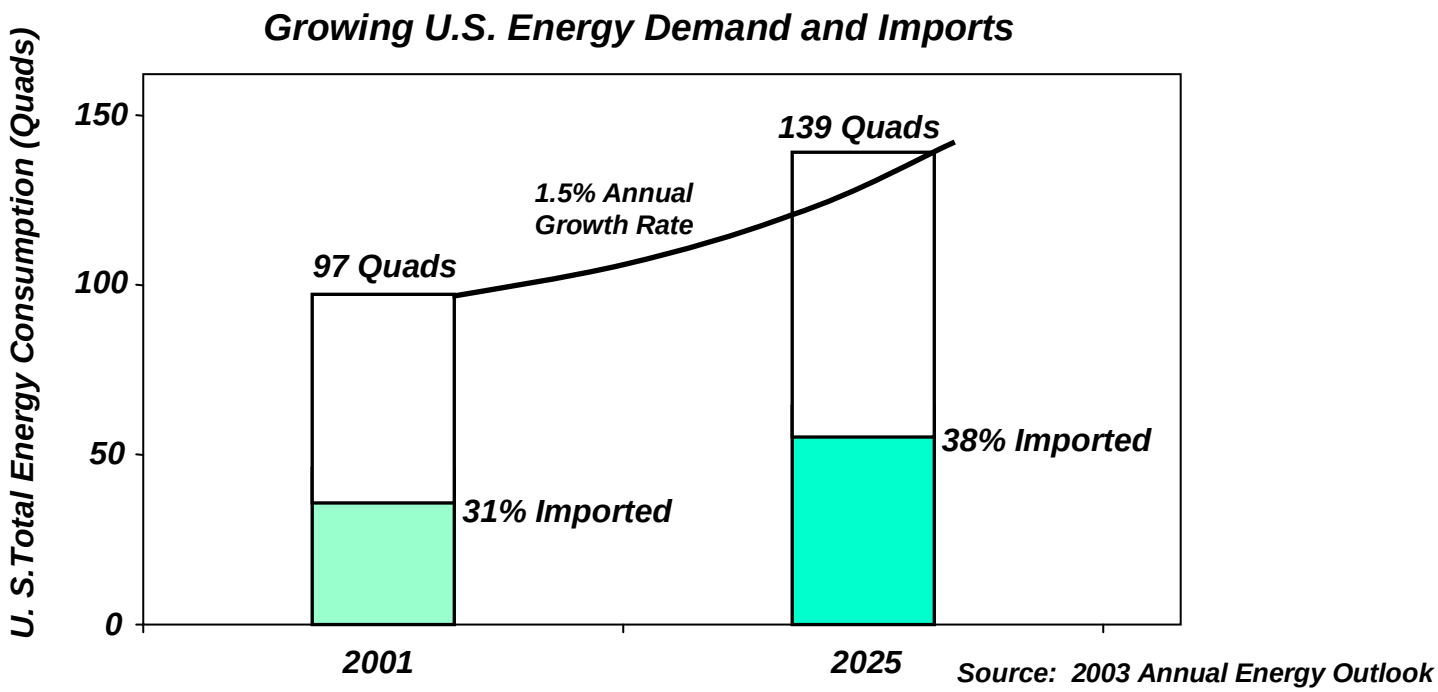
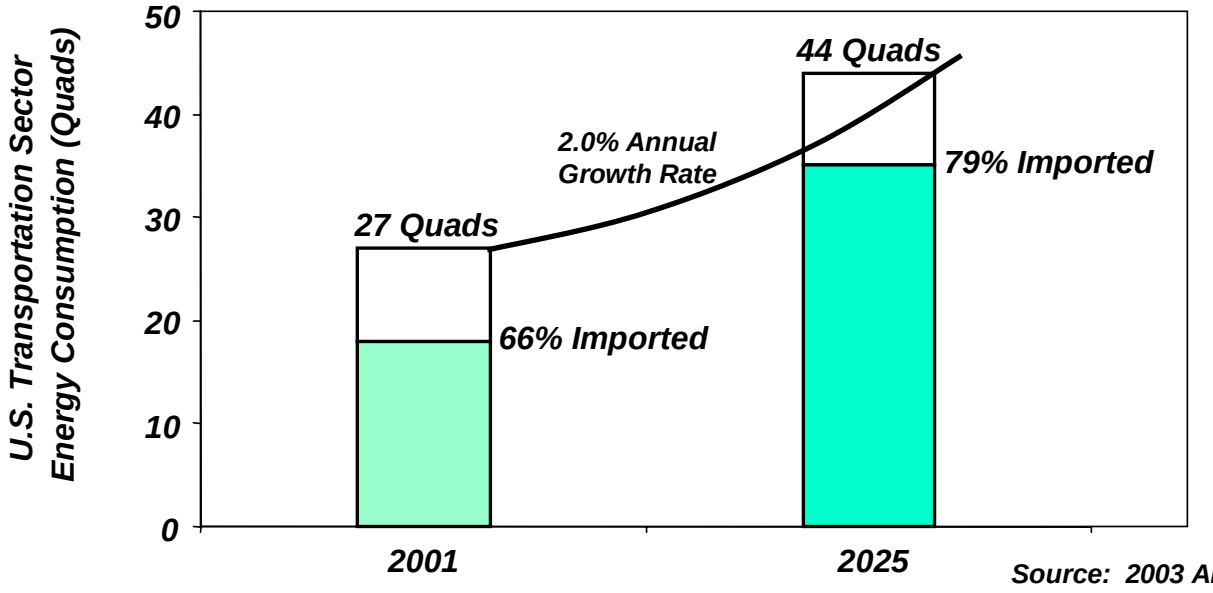
Forecast for Energy Growth:
Energy Demand Will Increase by 43 Percent by 2025



- **Annual outlook is 1.5 percent growth in U.S. energy to 2025**
- **Most growth is in natural gas and coal**
- **Imports will increase by 75 percent by 2025**
- **Nuclear can contribute if deployed in the near-term**

Energy for Transportation
A Potential Vulnerability

Growing U.S. Transportation Sector Energy Demand and Imports

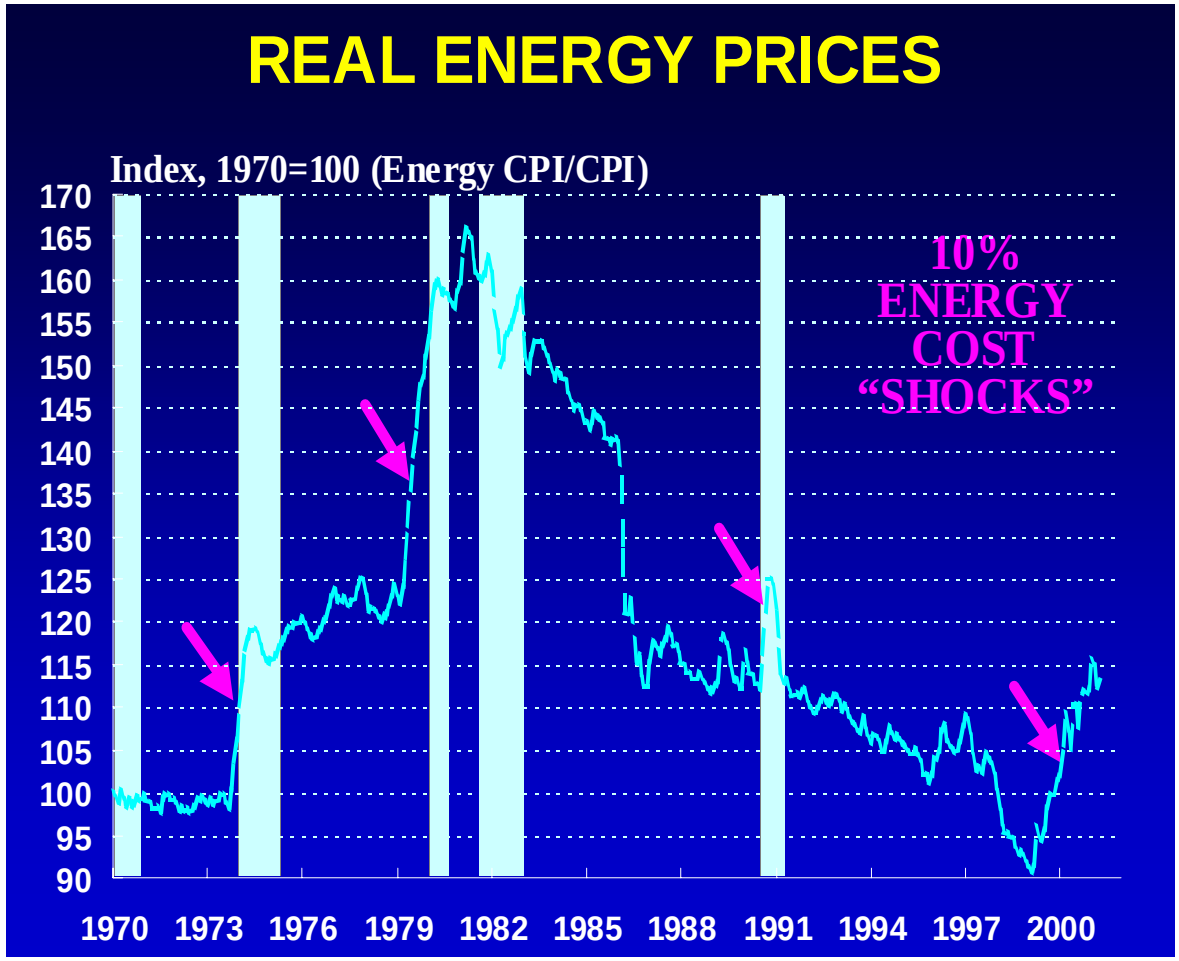


Source: 2003 Annual Energy Outlook

- **Transportation sector is experiencing the fastest growth in energy use -- demand will grow by 63 percent by 2025**
- **A large increase in imports appears inevitable**
- **Energy security and stability is undermined by increasing reliance on imports**

Energy Security = Economic Security = National Security

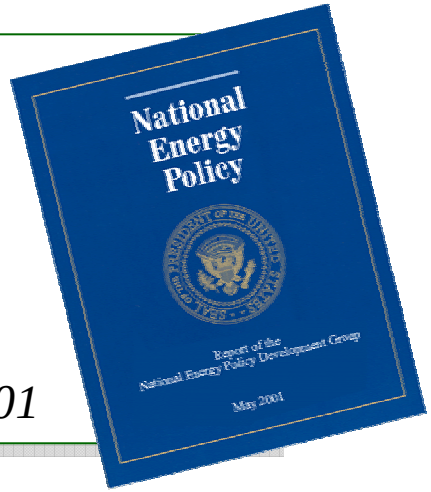
- All major economic downturns were preceded by energy supply disruptions and resultant price shocks
- Energy shortages have a significant impact on economic stability and growth



The National Energy Policy and Nuclear Power

"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

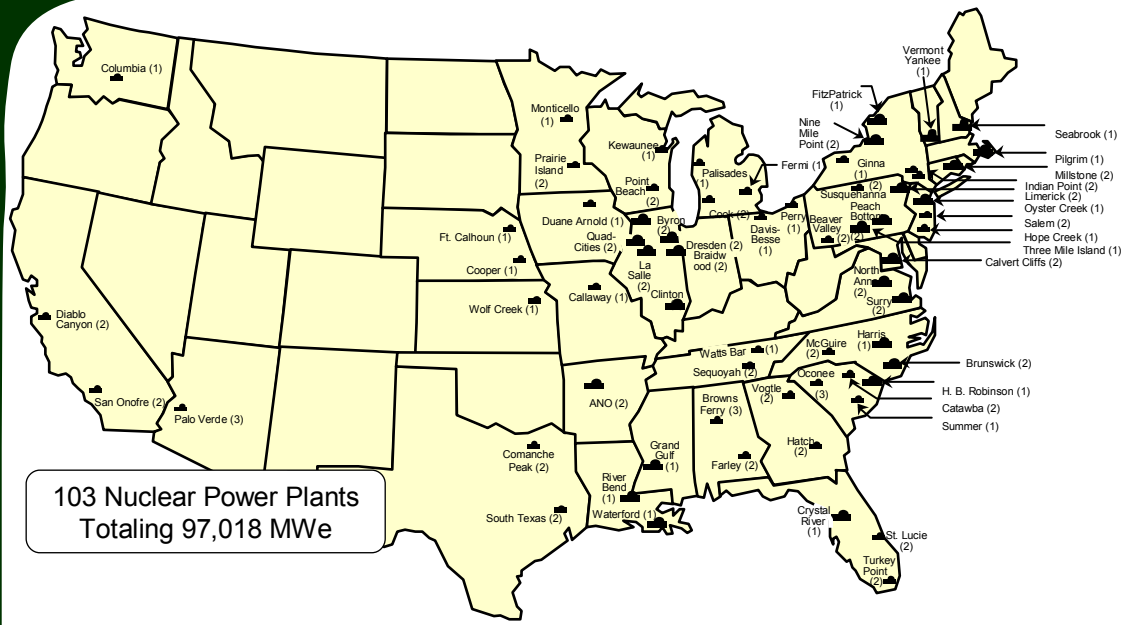


Calvert Cliffs Nuclear Power Plant

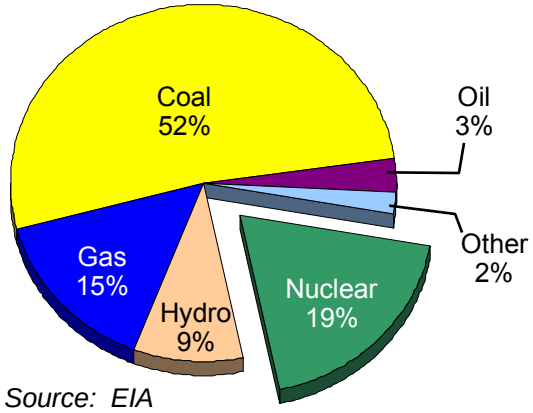
Recommendations:

- 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

Why Nuclear Energy? … it is already a success

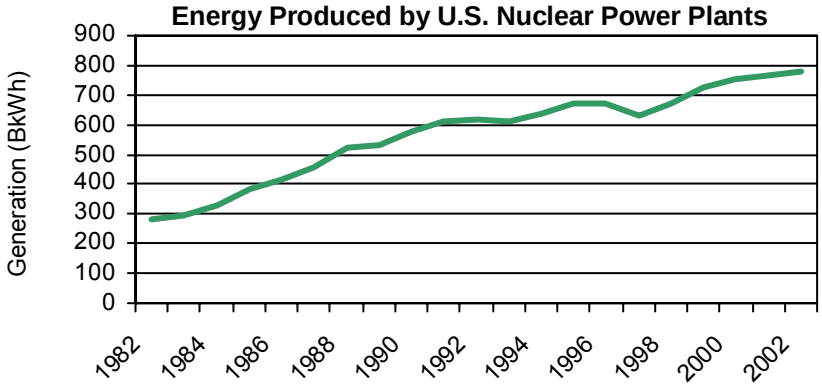


103 Nuclear Power Plants
Totaling 97,018 MWe

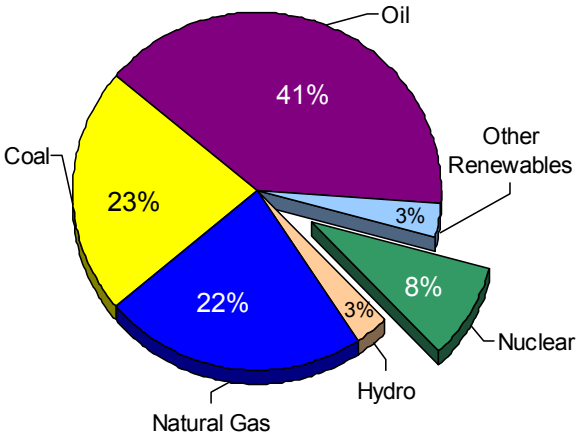


Source: EIA

Electricity Production



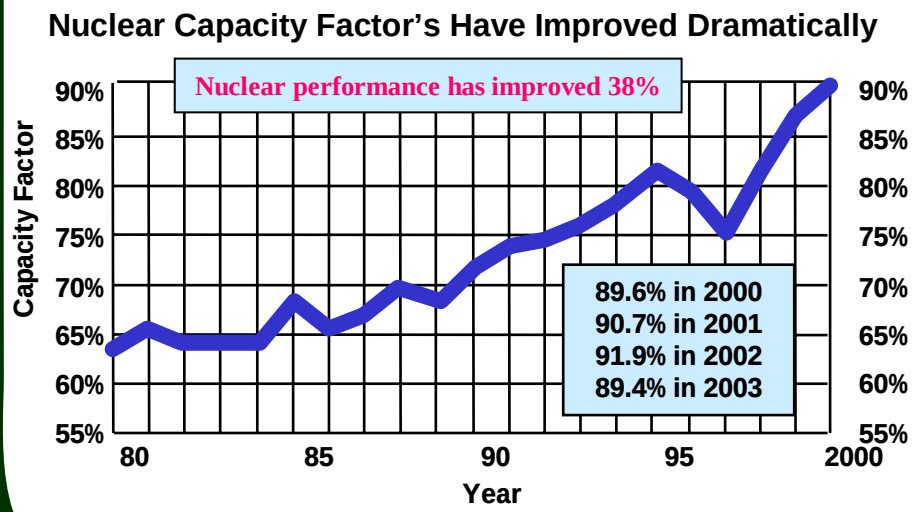
Sources: (1982 - 2001) EIA; (2002) IAEA

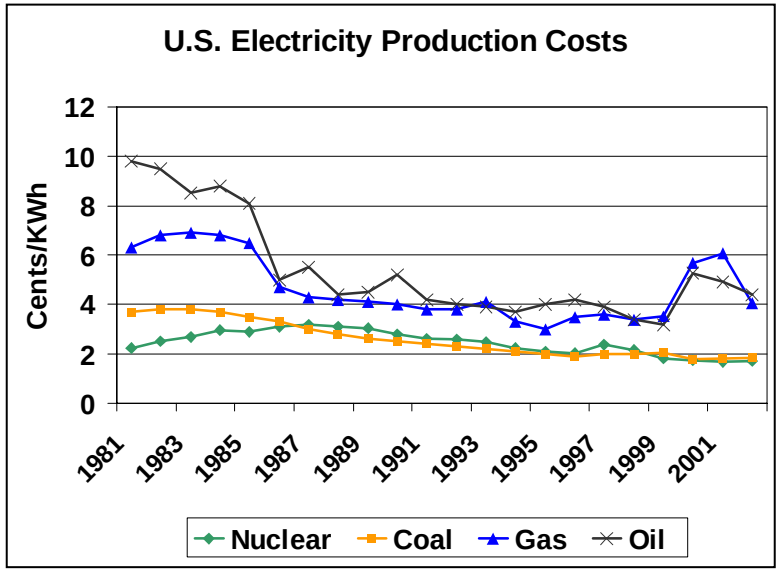


Energy Production

Why Nuclear Energy? … *plant safety, performance, and economics have steadily improved over the past 20 years*

- **Excellent plant management and operational experience**
- **Well-developed safety culture and effective regulation**
- **Low production costs compared to fossil fuels**
- **Provides greatest share of clean energy sources (over 70%) and avoids 175 MMTC each year**





Source: Utility Data Institute

Why Nuclear Energy? *. . . it can provide important benefits to the Nation*

- **Over the next decade, nuclear power is needed to:**
  - Reduce U.S. reliance on price-volatile fuels such as natural gas for electricity production
  - Enhance U.S. energy independence
  - Hedge against potential environmental regulation of fossil fuels

- **As we approach mid-century, nuclear power can:**
  - Become a major source of clean water
  - Produce large quantities of cost-effective hydrogen for transportation
  - Provide inexpensive electricity for future economic growth

But What About the Future?

- No successful nuclear power plant project has been launched since 1973
- Low prices of available fossil fuels (especially natural gas) and near-term overcapacity dampen industry interest in new, baseload plant investment
- The high capital cost and long construction times for nuclear plants seem ill-suited to today's competitive electricity market

We Will Need More Energy
But Where Will It Come From?

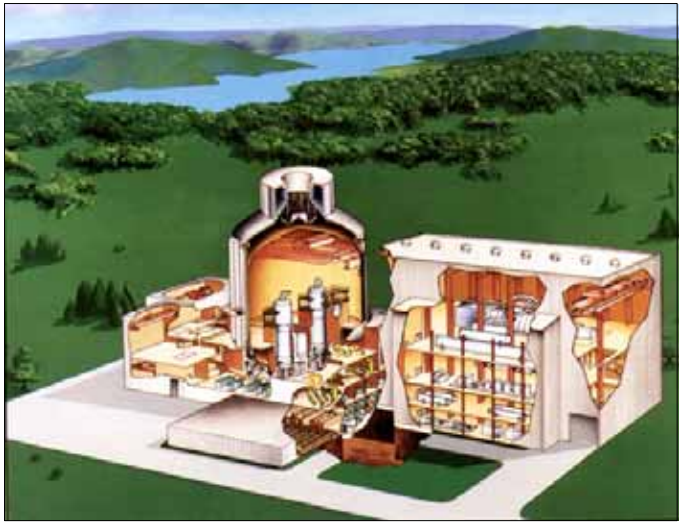
- **Oil:**
  - U.S. imports 51% of its oil supply
  - Vulnerable to supply disruptions and price fluctuations
- **Natural Gas:**
  - Today's fuel of choice
  - Future price stability?
- **Coal:**
  - Plentiful but polluting
- **Renewables:**
  - Capacity to meet demand?
  - Still expensive
- **Nuclear:**
  - Proven technology
  - Issues remain

Energy Source	% of U.S. Electricity Supply	% of U.S. Energy Supply	% Imported
Oil	3	39	51
Natural Gas	15	23	16
Coal	51	22	0
Nuclear	20	8	0
Hydroelectric	8	4	0
Biomass	1	3	0
Other Renewables	1	1	0

Source: Energy Information Administration

Nuclear Power
The Indispensable Option

- **Reliable, domestic base-load energy**
- **No carbon emissions**
- **Sustainable, long-term energy supply**
- **Supports use of advanced energy infrastructures to**
  - Increase the efficient use of energy
  - Reduce overall environmental impacts
  - Deal with transportation fuel needs through production of hydrogen



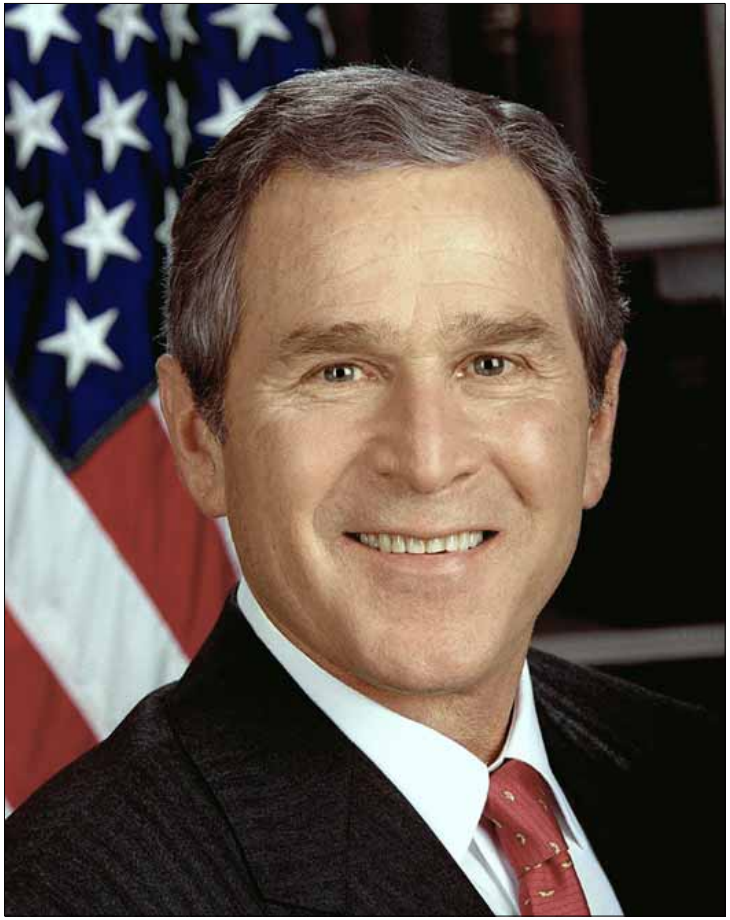
It Began With *Atoms for Peace*

Eisenhower Envisioned Atoms for Peace to:

- **Harness nuclear technology to benefit mankind**
- **Pave the way for commercialization of nuclear power**
- **Assist other nations in the peaceful development of nuclear technology**

"Peaceful power from atomic energy is no dream of the future. That capability, already proved, is here now - today."
President Eisenhower, "Atoms for Peace," December 8, 1953

And We Are Now Embarking on *Atoms for Prosperity*



- ***Yucca Mountain*** **designated the U.S. spent fuel repository**
- ***Nuclear Power 2010*** **initiated to pave the way toward new nuclear plants**
- ***Generation IV*** **program established with international community**
- ***National Hydrogen Fuel Initiative*** **set a far-sighted vision toward an emissions-free future**

"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

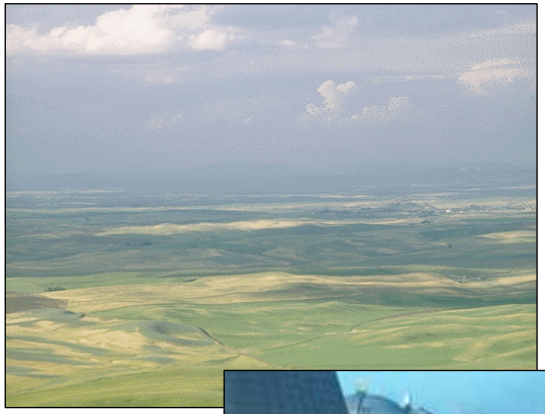
How to Change the World
Next Steps Toward A New Nuclear Era

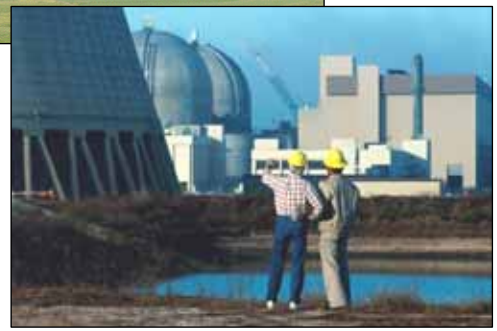
- **The U.S. must break through the "next plant barrier"**
- **We must develop a new generation of nuclear energy to serve the energy and environment requirements of the future**
- **We must deal with lingering issues of waste, proliferation, and safety**
- **We must strengthen our educational infrastructure to assure that a new generation of nuclear technologists is available to support future requirements**

Nuclear Power 2010

Next Major Step -- New Plant Licensing Demonstration Projects

- **Solicitation for power company plans leading to a license to build a new nuclear power plant**
  - Construction and Operating License
  - Advanced Reactor Design Completion
  - Project Cost and Financial Analysis
  - Siting Analysis and Permits





- **Three utility-led consortia have responded**
  - Dominion Energy with Atomic Energy of Canada Ltd., Bechtel and Hitachi
  - NuStart Energy LLC--nine nuclear utilities led by Exelon with General Electric and Westinghouse
  - Tennessee Valley Authority, General Electric, Toshiba, Global Nuclear Fuels-America, and the United States Enrichment Corporation

The Longer Term
Nuclear Energy Continues to Evolve

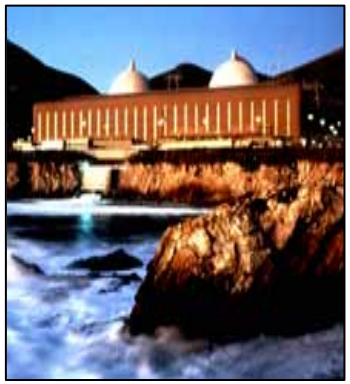
Generation I

Early Prototype Reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors



- LWR-PWR, BWR
- CANDU
- VVER/RBMK

Generation III

Advanced LWRs

- ABWR
- System 80+
- AP600
- EPR

Generation III+

Generation III Evolutionary Designs Offering Improved Economics

- AP1000
- ACR700
- IRIS

GEN IV Nuclear Energy Systems

- Highly Economical
- Enhanced Safety
- Minimize Wastes
- Proliferation Resistant

Gen I	Gen II	Gen III	Gen III+	Gen IV

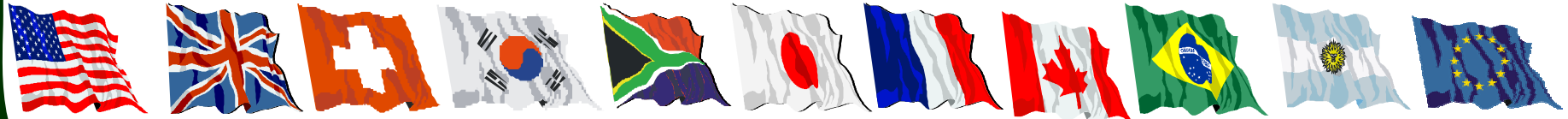
1950 1960 1970 1980 1990 2000 2010 2020 2030

Generation IV

International Pursuit Of A New Generation of Nuclear Energy

- **This international collaboration began in January 2000**
- **Its purpose: to bring next-generation nuclear energy system technology to a state of maturity allowing for commercial deployment**
- **Generation IV reactors will offer improvements in:**
  - Reactor safety and reliability
  - Proliferation resistance and physical protection
  - Economic competitiveness
  - Sustainability

- **The effort is led by the Generation IV International Forum**

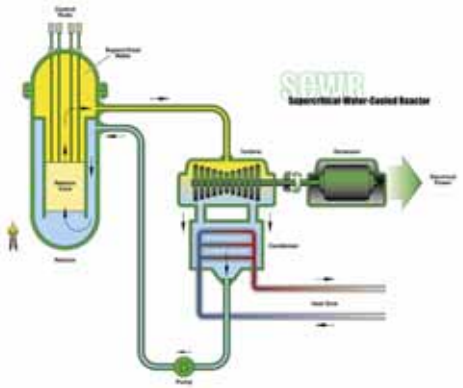


U.S.A. | United Kingdom | Switzerland | South Korea | South Africa | Japan | France | Canada | Brazil | Argentina | European Union

A Long-Term Strategy for Nuclear Energy
Generation IV Nuclear Energy Systems

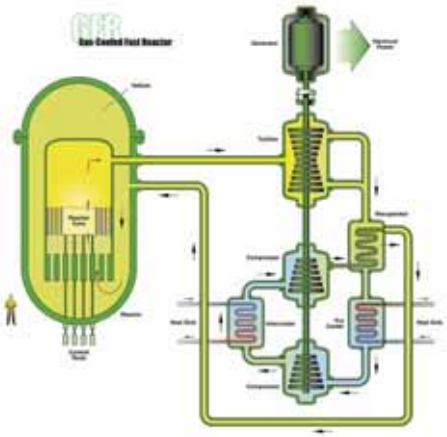
Generation IV Thermal Reactors -- Gen IV "A"

- Thermal neutron systems
- Advanced, high burnup fuels
- High efficiency, advanced energy products
- Available by 2020



Generation IV Fast Reactors -- Gen IV "B"

- Fast neutron systems
- Proliferation-resistant closed fuel cycles
- Minimize long-term stewardship burden
- Available by 2030 to 2040

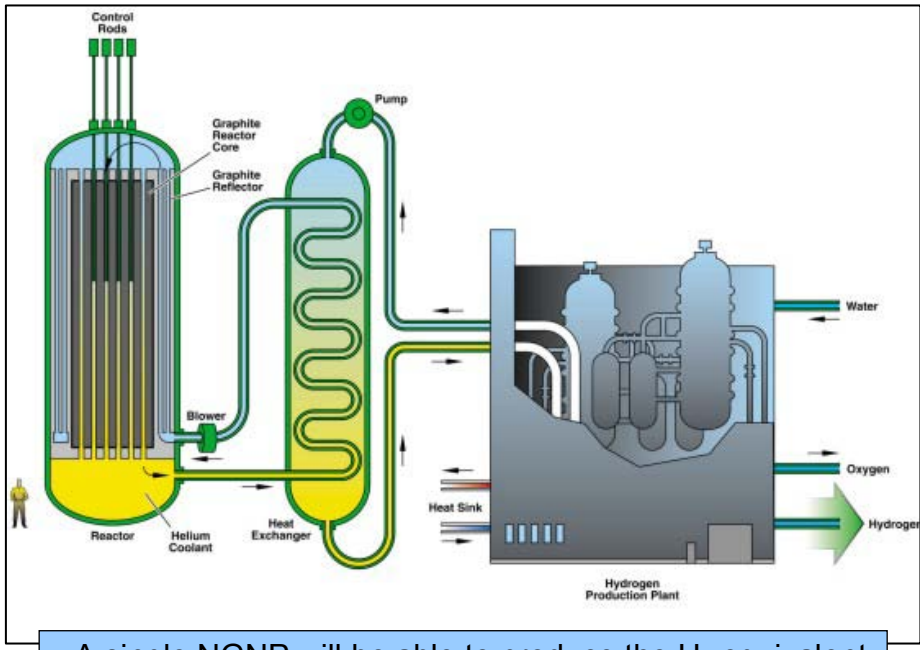


The U.S. Generation IV Program

Highest Priority: The Next Generation Nuclear Plant (NGNP)

What Does the NGNP Represent?

- **A very promising future option for economic, commercial-scale generation of hydrogen**
- **A better, safer, more economic nuclear energy plant**
- **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?

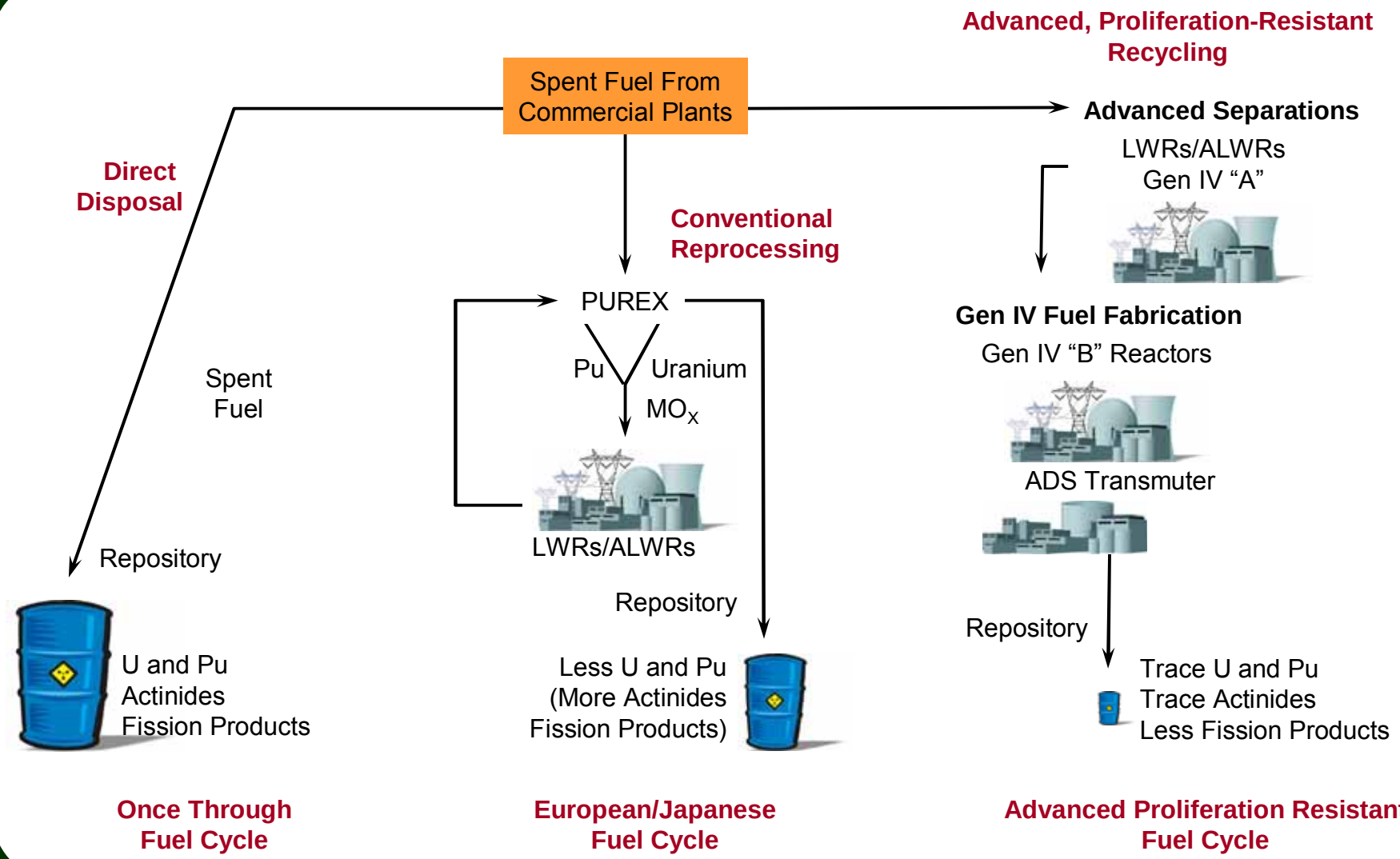
- **Early investment in key materials, fuels, and H_2 production technology**
- **Aggressive, well planned collaboration and cost-sharing with international partners (especially France, Japan and Korea) and the private sector (electric utilities, nuclear vendors)**

Hydrogen
Nuclear Power for Transportation

- **President Bush has announced the *National Hydrogen Fuel Initiative***
- **Advanced nuclear technology could provide the primary energy to power a "hydrogen economy"**
- **A single NGNP could produce the H_2 equivalent of 200,000 gallons of gasoline each day at a cost of less than $2.00/gallon of gasoline**

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

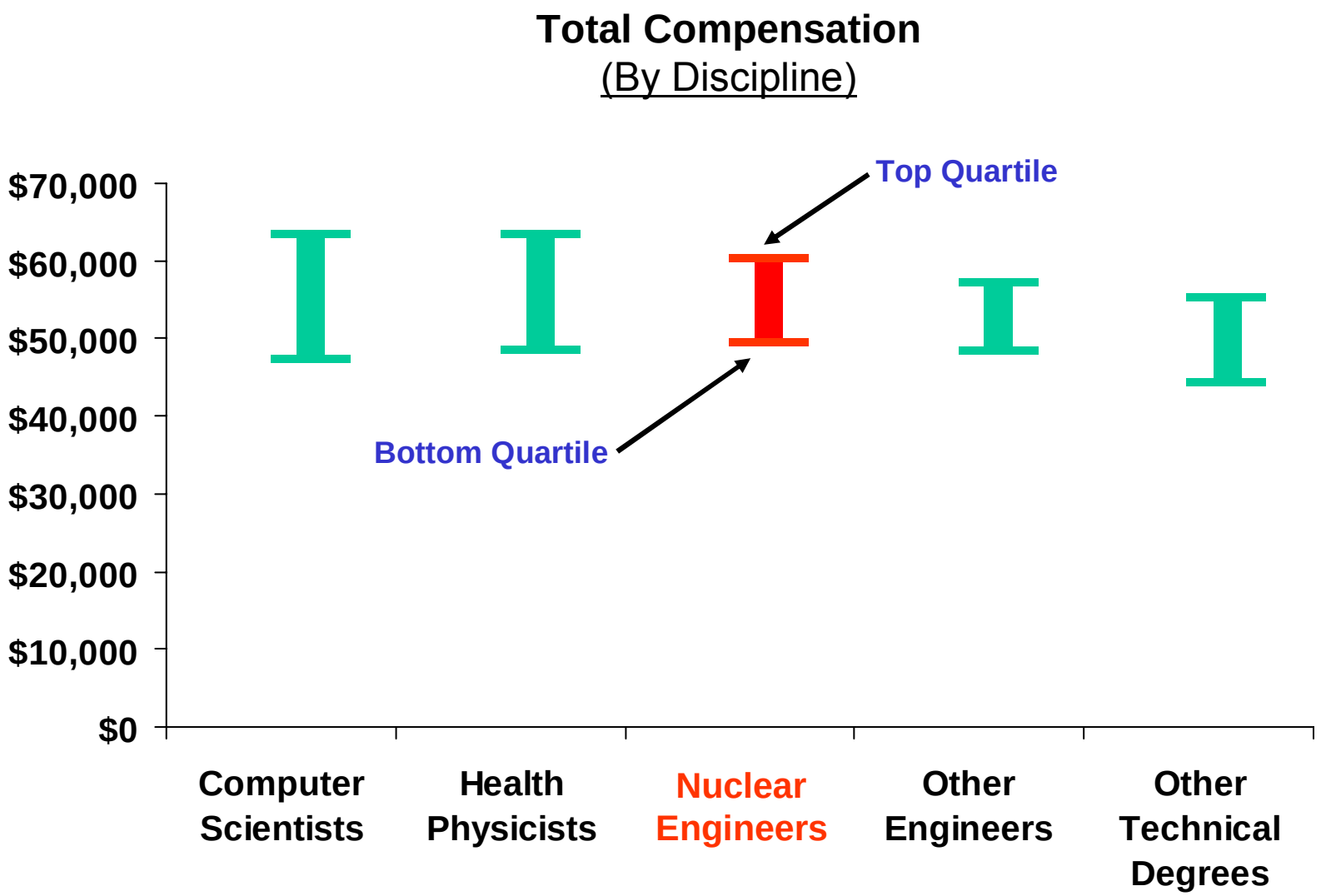
Advanced Fuel Cycle Initiative
Reducing the Waste Burden



Nuclear Energy Faces Significant Human Resource Issues

- **Nuclear Workforce is aging in industry, Government, National labs and universities**
- **Recent domestic and international studies have confirmed: *the human resource crisis is here and will get worse in coming years***
- **This human resource need creates new opportunities for today's generation of students - high paying technology jobs**

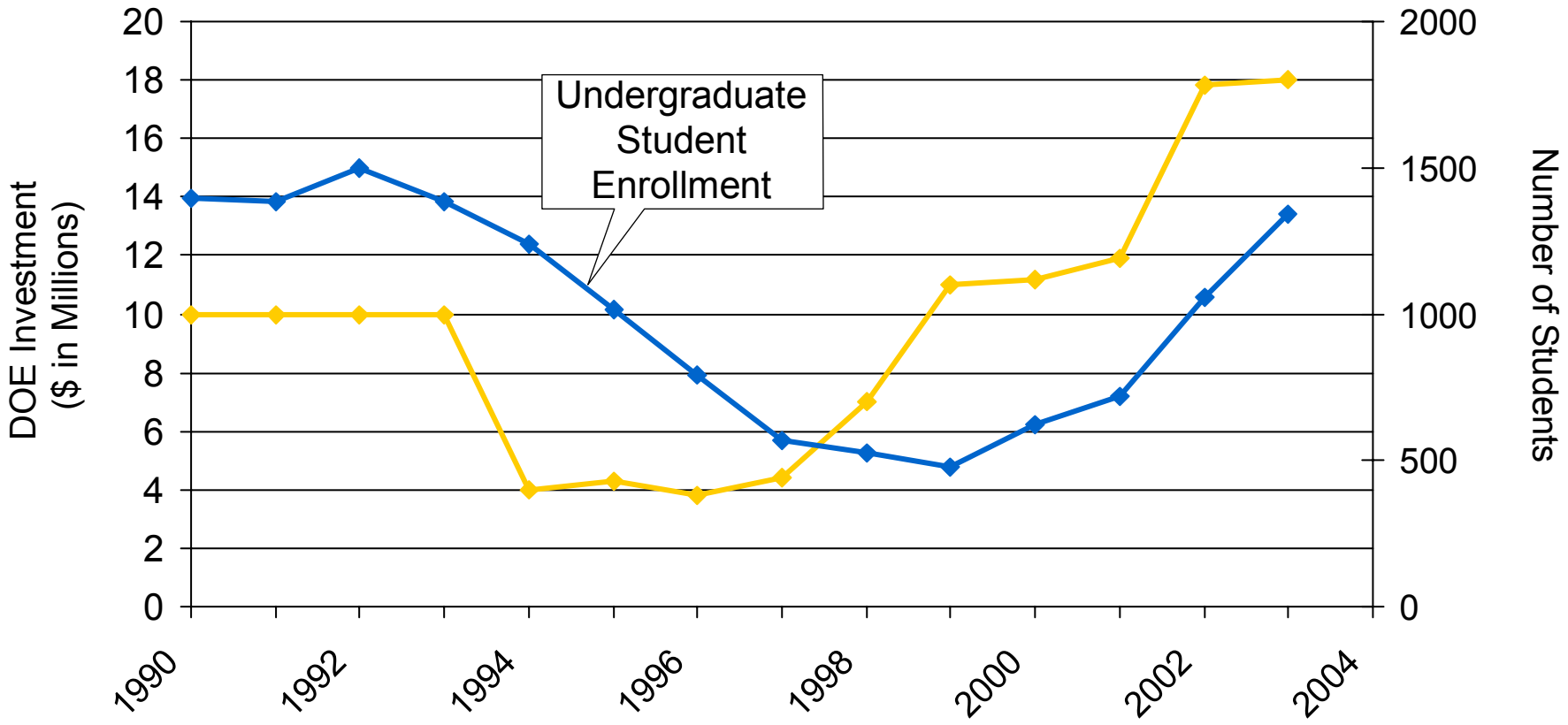
Nuclear Engineers: High Demand = High Compensation



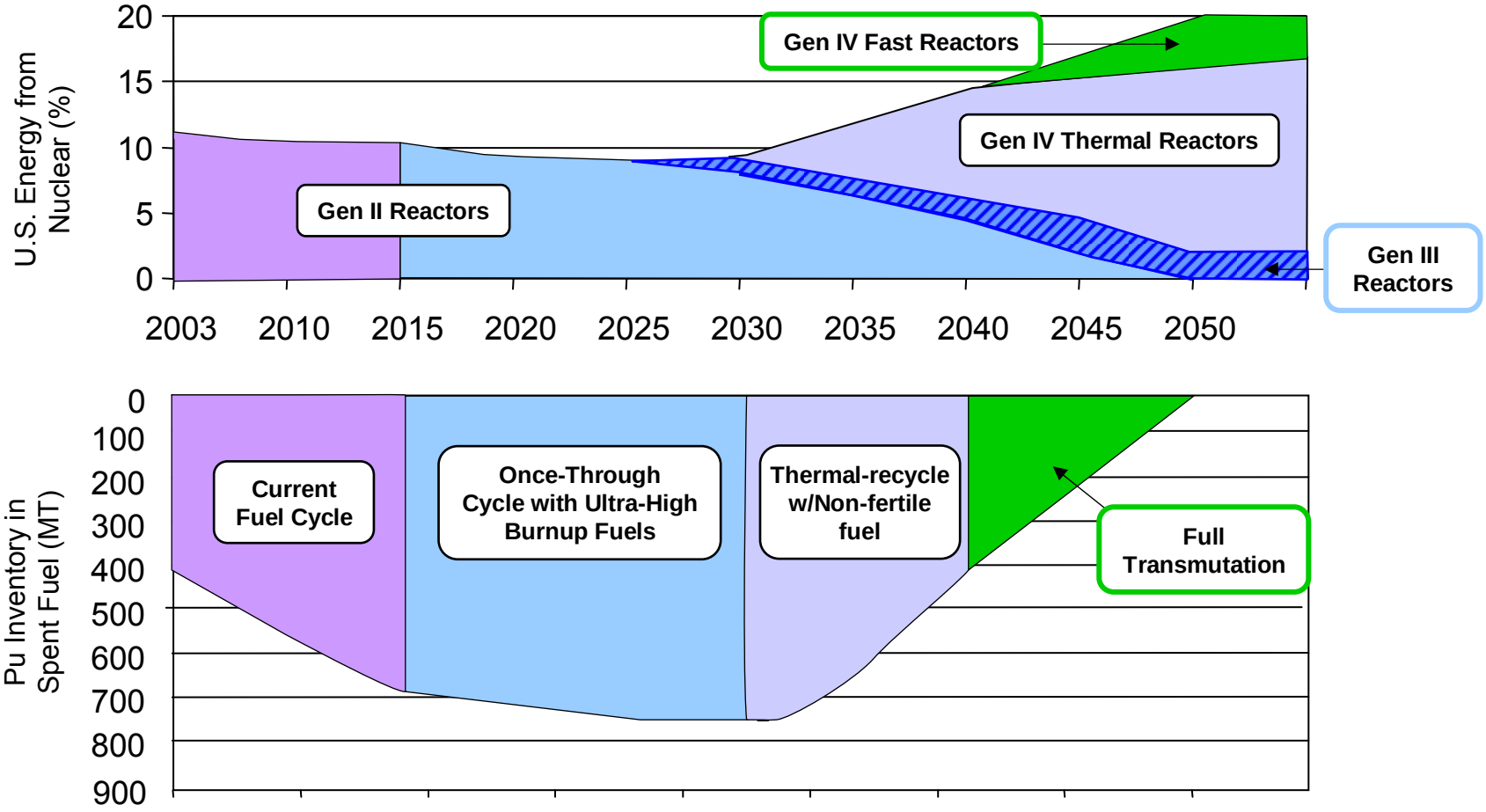
University Initiatives: Rebuilding the Infrastructure

- **For the past seven years, DOE has invested heavily in re-establishing a nuclear infrastructure supporting U.S. universities and their nuclear engineering programs**
- **DOE is investing over $18 million/year to ensure that the nuclear education infrastructure is strengthened**
  - Providing fellowships and scholarships
  - Providing nuclear research funds and other grants
  - Partnering with the private sector, which matches DOE funding for university nuclear engineering support
  - Linking universities, National labs, utilities, and the private sector in partnerships to expand cooperation and leverage resources
  - Refurbishing university research reactors
- **We will invest more in coming years**

Trends In Enrollments



A Long-Term Strategy for Nuclear Energy
Maximum Plutonium Consumption Scenario



Conclusion

- **Current nuclear plants are a success in today's electricity market and will continue operating through mid-century**
- **New plants (Generation III) are being built in Europe and Asia, and U.S. utilities are actively considering these technologies for the U.S. market**
- **Next-generation technologies (Generation IV) are under development and may be available in the 2020s for:**
  - Cost-competitive electricity production
  - Commercial-scale production of hydrogen
  - Production of plentiful clean water from sea water

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