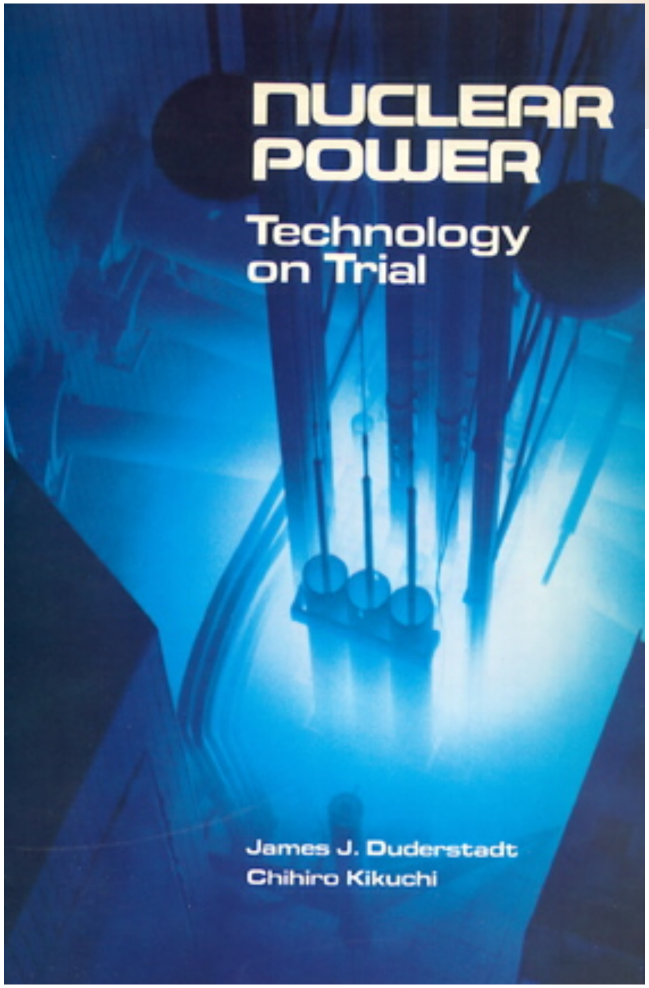
The Nuclear Energy Research Advisory Committee (NERAC) of the Department of Energy

and the Future of DOE’s Nuclear Energy Research Programs

The Nuclear Power Wars



Before TMI

- OPEC oil embargo (crude oil > $40/bbl)
- Great concern about future energy sources
- Projections: 1,000 nuclear plants in U.S. by 2000
- Major investment in nuclear power

The Turning Point: 1979

- Early Resistance (Nader, Cherry, Sinclair,…)
- Hollywood ("The China Syndrome")
- AEC --> ERDA –> DOE + NRC
- Three Mile Island II (March 28, 1979)

The Decline and Fall of Nuclear Power in the United States

- Public opinion: TMI --> no new plant orders after 1978
- Far harsher regulatory climate
- Licensing uncertainty and delays (and escalating costs)
- Next generation technologies were strangled
  - Fast breeder reactor (Clinch River)
  - Plutonium recycling (reprocessing)
- Little progress in radioactive waste disposal (NIMBY)
- Deregulation of electrical utility industry

Nuclear Energy R&D

- In 1970s and 1980s most R&D channeled into large projects such as LMBBR, IFR, and ALWR.
- By mid 1990s, Clinton administration had eliminated essentially all civilian nuclear power R&D by (declining from greater than $1 B/year to zero).
- Both the physical and human infrastructure necessary to sustain a U.S. nuclear power option declined quite seriously.

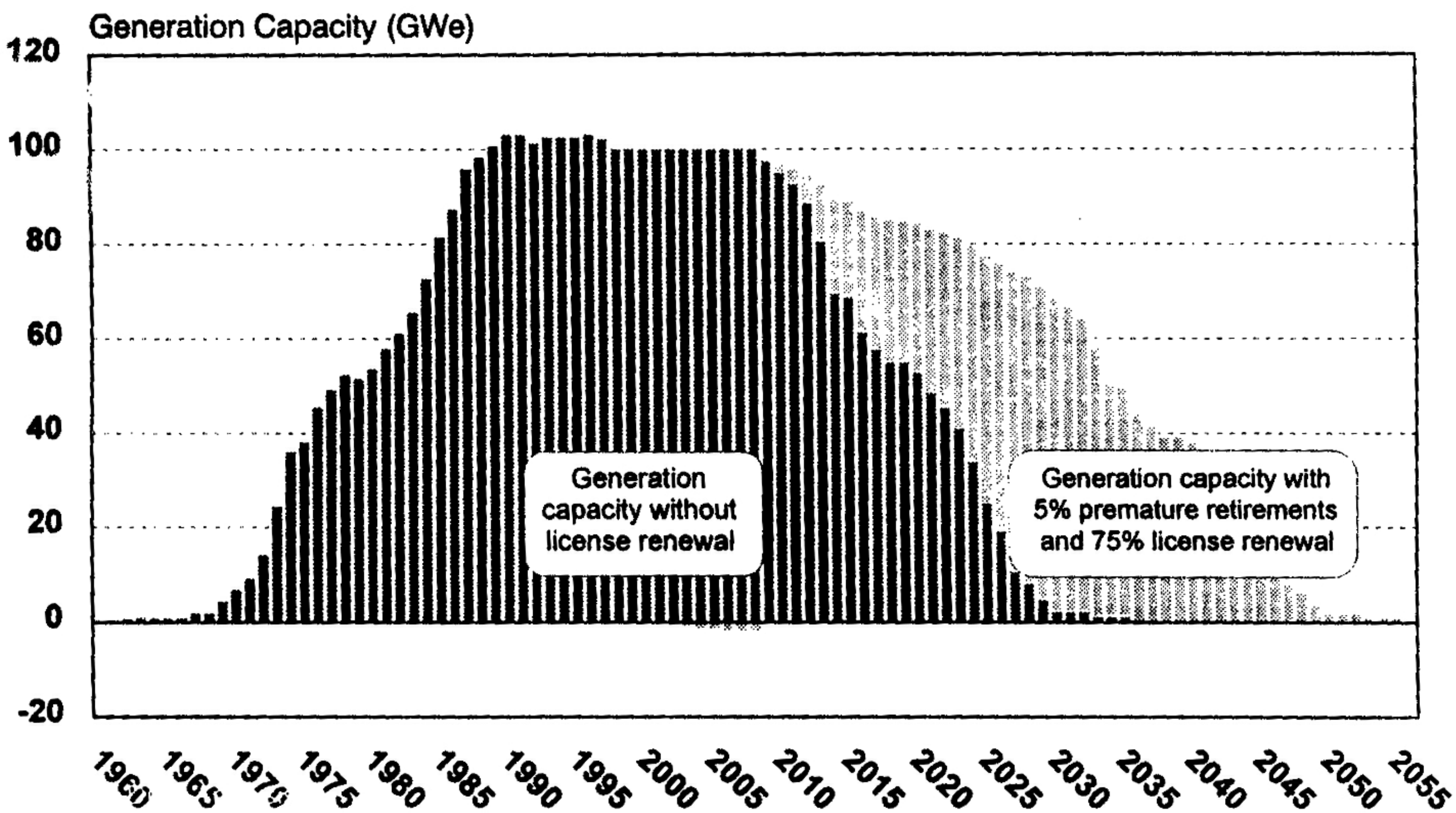
Current Situation

There are currently 104 commercial nuclear power plants in operation in the U.S. supplying 20% of our generated electricity.

U.S. nuclear plants are licensed by NRC for 40 years and will reach end of license in large numbers by 2010.

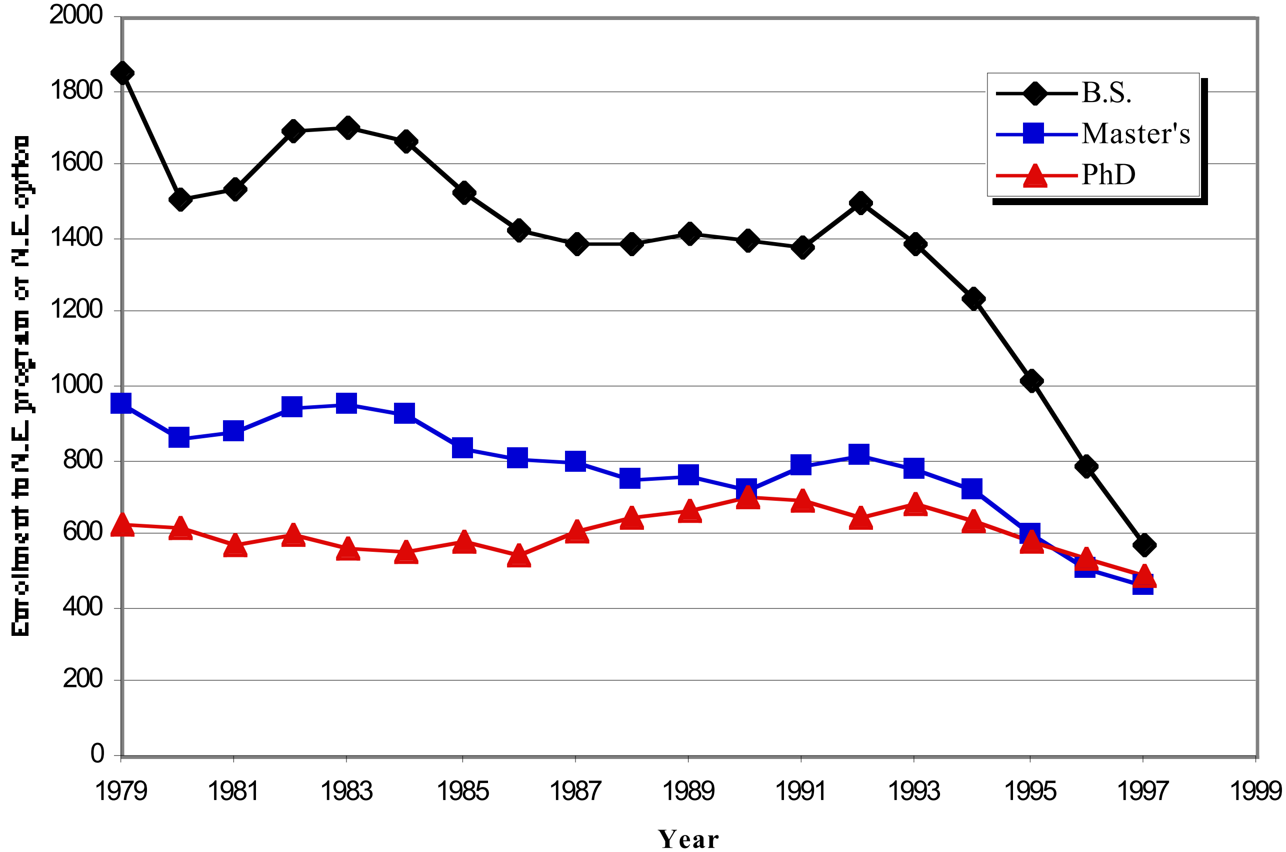
Some estimates are that U.S. nuclear generating capacity will drop to 40% of current levels by 2020 (5% of U.S. capacity).

U.S. Nuclear Power Generation



U.S. Nuclear Generation Capacity

Nuclear Engineering Enrollments in U.S. Universities



Future Challenges

U.S. will need 360,000 MWe of new generating capacity by 2020.

Environmental concerns may rule out major expansion of fossil fuels:

Clean Air Act (SO_2, NO_X, ozone, particulates)

Kyoto Protocol (CO_2)

Nuclear Security (warhead disposal, etc.)

PCAST Energy R&D Panel (1997)

"Fission's future expandability is in doubt in the United States and many other regions of the world because of concerns about high costs, reactor-accident risks, radioactive-waste management, and potential links to the spread of nuclear weapons. We believe that the potential benefits of an expanded contribution from fission in helping address the carbon dioxide challenge warrant the modest research initiative proposed here (NERI and NEPO), in order to find out whether and how improved technology could alleviate the concerns that cloud this energy option's future.

To write off fission now as some have suggested, instead of trying to fix it where it is impaired, would be imprudent in energy terms and would risk losing much U.S. influence over the safety and proliferation resistance of nuclear energy in other countries. Fission belongs in the R&D portfolio."

PCAST Recommendations on Nuclear Energy R&D

- A major extramural research program (investigator-initiated, peer reviewed, long range) (NERI)
- A major research program aimed at extending the life of operating plants (NEPO)
- A high level advisory body to DOE (NERAC)

NERAC

Nuclear Energy Research Advisory Committee

"Provide expert, independent advice on long-range plans, priorities, and strategies in nuclear energy research to the U.S. Department of Energy"

NERAC Membership

- John Ahearne, Duke
- Tom Cochran, NRDC
- Allen Croft, Oak Ridge NL
- Marvin Fertel, Nuclear Energy Institute
- Beverly Hartline, LANL
- Bill Kastenberg, UC-Berkeley
- Dale Klein, U Texas - Austin
- Bob Long, Nuclear Stewardship
- Warren Miller, Jr., LANL
- Richard Reba, U. Chicago
- Lynn Rempke, INEEL
- Paul Robinson, Sandia NL
- Robert Socolow, Princeton
- Allen Session, Queens College
- Daniel Sullivan, NIH
- Bruce Tarter, LLNL
- John Taylor, EPRI
- Charles Till, Argonne NL
- Neal Todreas, MIT
- Joseph Comfort, Arizona State
- Maureen Crandall, ICAF
- Jose Luis Cortez, New Mexico M&T
- Tom Boulette, Worcester Polytechnic
- Jim Duderstadt, Michigan, Chair

DOE Office of Nuclear Energy, Science, and Technology

- Address the obstacles to continued operation of existing nuclear power plants and maintain nuclear power as a viable option for the future
  - Nuclear Energy Research Initiative
  - Nuclear Energy Plant Optimization
- Develop DOE mission critical technologies
  - Advanced radioisotope power systems
  - Isotope Support
- Maintain vital nuclear research facilities and education infrastructure
  - Test reactor area
  - University reactor fuel assistance and support
  - Fast Flux Test Facility
- Reduce the life-cycle costs of environmental cleanup
  - Uranium program
  - Termination costs

DOE Nuclear Energy Research Programs

- Nuclear Energy Research Initiative (NERI)
- Nuclear Energy Plant Optimization (NEPO)
- University Nuclear Science and Reactor Support Program
- Nuclear Engineering Education Research (NEER)
- Radioisotope Research Program
- Nuclear Space Power Systems
- Accelerator Transmutation of Waste Program (ATW) (and AAA program)

NERAC Subcommittees

- Long Range Planning (Ahearne)
- Nuclear Science and Technology Infrastructure (D. Klein)
- Operating Nuclear Power Plant R&D (Taylor)
- Isotope Research and Production (Reba)
- Proliferation Resistant Nuclear Technologies (Taylor)
- Transmutation of Radioactive Waste (Richter)
- Blue Ribbon Committee on Nuclear Engineering (Corradini)
- Nuclear Space Propulsion (A. Klein)
- Nuclear Impact on Air Quality (Ahearne)

Early NERAC Activities

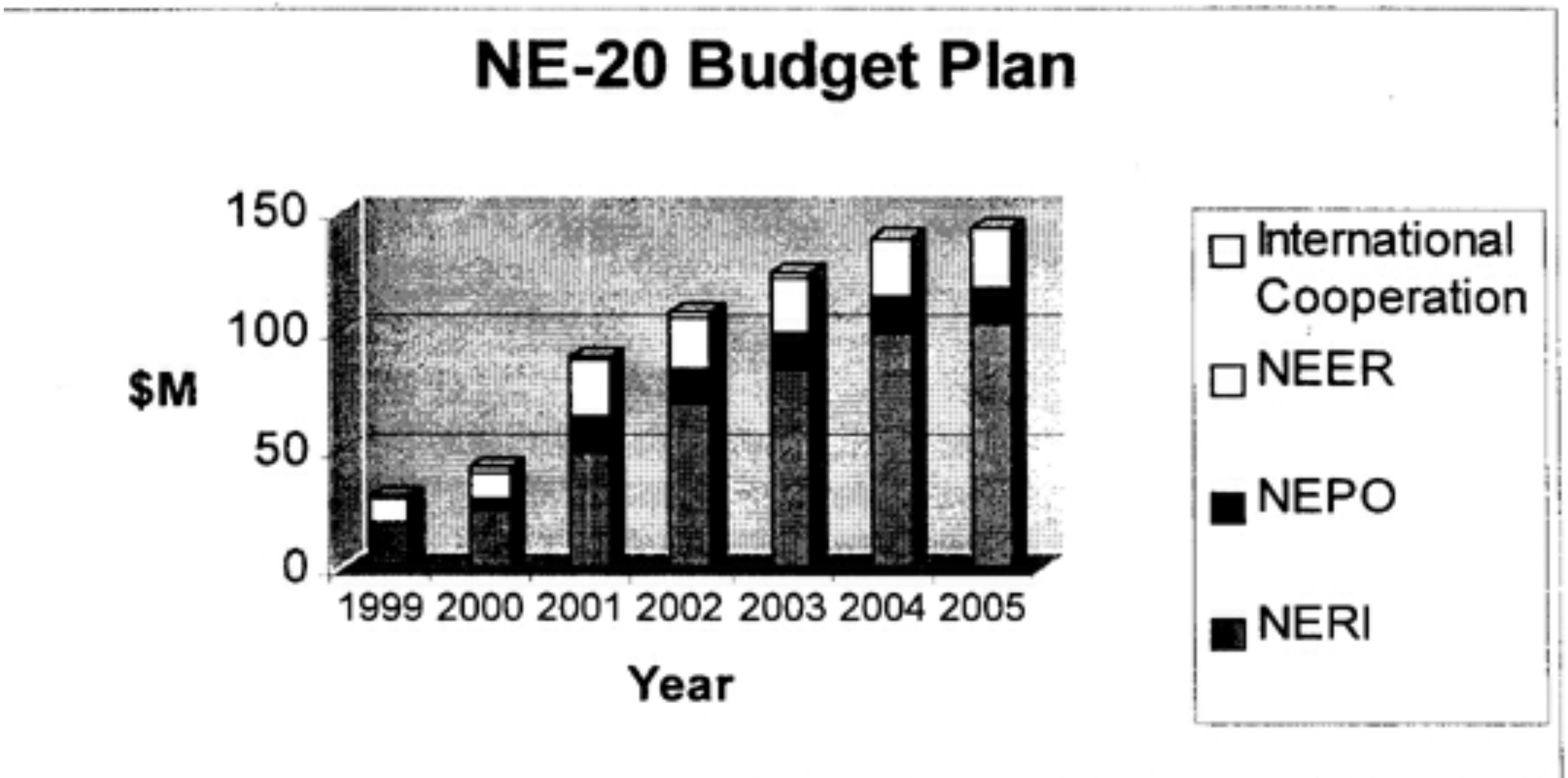
- Nuclear S&T Infrastructure Roadmap
- Specific Nuclear Facilities
  - **FFTF**
- Long Range R&D Plan for 21st Century
- Isotope Production
- Human Resource Issues

Fast Flux Test Facility

Long-Range R&D Plan

- Basic Science and Engineering Research
- Nuclear Power
  - Advanced Fuels
  - Instrumentation and Controls
  - Technology and Economics
- Isotopes and Radiation Sources
- Space Nuclear Systems

DOE NE Budget Plan



FY2005 NE R&D Budget

Science and Engineering	$60 M	
Advanced Fuels	$42 M	(includes $20 M for TREAT, $10 M for ATR
Instrumentation and Controls	$30 M	
Nuclear Power	$60 M	
Isotopes	$23 M	(does not include funding for a new facility)
Space Nuclear Systems	$25 M	(>$200 M/y for flight qualified systems)
Total	$240 M	

Human Resources

"Perhaps the most important role for DOE/NE in the nuclear energy area is to insure the educational system and facility infrastructure are in good health. It is important that the U.S. maintain a strong commitment to the education and training of nuclear scientists and engineers, to support a wide range of nuclear activities.

In support of these roles, one of DOE/NE's primary responsibilities is to assure the country has the supply of nuclear scientists and engineers that will be needed to provide worldwide leadership in scientific, nonproliferation, commercial, and other uses of nuclear science, technology, and materials. This leads to the need to support undergraduate and graduate students, faculty, and both university and DOE infrastructure as well as to fund long-term nuclear-related R&D that is in the national interest.

Nuclear engineering programs in the US are disappearing. Without concerted action by DOE, supported by OMB and the Congress, most of the existing nuclear engineering programs will soon evaporate or be absorbed and diffused in other engineer disciplines. Direct support to researchers is needed, not only support provided through projects run by industry or the national laboratories, valuable as these last have been and will continue to be."

NERAC Long Range R&D Plan (May, 2000)

Decline in Nuclear Engineering

Over the past two decades, there has been a decline in

Nuclear Engineering Programs: 80 --> 40

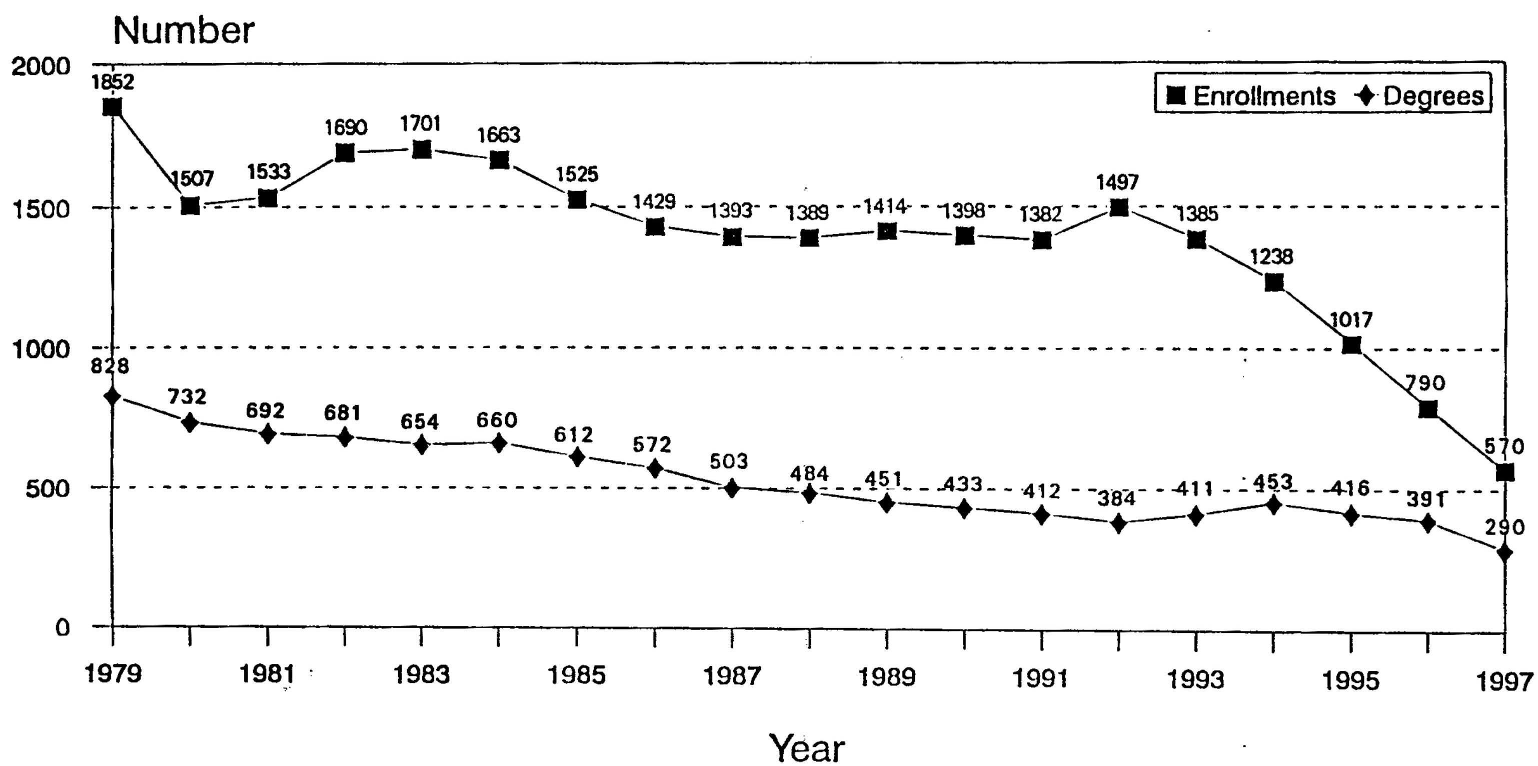
University Research Reactors: 76 --> 28

Undergraduate Enrollments: 1,852 --> 570

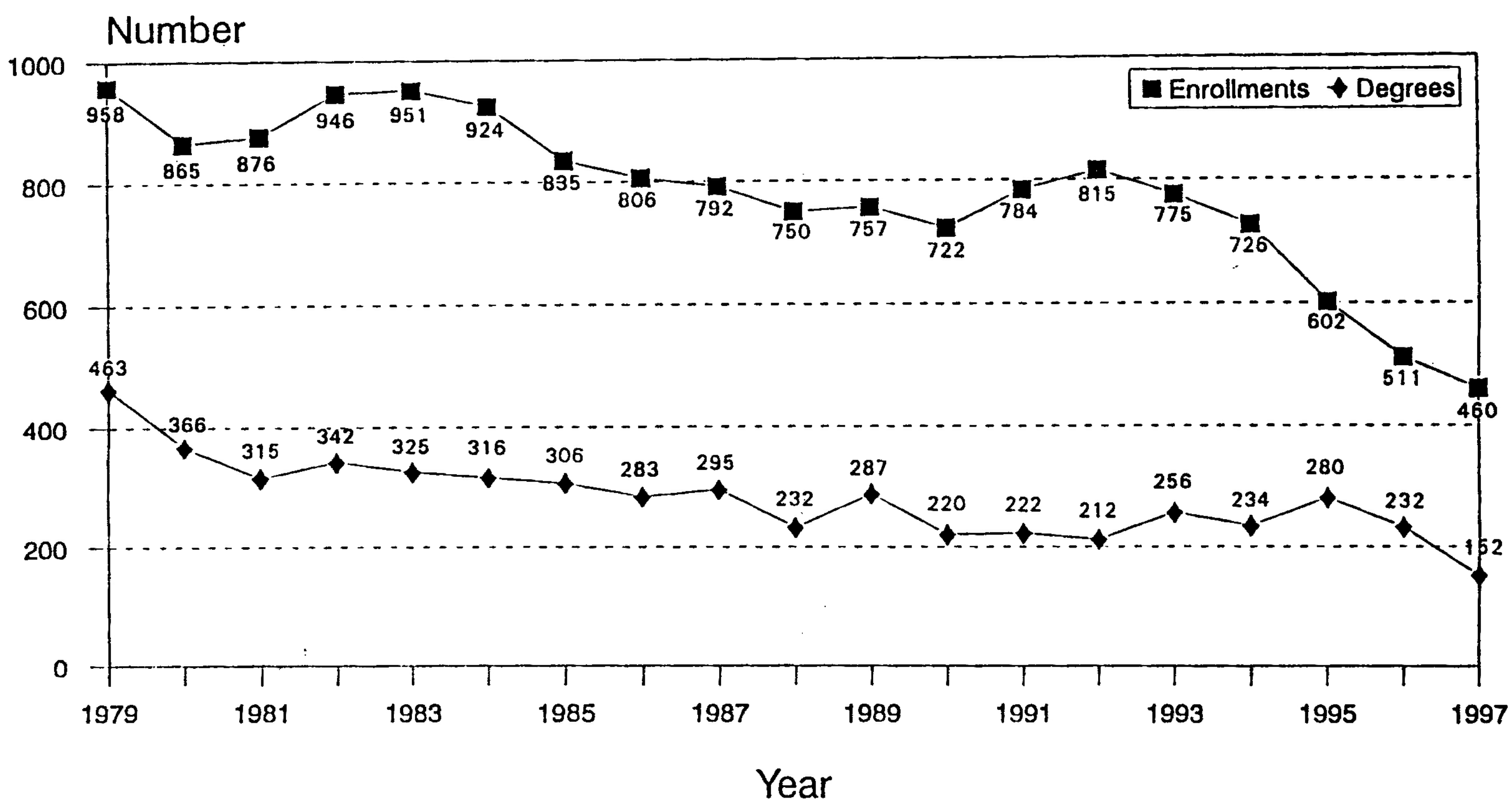
M.S. Enrollments: 958 --> 460

Ph.D. Enrollments: 630 --> 490

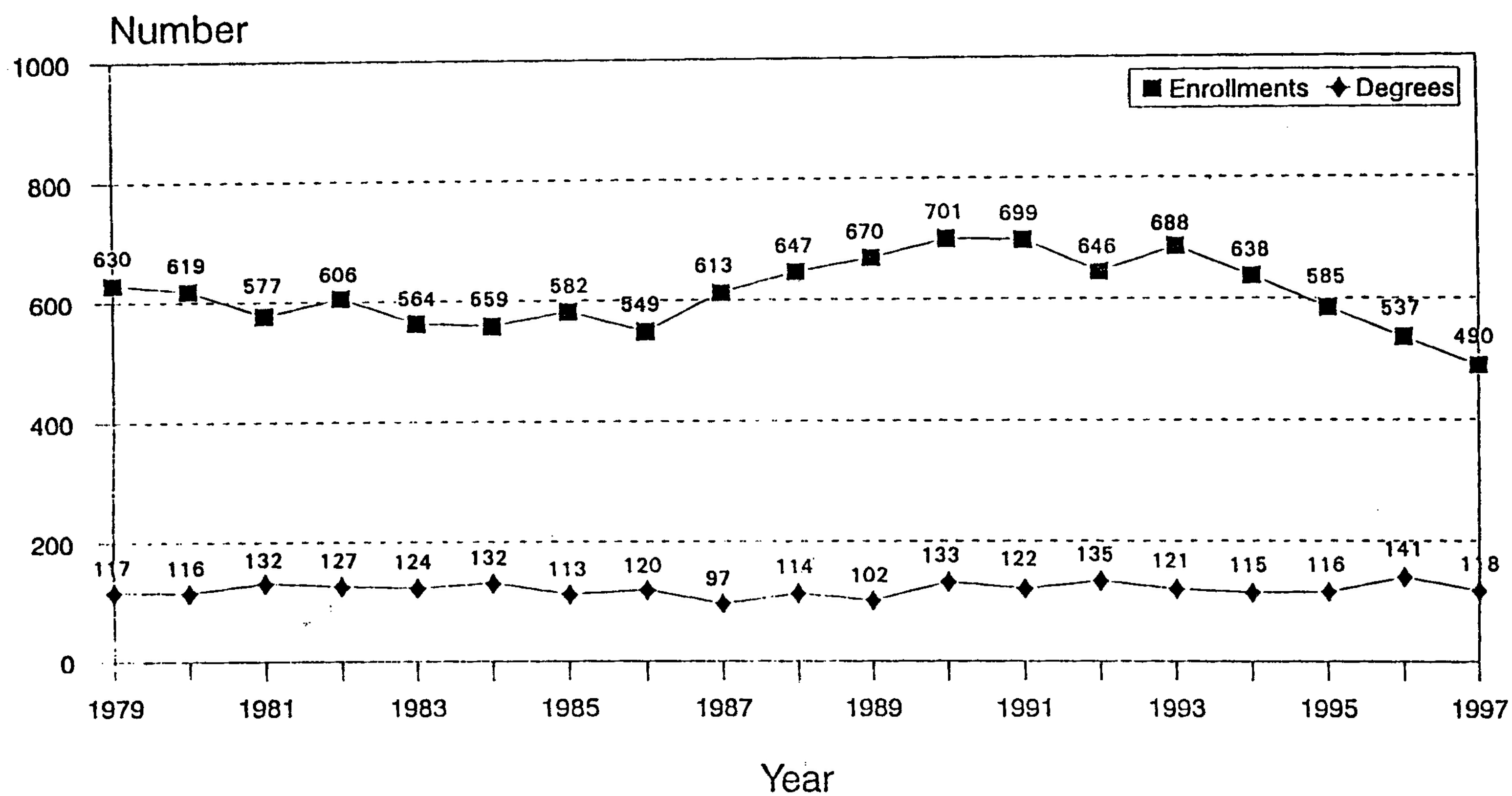
Nuclear Engineering Students (UG)



Nuclear Engineering Students (MS)



Nuclear Engineering Students (PhD)



The Future of Nuclear Engineering

NERAC Blue Ribbon Committee on Nuclear Engineering
(Chair, Mike Corradini, U. Wisconsin)

Charge:

- The intellectual nature of nuclear engineering
- The future of university reactors
- The relationship between university programs and the national laboratories
- The level and nature of federal funding necessary to sustain university nuclear engineering programs.

Intellectual Issues

The most important issue before the blue ribbon committee is the intellectual evolution and "focus" of nuclear engineering programs.

In the past nuclear engineering programs have been distinguished by the way they couple microscopic science with macroscopic engineering (e.g., quantum mechanics with systems design).

Today most programs that have survived have broadened considerably, including nuclear power, radiological science, materials science, medical physics, etc.

University Reactors

Of the 28 remaining campus-based nuclear reactors, how many are capable of significant research? How many can really make contributions in training?

Perhaps we should concentrate limited resources on only a small number of university reactors that would serve as national user facilities.

Perhaps we should make more use of national laboratory facilities through collaboratories for research; perhaps we should use simulators for training.

Relationships between university programs and the national laboratories

There is a long history of mistrust because of the competition between intramural research programs in the labs and the extramural funding of research on the campuses.

Universities also need to more effectively use the resources of the labs for education, e.g., lab facilities for training and lab staff as adjunct faculty.

Although the involvement of universities in programs led by the national labs and industry is important, DOE also needs to provide direct support to university programs.

Federal Funding

Clearly a dramatic increase in funding of university nuclear engineering programs is necessary if we are to sustain the human infrastructure necessary to meet national needs.

Clearly as well the bulk of this funding must come from DOE (since NSF and other mission agencies have long viewed the support of nuclear engineering as the responsibility of DOE).

Federal Funding Options

- Investigator-initiated, peer-reviewed research grants (NEER and NERI)
- Subsidy of university reactors (and other facilities)
- Undergraduate scholarships
- Graduate fellowships and traineeships
- Curriculum development grants

Proposed Budget for University Programs

Area	Current Level	Proposed Level
NEER Program	$5 M	$15 M to $20 M
Fellowships/Traineeships	$1.3 M	$5 M
Curriculum Development	0	$1 M
URR Operations	$4.2 M	$4.2 M
URR Upgrade and Research	0	$15 M to $20 M
Total	$12	$40 M to $50 M

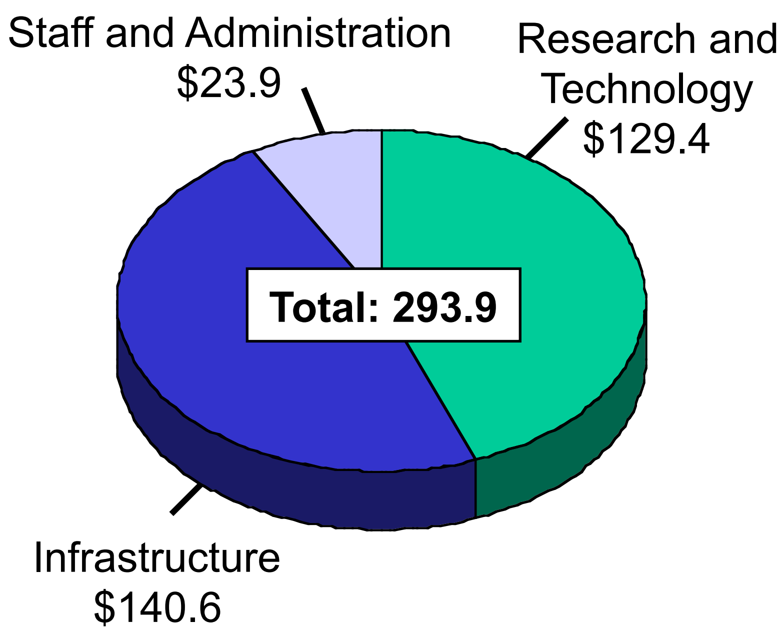
Some interesting comparisons

NSF ITR	$125 M/y
NSF Nanotechnology	$217 M/y
DOE Nuclear Physics	$370 M/y
DOE High Energy Physics	$715 M/y
DOE Nuclear Science and Engineering	$12 M/y

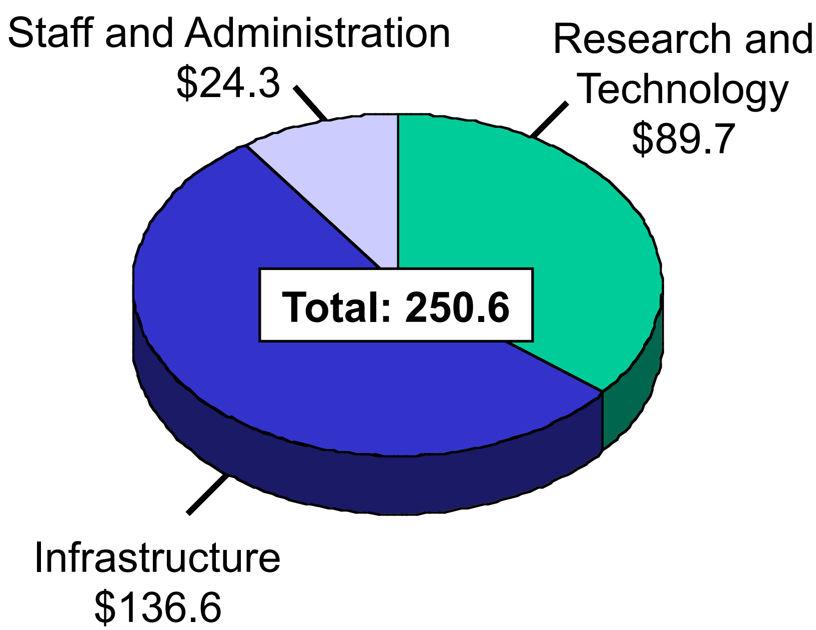
So where are we today?

Total Nuclear Energy Funding ($ in Millions)

FY 2002 Appropriation



FY 2003 Request

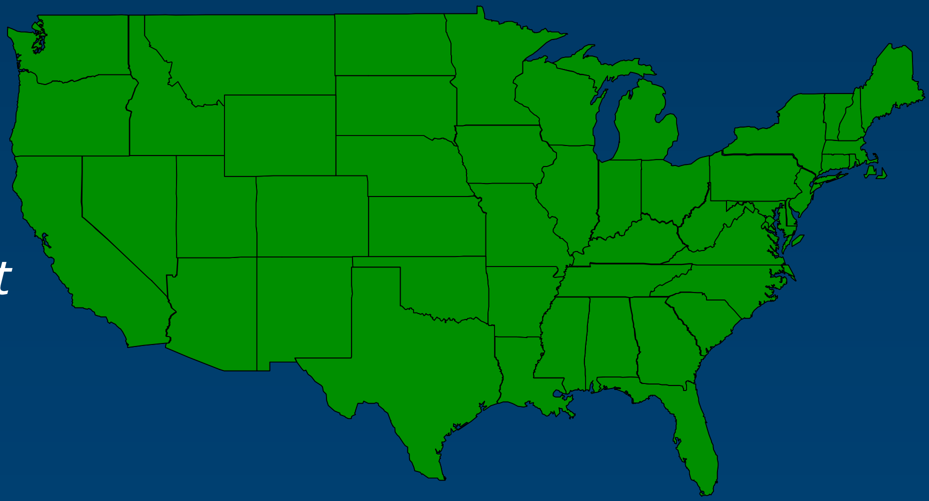


Continued Evolution of Nuclear Energy Budget
($ in Thousands)

	FY 2001 Adjusted Approp.	FY 2002 Current Approp.	FY 2003 Request
University Program	$ 11,974	$ 17,500	$ 17,500
NEPO	4,857	6,500	0
NERI	33,903	32,000	25,000
NET	7,483	12,000	46,500
ANMI	2,500	2,500	0
FFTF	38,439	36,439	36,100
Spent Fuel Pyroprocessing & Transmutation	68,698	77,250	18,221
Radiological Facilities Management	88,284	86,682	83,038
Program Direction	23,839	23,875	24,300
Adjustments	-2,872	-818	0
TOTAL	**$277,105**	**$293,928**	**$250,659**

Restructuring Status

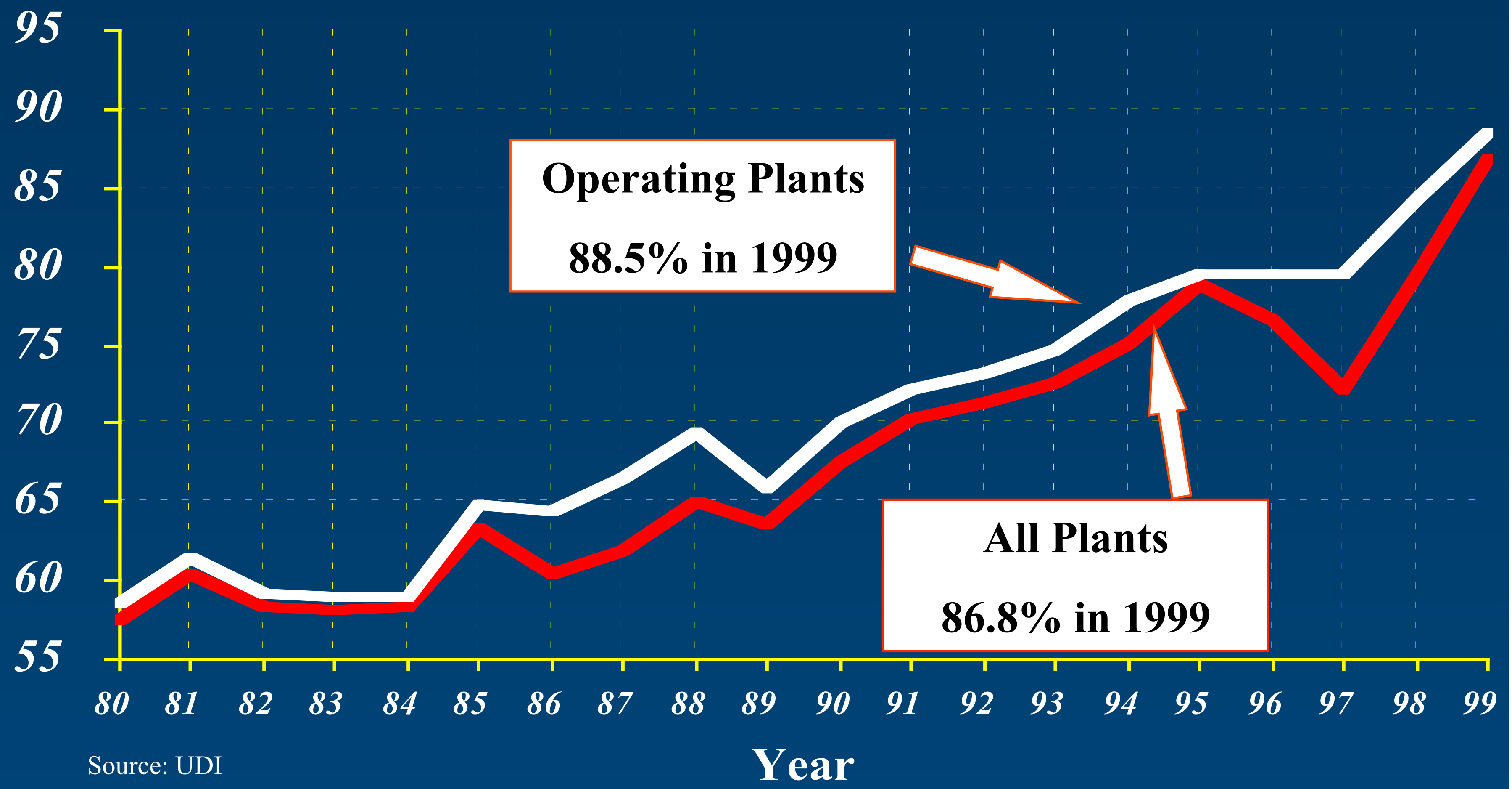
24 states have restructured their electric power industry



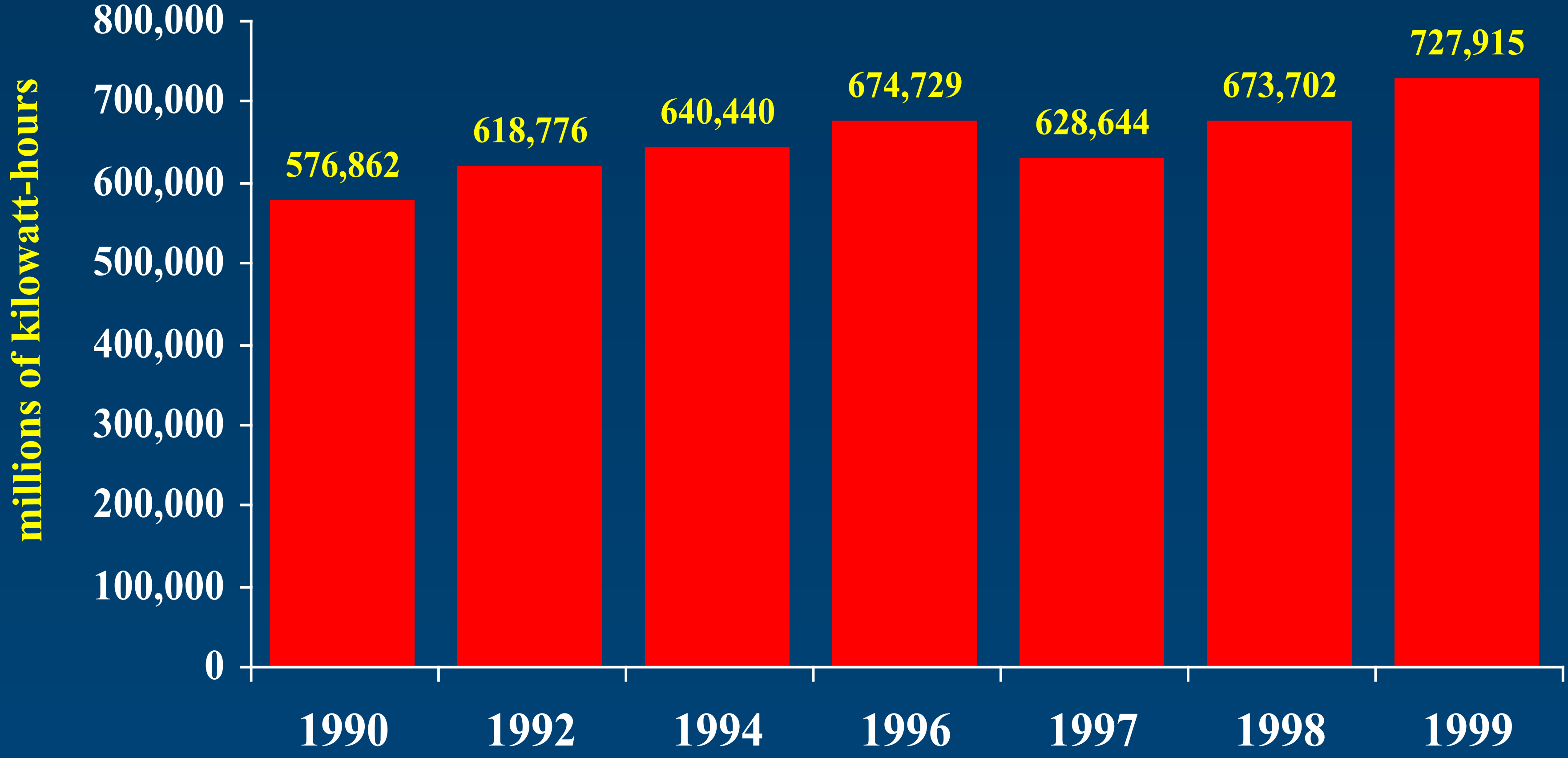
- Arizona
- Arkansas
- California
- Connecticut
- Delaware
- Illinois
- Maine
- Maryland
- Nevada
- New Hampshire
- New Jersey
- New Mexico
- New York
- Massachusetts
- Michigan
- Montana
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- Rhode Island
- Texas
- Vermont
- Virginia

Industry Is Achieving Record Levels of Performance

(in average industry capacity factors)



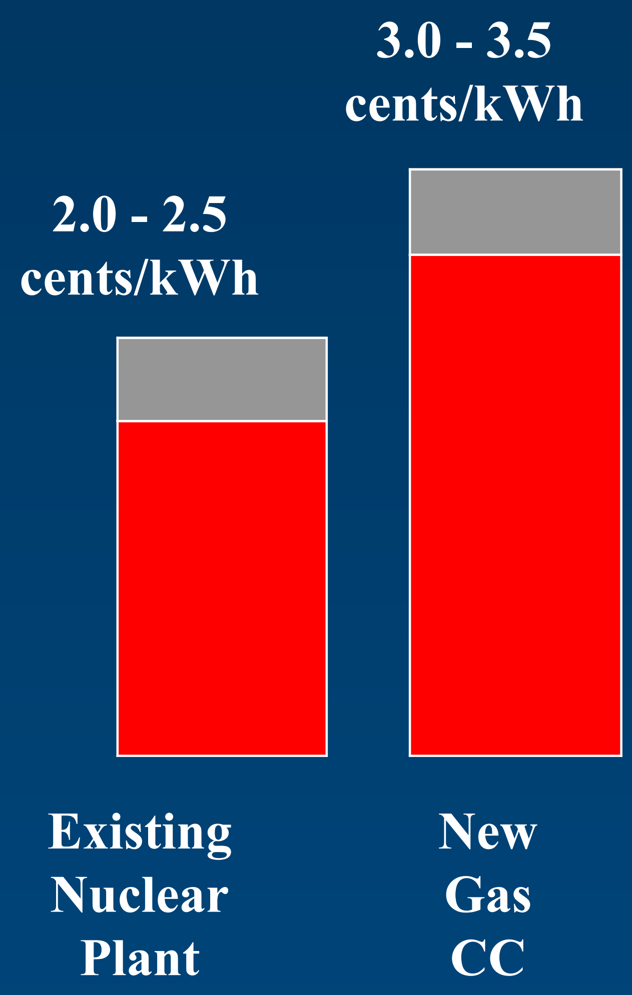
Dramatic Increase in Output in 1999



Source: EIA

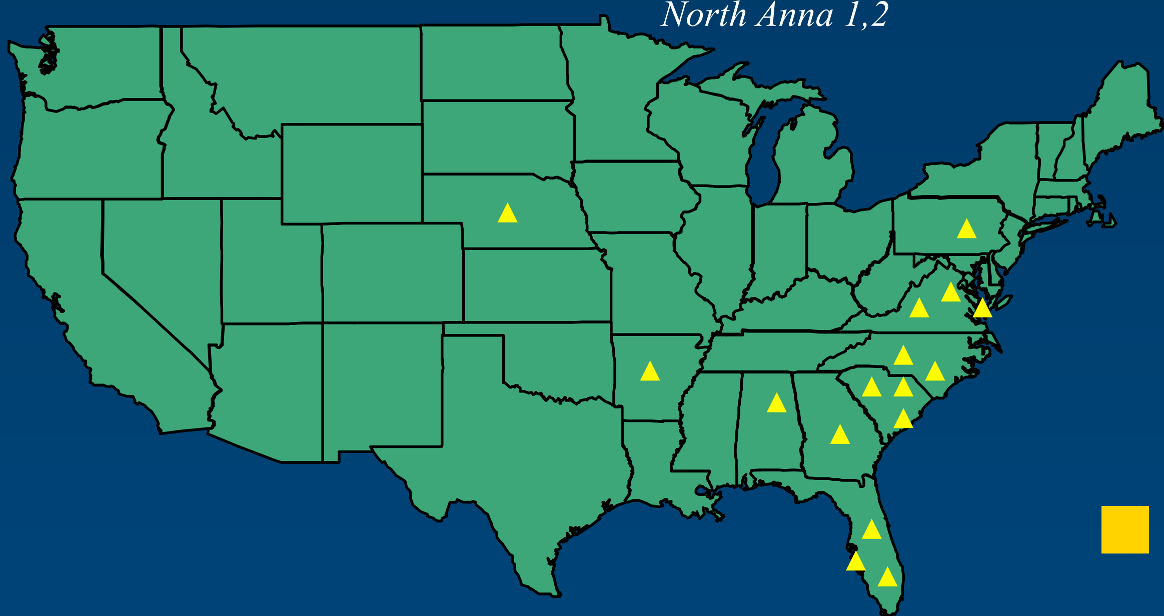
The Generating Company's Decision: Run the Nuclear Unit Or Build a New Gas Plant?

- "Going forward" cost for a well-run nuclear power plant: 2.0 - 2.5 cents/kWh
- "Going forward" cost for new gas-fired combined cycle plant: 3.0 - 3.5 cents/kWh
  - *$400-450 per kW*
  - *gas at $2 per million Btu*



Competitive Market: Major Stimulus For License Renewal

Already Filed	2000	2001	2002	2003
Calvert Cliffs 1,2	*Hatch 1,2*	*Catawba 1,2*	*St. Lucie 1,2*	*Robinson 2*
Oconee 1,2,3	*Turkey Point 3,4*	*McGuire 1,2*	*Summer*	*Farley 1,2*
Arkansas Nuclear One Unit 1		*Peach Bottom 2,3*	*Crystal River 3*	*Arkansas Nuclear One Unit 2*
		Surry 1,2	*Fort Calhoun*	*Cooper*
		North Anna 1,2		



Extension granted March 23, 2000

Consolidation:
Greater Efficiency, Lower Cost

- Occurring in all industry sectors:
  - *Nuclear plant ownership, operating responsibility*
  - *Infrastructure (equipment, services, fuel supply)*
- Natural business response to competitive pressures, state restructuring initiatives
- Result: Safer, stronger, leaner industry going forward

NEI

Nuclear Industry Consolidation

(May 2000)

Plants or ownership shares likely for sale:

Millstone 2,3
Seabrook
Indian Point 2
San Onofre 2,3
Diablo Canyon 1,2

Prairie Island 1,2
Kewaunee
Point Beach 1,2
Monticello
Duane Arnold
Nuclear Management Co.

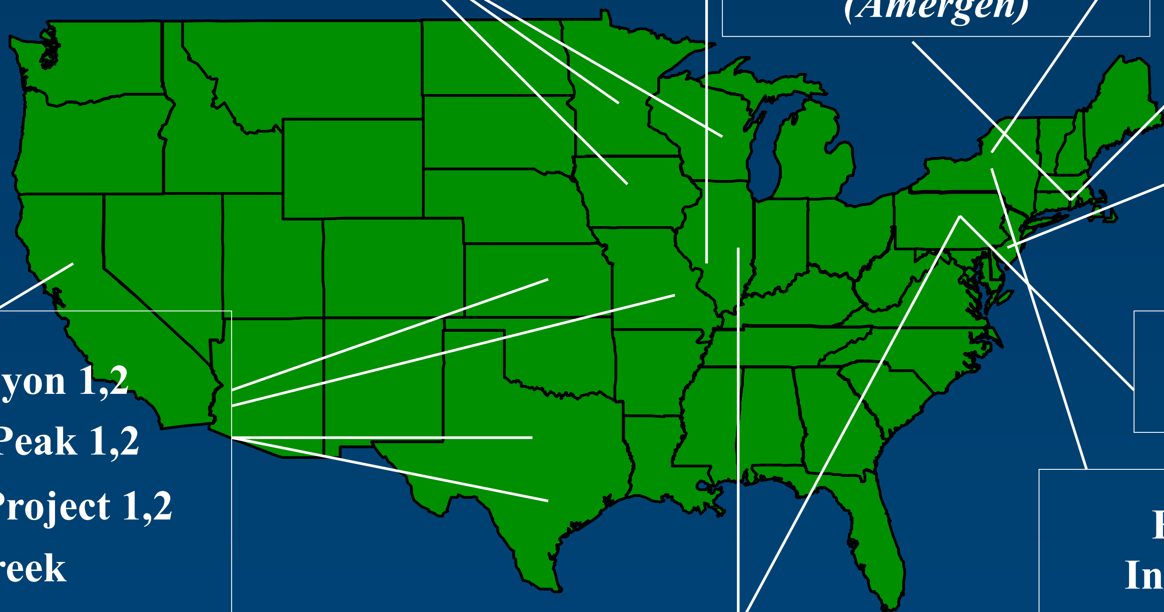
Clinton
(Amergen)

Nine Mile Point 1,2

Vermont Yankee
(Amergen)

Pilgrim
(Entergy)

Oyster Creek
(Amergen)



Diablo Canyon 1,2
Comanche Peak 1,2
South Texas Project 1,2
Wolf Creek
Callaway
(STARS)

TMI 1
(Amergen)

FitzPatrick
Indian Point 3
(Entergy)

Peco/Unicom merger
(14 units)

Factors Affecting New Nuclear Plants in a Competitive U.S. Market

Driving Forces

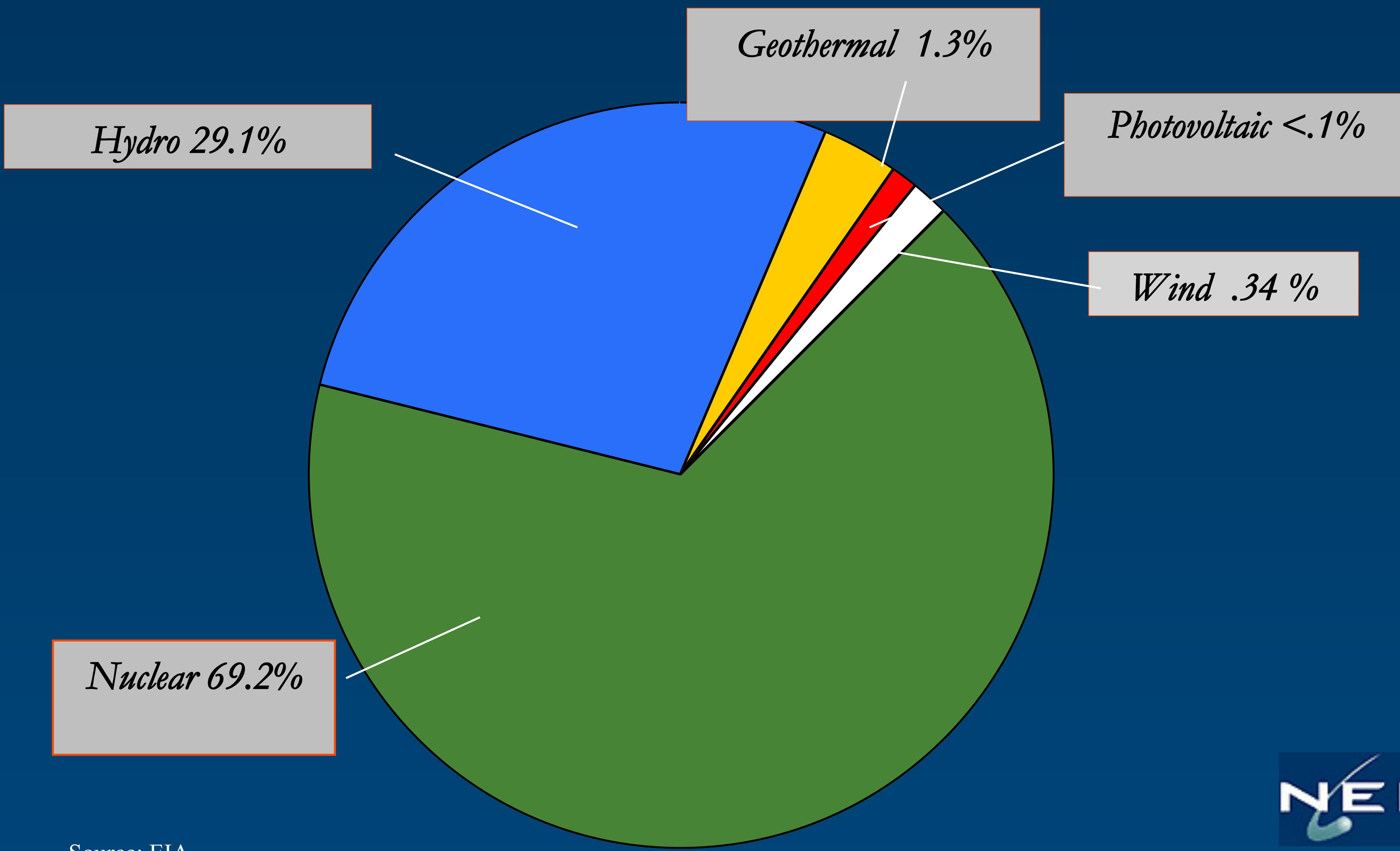
- Evolution of large nuclear generation companies
- Growing electricity demand
- Increasing air pollution control requirements
- Potential electricity and environmental initiatives

Factors Affecting New Nuclear Plants in a Competitive U.S. Market (Continued)

Challenges

- High initial capital costs
- Length of overall project schedule
- Certainty of Government Waste Management Program

Breakdown of US Sources of Emission Free Generation (1999)



Source: EIA

NEI

Clean Air Compliance Value of Existing Nuclear Power Plants

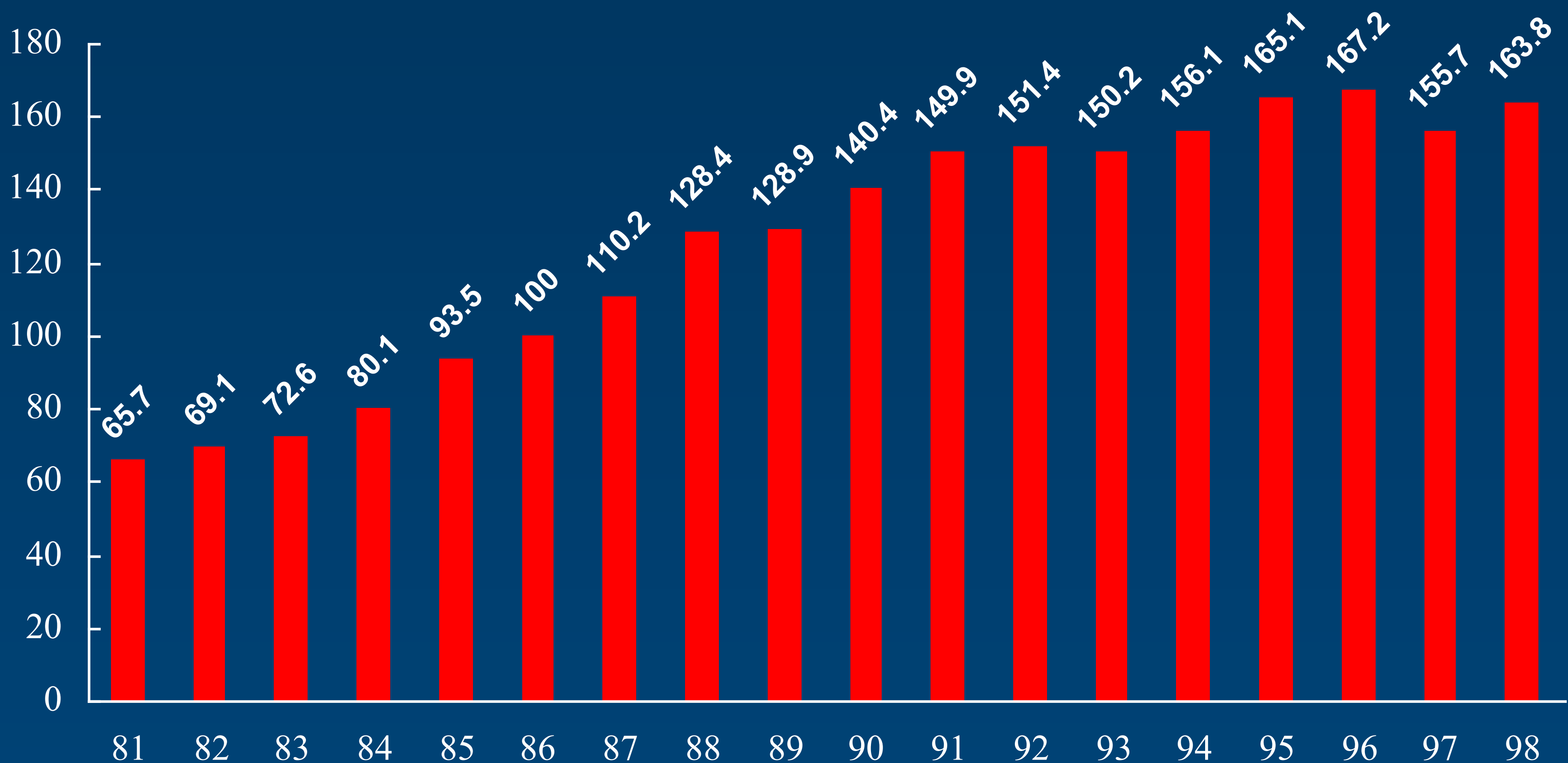
- Nuclear power plants (and other emission-free sources) are "silent partner" in compliance plans: emissions avoided not explicitly recognized

- Emission-free sources reduce compliance cost otherwise imposed on fossil-fired units

- Clean air compliance value is "hidden" value:
  - *Ceases to be "hidden" when nuclear unit shuts down*
  - *In the absence of nuclear energy, increased compliance cost for new and existing replacement capacity*

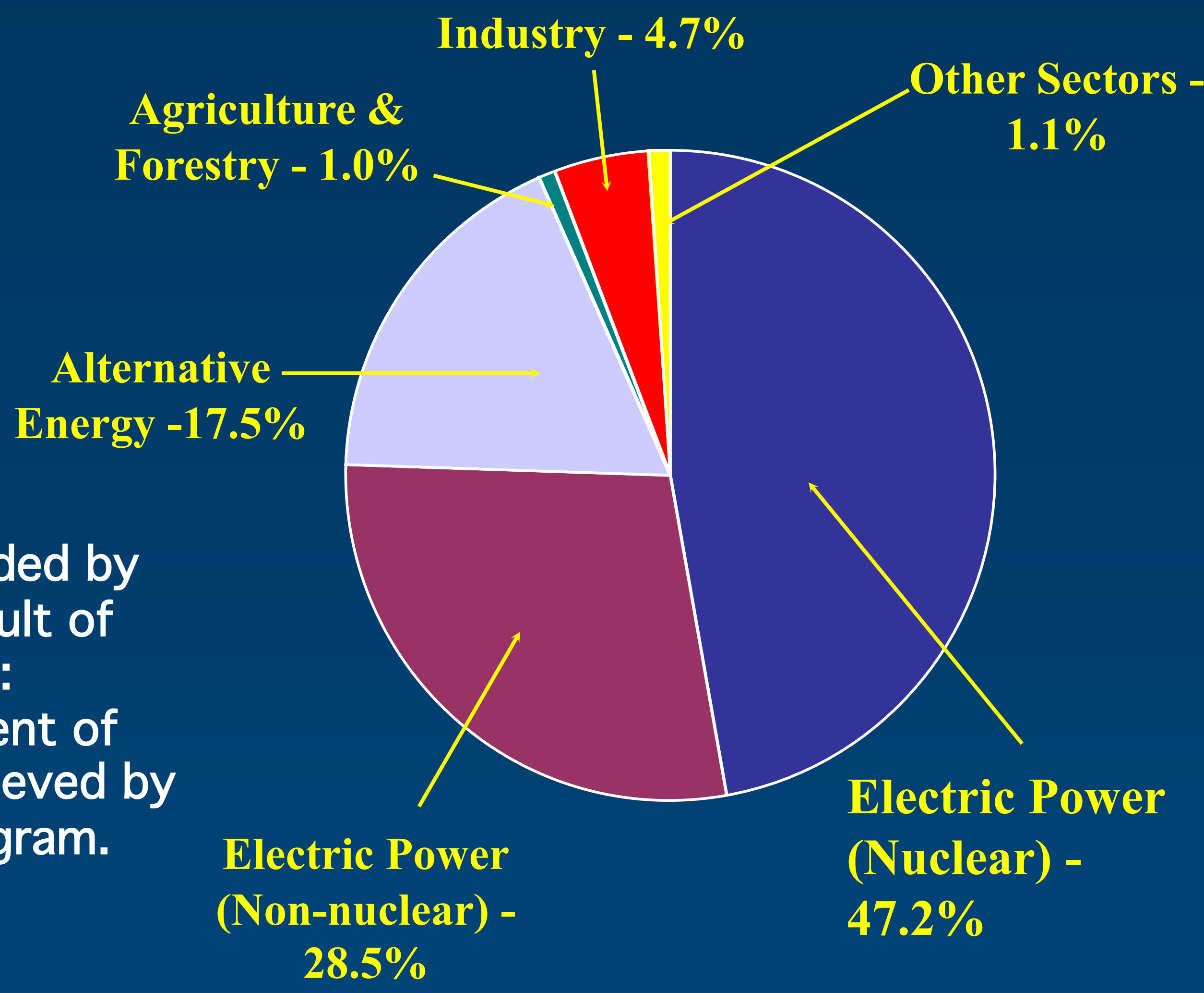
NEI

US Nuclear Industry CO_2 Avoidance in Million Metric Tons of Carbon



Source: Nuclear Energy Institute (NEI)

Carbon Reductions: Nuclear Power Dominates U.S. Voluntary Program



- Carbon emissions avoided by nuclear plants as a result of improved performance: largest single component of carbon reductions achieved by the U.S. voluntary program.

Source: DOE/EIA

Nuclear Power 2010

Nuclear Power 2010
is a new R&D initiative announced by Secretary Abraham on February 14, 2002. This initiative is designed to clear the way for the construction of new nuclear power plants by 2010.

Can We Build New U.S. Reactors By 2010?
Yes!

<u>Can</u> Be Deployed by 2010
- ABWR (General Electric)

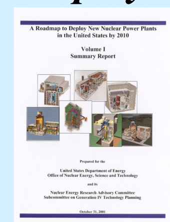
<u>Probably</u> Can Be Deployed by 2010
- AP600 (Westinghouse)
- AP1000 (Westinghouse)
- PBMR (Exelon)

<u>Possibly</u> Can Be Deployed by 2010
- SWR-1000 (Framatone)
- ESBWR (General Electric)
- GT-MHR (General Atomics)

<u>Cannot</u> Be Deployed by 2010
- IRIS (Westinghouse)

2010

Conclusions of the Expert Study: *A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010*

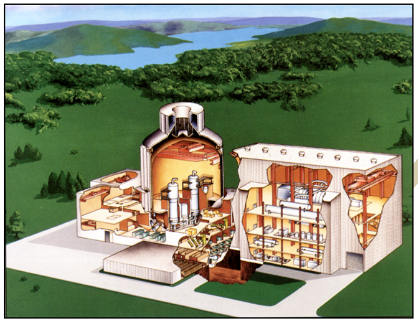


But More Work Must Be Done

Early Site Permit Application

- Complete DOE/Industry Scoping Studies
- Launch Cooperative Demonstration of ESP process

Design Certification and Completion of Detailed Design & Engineering



- R&D on First-of-a-Kind Engineering
- Material, Component, and Fuel Testing

Combined Construction and Operating License Application

- Conduct DOE/Industry cost-shared demonstration

Advanced Nuclear Power Systems Online by 2010

- ALWRs
- Gas-cooled reactors

For new U.S. Nuclear Power Plants to be a reality by 2010, DOE must support key R&D and assist industry to demonstrate unproven NRC processes

Early Site Permit Application

Purpose - Demonstrate new, untested Early Site Permit (ESP) licensing process - 10 CFR Part 52

- **Conduct DOE/Industry Scoping Study**
  - Develop schedule & cost estimates for ESP application
  - Competitive cost-shared proposals
- **Conduct ESP Regulatory Demonstration Projects**
  - Demonstrate effectiveness of NRC licensing process
  - Implement generic industry guidelines
  - Demonstrate process at several sites

Major Program Developments
Further Focussing on Nuclear R&D

6 **Radiological Facilities Management**

- RTG Manufacturing
- Research Reactor and Other Nuclear Infrastructure
- Isotope Production

6 **Nuclear Energy Protocol for Research Isotopes (NEPRI)**

- Requires peer review to establish annual list
- Requires advanced payment
- No more subsidy for research isotopes

Major Program Developments
Further Focussing on Nuclear R&D (cont.)

6 **Innovations in Nuclear Infrastructure and Education (INIE)**

- Implementation of NERAC recommendations
- Encourages close cooperation between universities, industry, and laboratories
- $5 million available in FY 2002

6 **Fast Flux Test Facility**

- Secretary of Energy decision in December 2001
- Proceeding with deactivation

Major Program Developments
Further Focussing on Nuclear R&D (cont.)

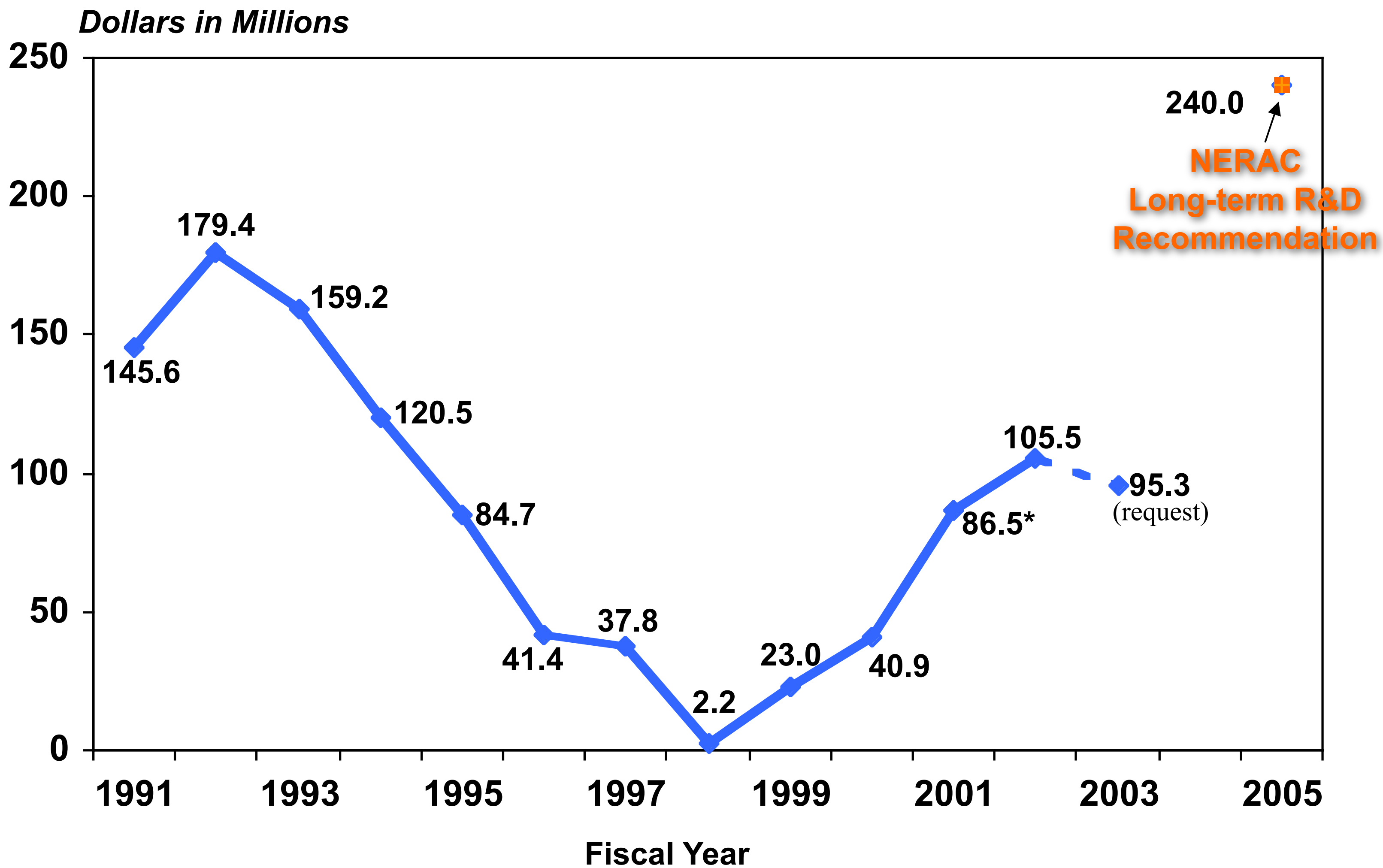
6 **Transmutation of Radioactive Wastes**

- Richter Committee recommendations
- Proposed R&D program: $500 M over five years)
- Demonstration program: Billions..

6 **Space Nuclear Power Systems**

- NASA program for FY03 ($850 M over five years)
  - Space nuclear power systems (Mars, Outer Planets)
  - Space nuclear propulsion

Research & Development Budget History



**Does not include $34 million of funding for the APT budget which was funded by DP in FY 2001.*