Nuclear Resurgence in the United States

LAS/ANS Latin American Section American Nuclear Society

LAS/ANS Symposium

Energy Crisis in Latin America and Nuclear Power

27 June 2006

Harold McFarlane

President
American Nuclear Society

INL Idaho National Laboratory

Why nuclear expansion now?

- Climate change
- Global competition for energy resources
- Favorable economics
- Positive experience for past 20 years
- Opinion shift by public and policymakers
- Emergence of potential for other applications
  - Transportation fuel
  - Fresh water production
  - Industrial heat

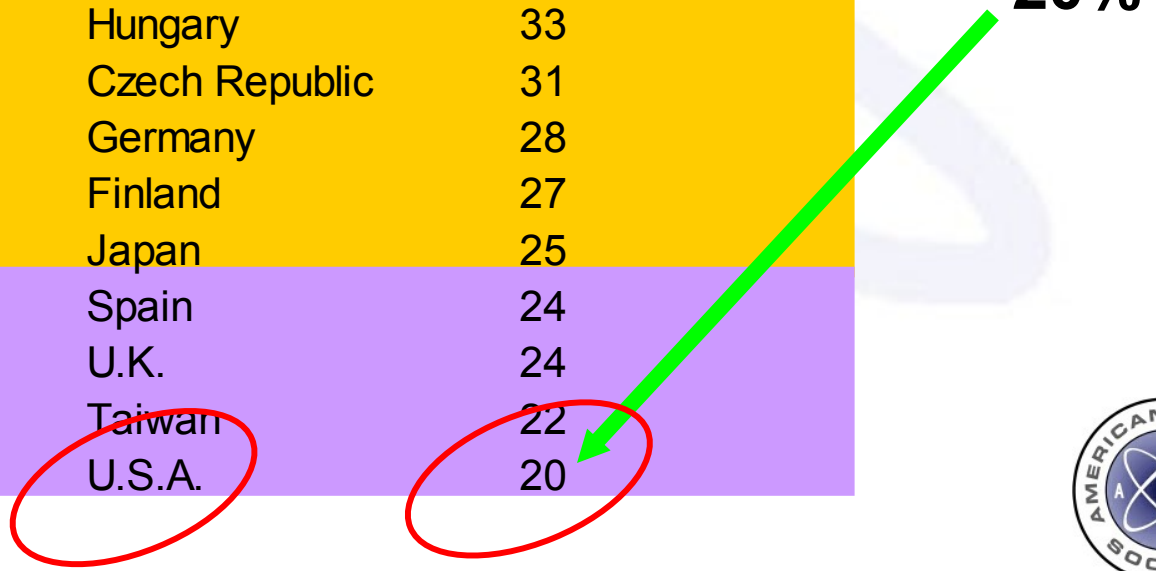
International nuclear electric production

	Number	% CF	% of Total Generation
United States	103	92	20
France	59	88	78
Japan	52	70	25
Russia	30	68	17
Canada	21	64	13
South Korea	20	92	40
China	9	84	2
Taiwan	6	88	22
Mexico	2	79	5

Holding constant

Top Nuclear Output

Country	% of Nuclear Power to Total Output
Lithuania	80
France	78
Slovakia	57
Belgium	55
Sweden	50
Ukraine	46
South Korea	40
Slovenia	40
Switzerland	40
Bulgaria	38
Armenia	35
Hungary	33
Czech Republic	31
Germany	28
Finland	27
Japan	25
Spain	24
U.K.	24
Taiwan	22
U.S.A.	20

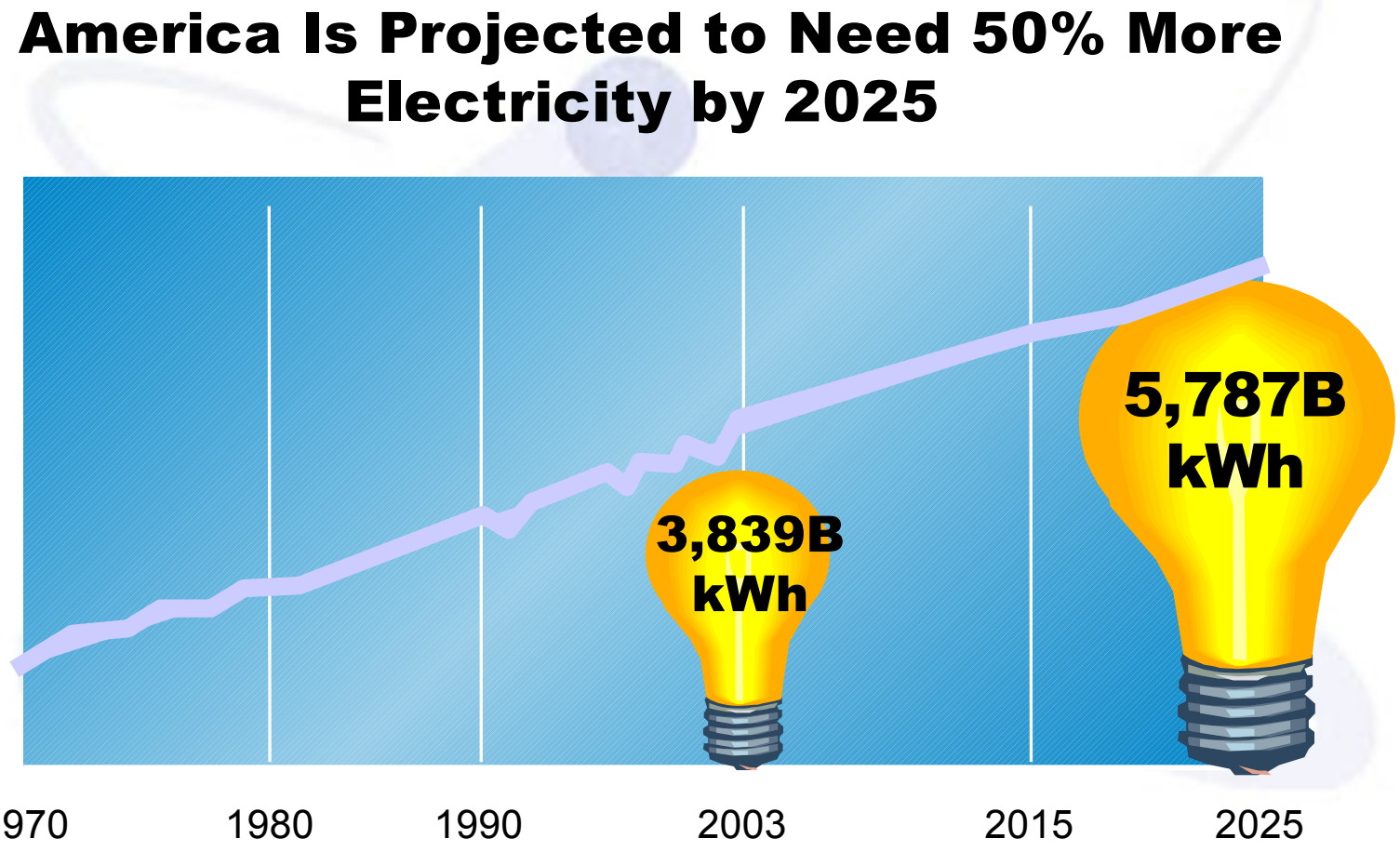


Evidence of a pending renaissance

- ✓ Enabling legislation
- ✓ Public announcements of pending nuclear plant orders
- ✓ Nuclear industry staffing
- ✓ Nuclear engineering enrollment
- ✓ Surge in favorable news stories
- ✓ Significant financial investment
- ✓ Shift in public policy to favor nuclear along with other environmentally friendly sources of power

- *It is a great year to be ANS president!*

U.S. Energy Demand



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Source: U.S. Department of Energy

The Energy Policy Act of 2005

Nuclear incentives provided by the Energy Policy Act of 2005 (EPACT2005)

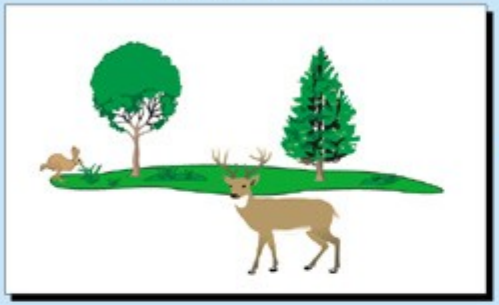
- Risk insurance
  - 100% for delays of first two plants up to $500M each
  - 50% for delays for next four plants up to $250M
  - No cost to government if licensing process works
- 80% loan guarantees (like FHA loan)
  - No cost to government if new plant operates
- Production tax credit of $18/MWH
  - For first 6,000 MWs of new plants
  - For eight years only, $125M cap per plant
  - Same as windmills have had since 1992

Key provisions for new plant construction

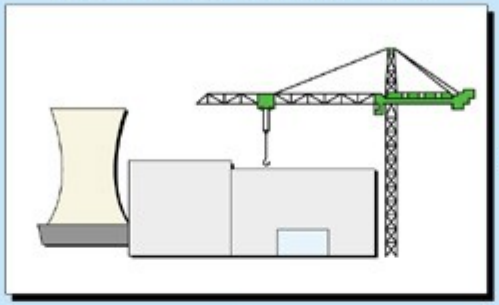
Loan guarantees	80% of project cost	• Higher leverage • Lower debt cost
Production tax credit	$18/MW hr	• Through 2021 • $125M/1000 MW per year • 6,000 MW eligible • IRS rule making: February 2006
Risk assurance	Delay protection	• $500M for 1st 2 plants • $250M for next 4 plants • Final rules: August 2006
Price-Anderson	Liability insurance	• Reauthorization for 20 years
Decommissioning funds	Updates for treatment	• Allows companies to establish funds and make contributions • Allows transfer of nonqualified funds to qualified funds

Combined Licenses, Early Site Permits, and Standard Design Certifications

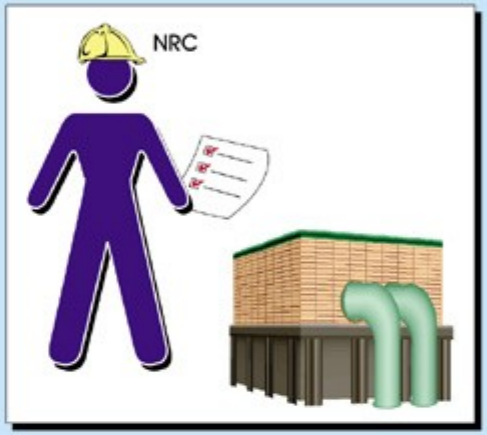
Early Site Permit*



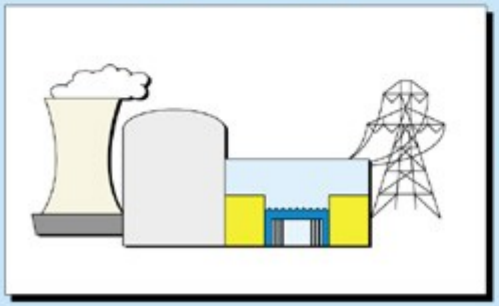
Reactor Construction



Verification of Inspection, Tests, Analyses, and Acceptance Criteria



Standard Design Certification*

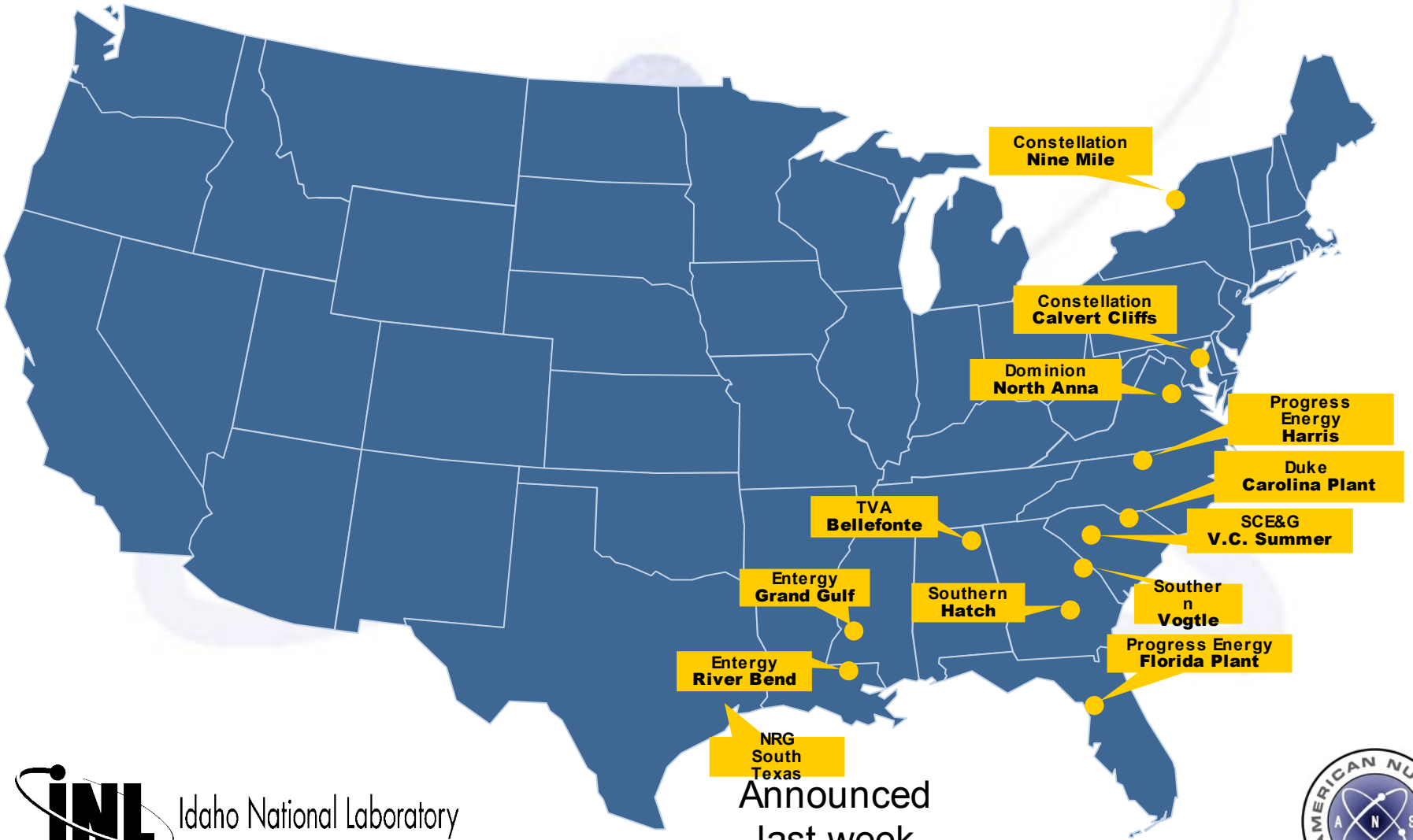


Combined License Review and Hearing

Reactor Operation

* or equivalent process

U.S. Nuclear Industry—First Movers



Announced last week

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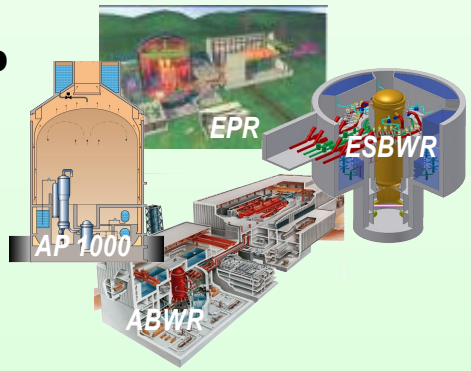
United States new generation

Utilities

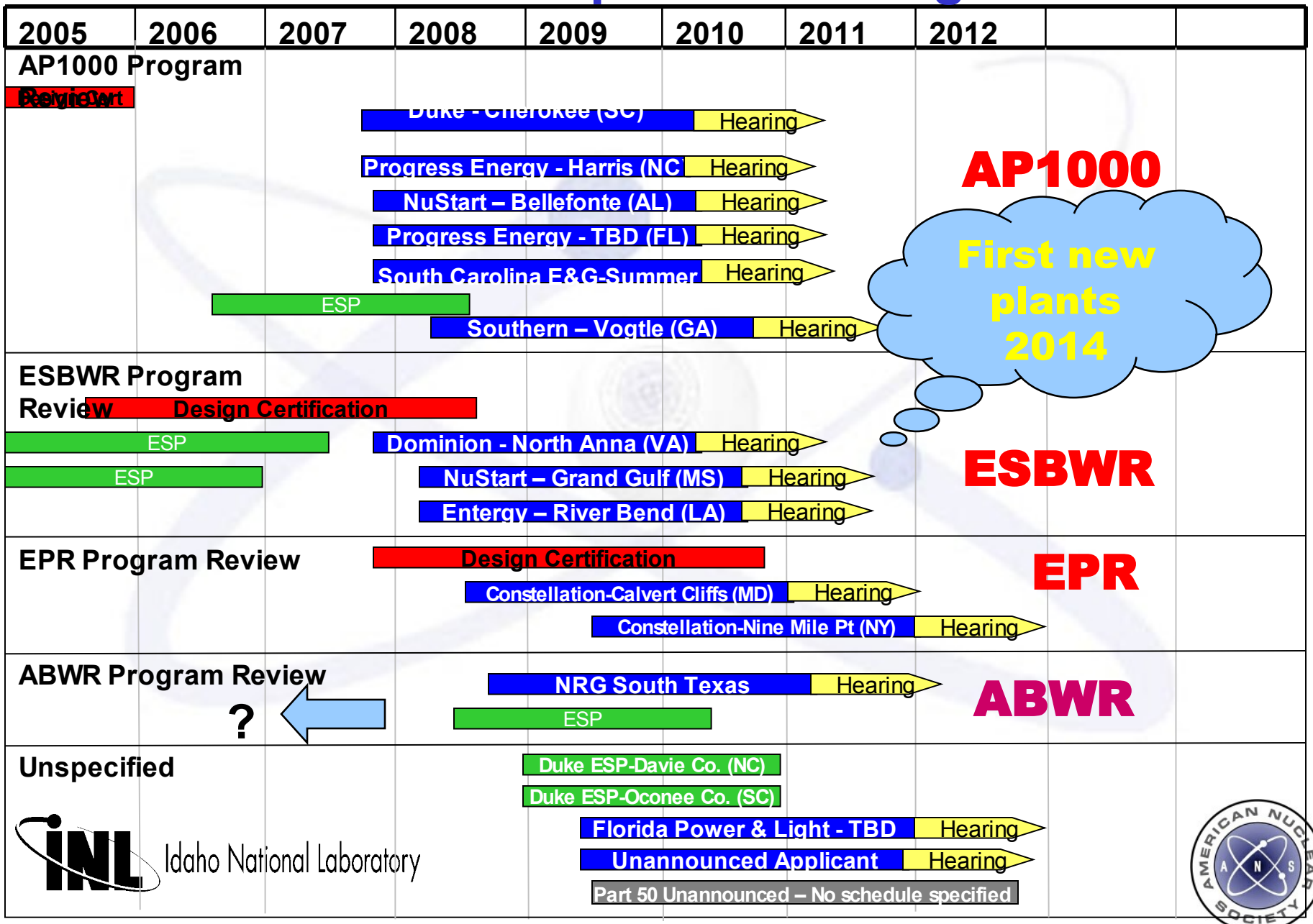
Technologies

Southern
Constellation
Dominion
SCE&G
Entergy
Duke
Progress Energy
TVA
FPL
NRG

AREVA/Framatome ANP
Westinghouse
General Electric



NRC's estimated new plant licensing schedule



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Aggressive industry staffing

- Westinghouse hired 1000 last year, 500 this year, and expects to hire 2000 more in next decade.
- Others vendors and nuclear utilities are attempting similar staffing growth *(including the Idaho National Laboratory)*
- Nuclear Regulatory Commission is hiring 300 per year for 3 years to handle anticipated licensing "tsunami"

Nuclear engineering enrollment up

- Nuclear engineering enrollments have risen sharply, reaching a **record high** this year
- Domestic students have largely replaced the previous supply of overseas graduate students
- 27 senators signed a letter to restore funding to nuclear engineering education programs
  - Bipartisan
  - Includes John Kerry and Hillary Rodham Clinton

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The New York Times
nytimes.com

May 13, 2006

EDITORIAL

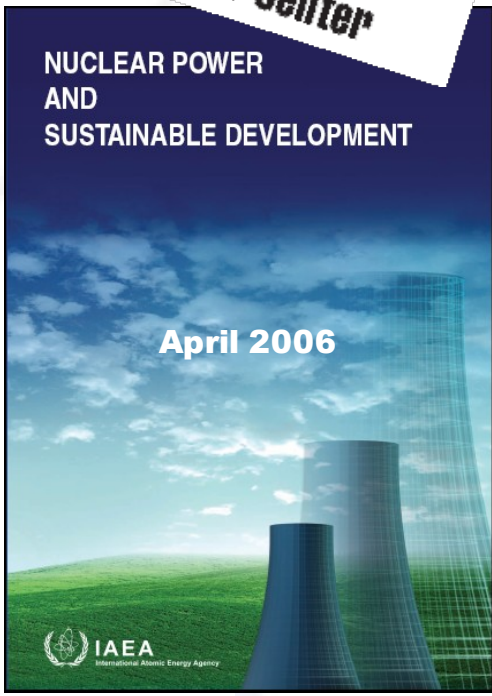
The Greening of Nuclear Power

Not so many years ago, nuclear energy was a hobgoblin to environmentalists, who feared the potential for catastrophic accidents and long-term radiation contamination. But this
energy supplies and global warming. Suddenly nuclear power is looking

Feb. 8, 2006

U.S. Must Maintain Nuclear Power Plants to Address Climate Change, Says Pew Center

"The replacement of Britain's nuclear power stations is "back on the agenda with a vengeance," Tony Blair, May 17, 2006



"The world's biggest technical failure over the last half-century has been the refusal to make full use of nuclear power. .. **I hope that President Bush and Congress will have the intellectual gallantry and long-term willpower to do so on a gigantic scale,** one that will once again put the U.S. a generation ahead of others in what is perhaps the single most important field of economic activity."

Paul JohnsonForbes, June 2006

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washingtonpost.com

Going Nuclear

A Green Makes the Case

By Patrick Moore
Sunday, April 16, 2006; B01

In the early 1970s when I helped found Greenpeace, I believed that nuclear energy was synonymous with nuclear holocaust, as did most of my compatriots. That's the conviction that inspired Greenpeace's first voyage up the spectacular rocky northwest coast to protest the testing of U.S. hydrogen bombs in Alaska's Aleutian Islands. Thirty years on, my views have changed, and the rest of the environmental movement needs to update its views, too, because nuclear energy may just be the energy source that can save our planet

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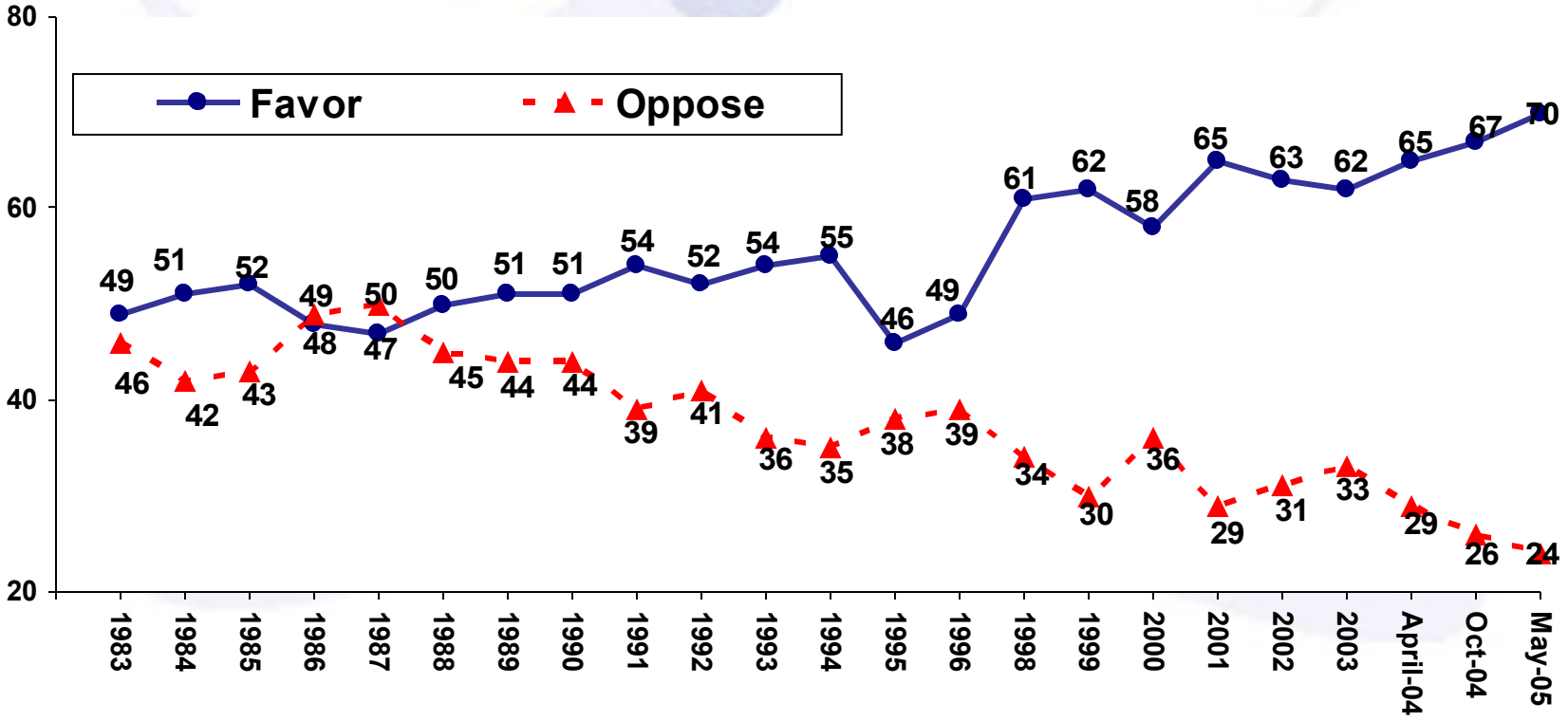
Nuclear Energy widely favored in USA



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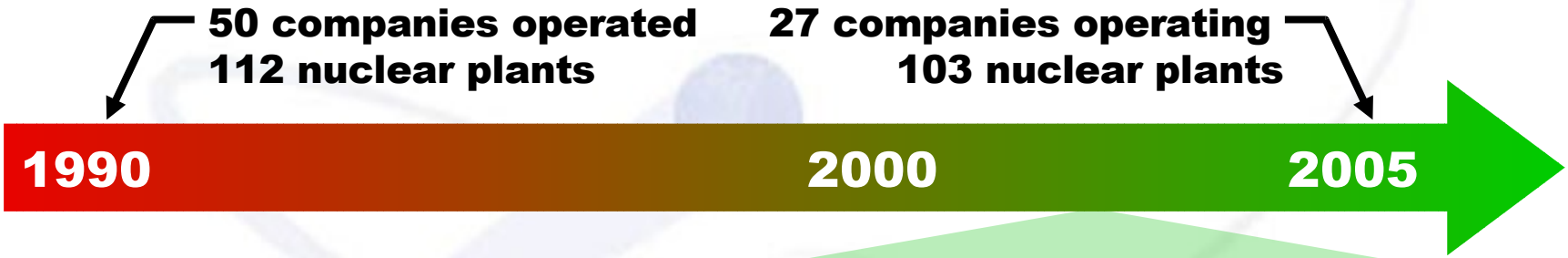
Consolidation of nuclear ownership



Last 5 years

- Substantial consolidation
- Top 10 operators have 61% of nuclear market
- Top 5 operators have 42% of nuclear market

Consolidation of Ownership *resulted*

- Corporate M&A
- Asset sales by companies desiring to exit nuclear ownership

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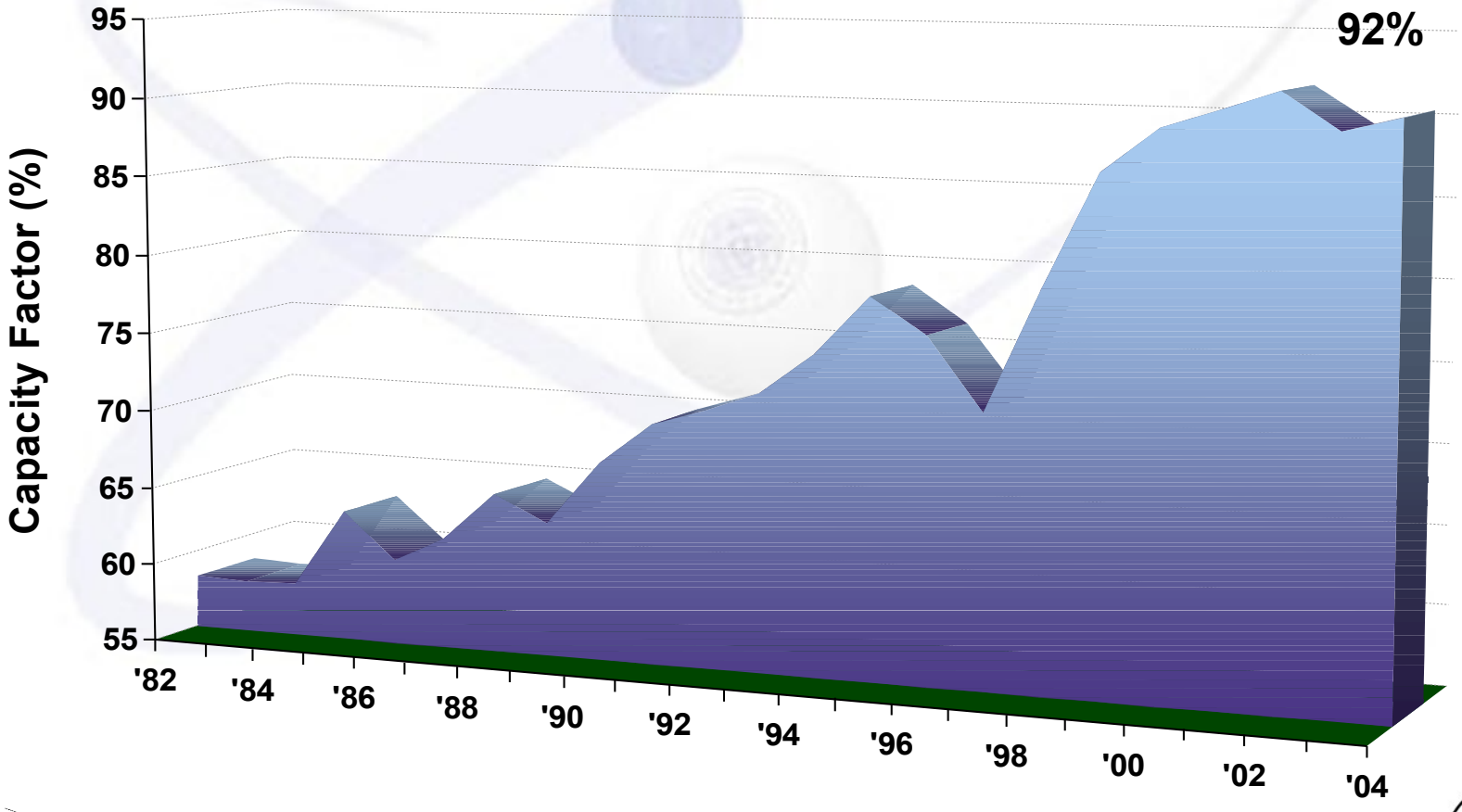
Nuclear power's proven performance in US



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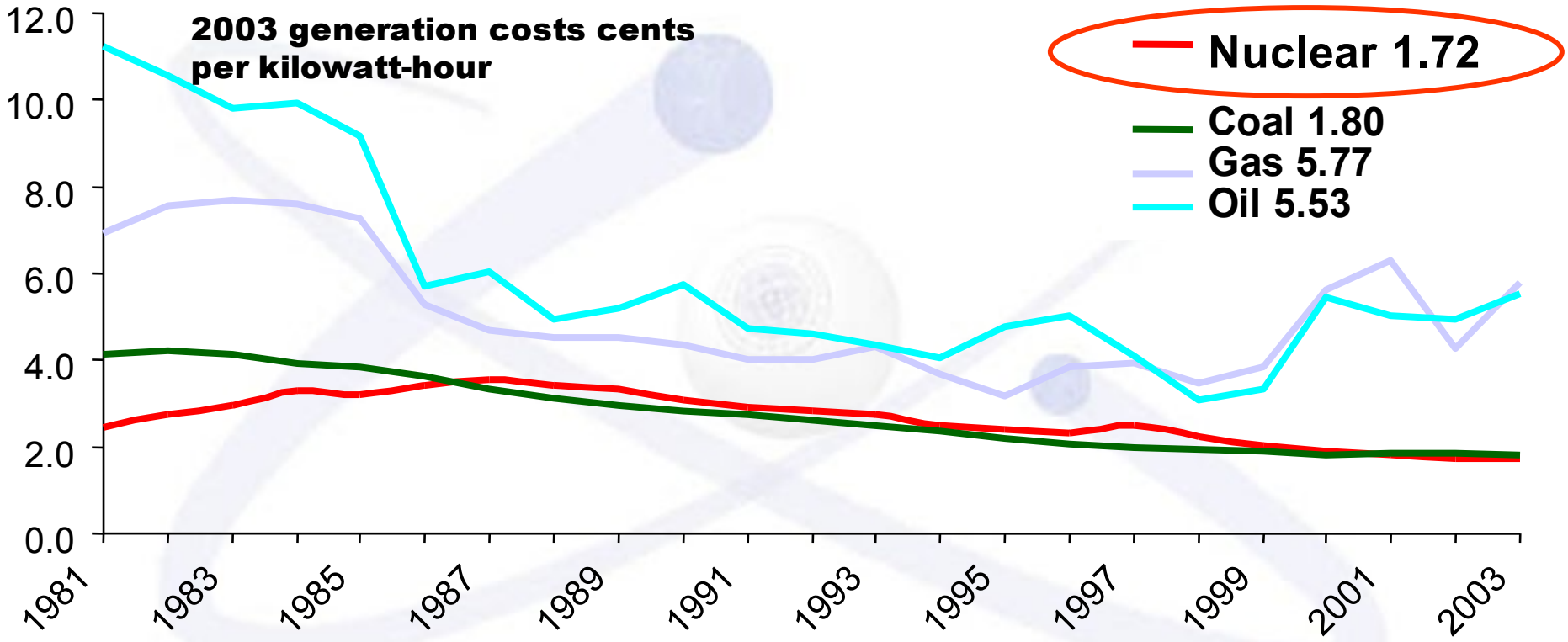
Source: Energy Information Administration/Nuclear Regulatory Commission

Nuclear energy is competitive



Nuclear is the lowest cost of all (except hydro)

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Nuclear Energy Institute

Performance improvements since President Carter's administration

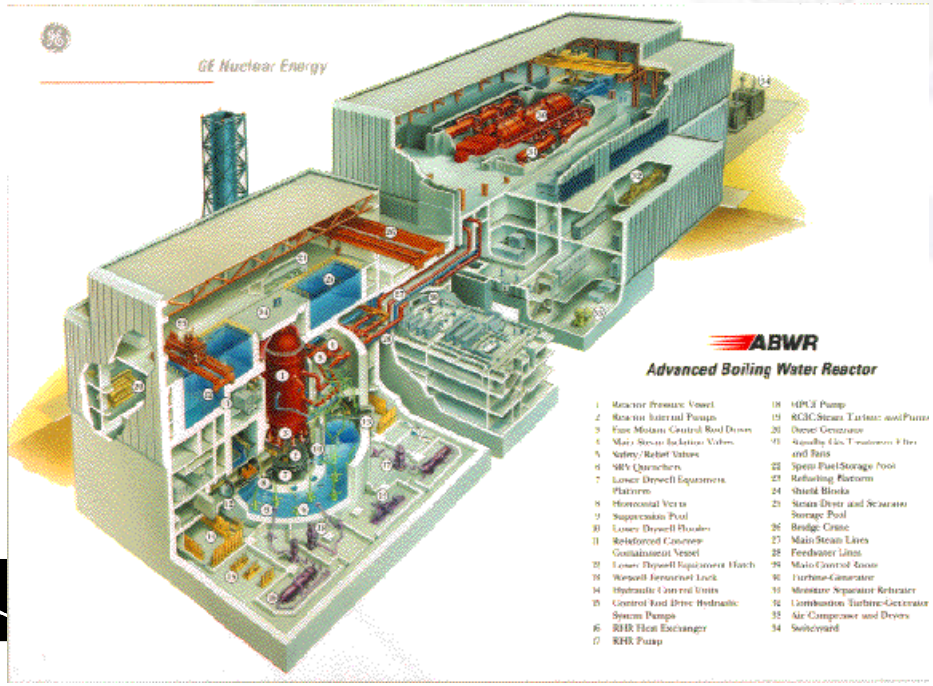
Performance indicator	1979	Today
No. of commercial reactors	69	103
Electricity prod. (kilowatt-hours)	255 billion	789 billion
Fleet average capacity factor	56.3%	90.5%
Unplanned reactor shutdowns/7000 hr	7.3%	0
Industrial safety accident rate/200k-hr	2.1	0.25

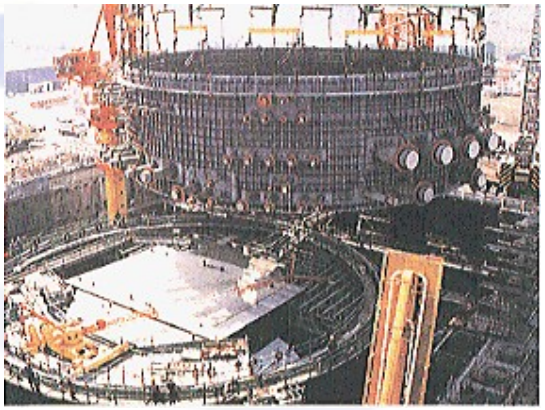
Reactor design certification

- Generation III
- Generation III+
- Generation IV?

Generation III: the ABWR

- Advanced Boiling Water Reactor - an "Evolutionary" design
- Developed by General Electric, Hitachi and Toshiba
- 1350-MWe capacity
- 3 units constructed in Japan
- 3 units under construction in Taiwan and Japan

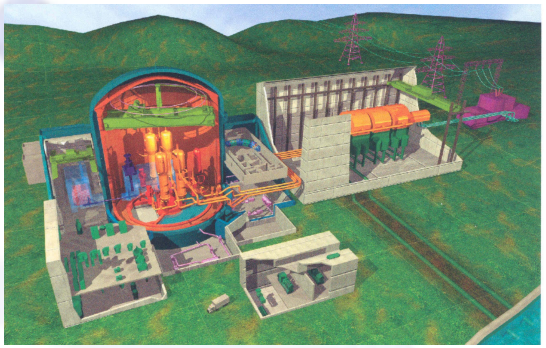




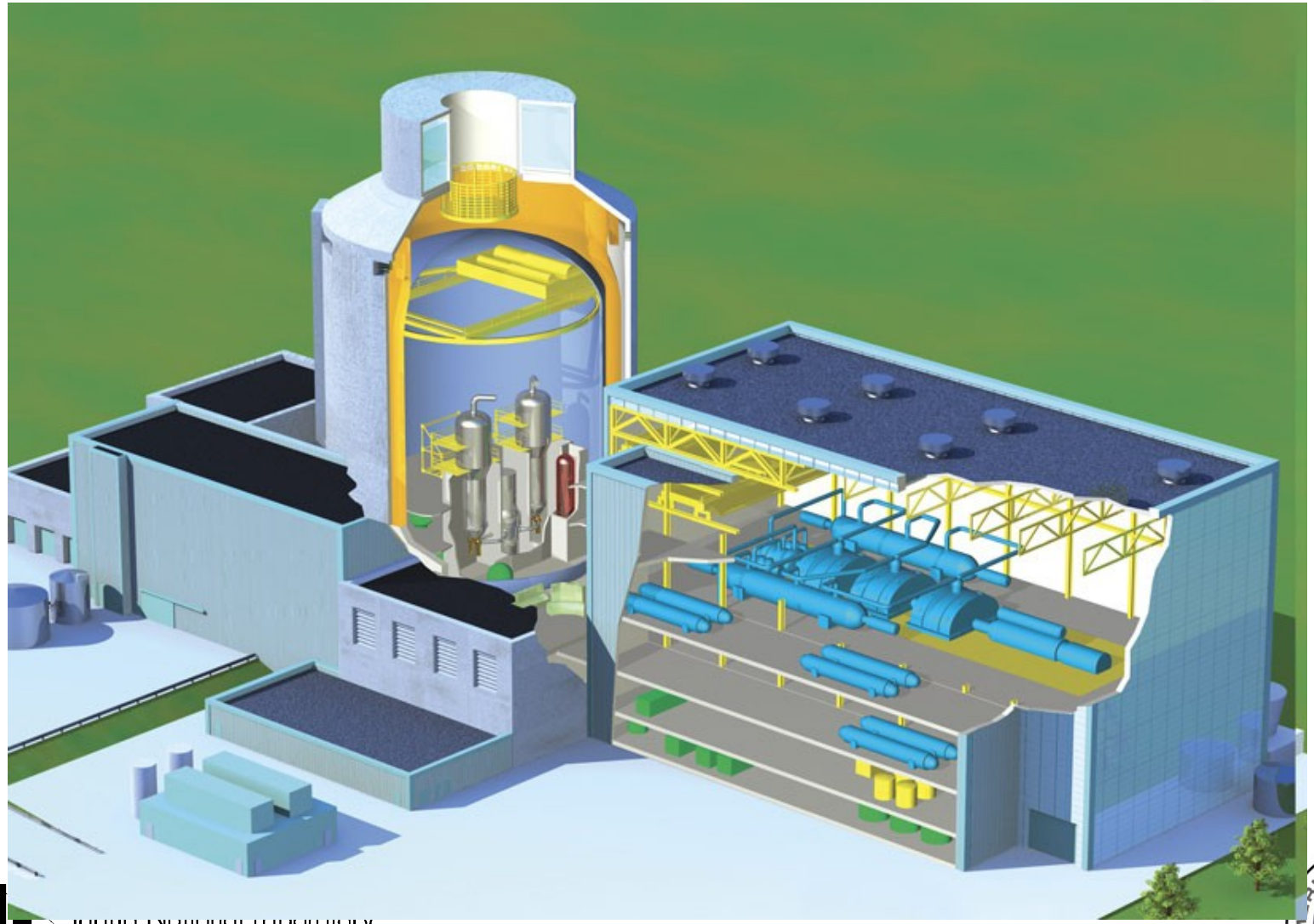
Modular assembly reduced construction time to 52 months

Generation III (+) EPR

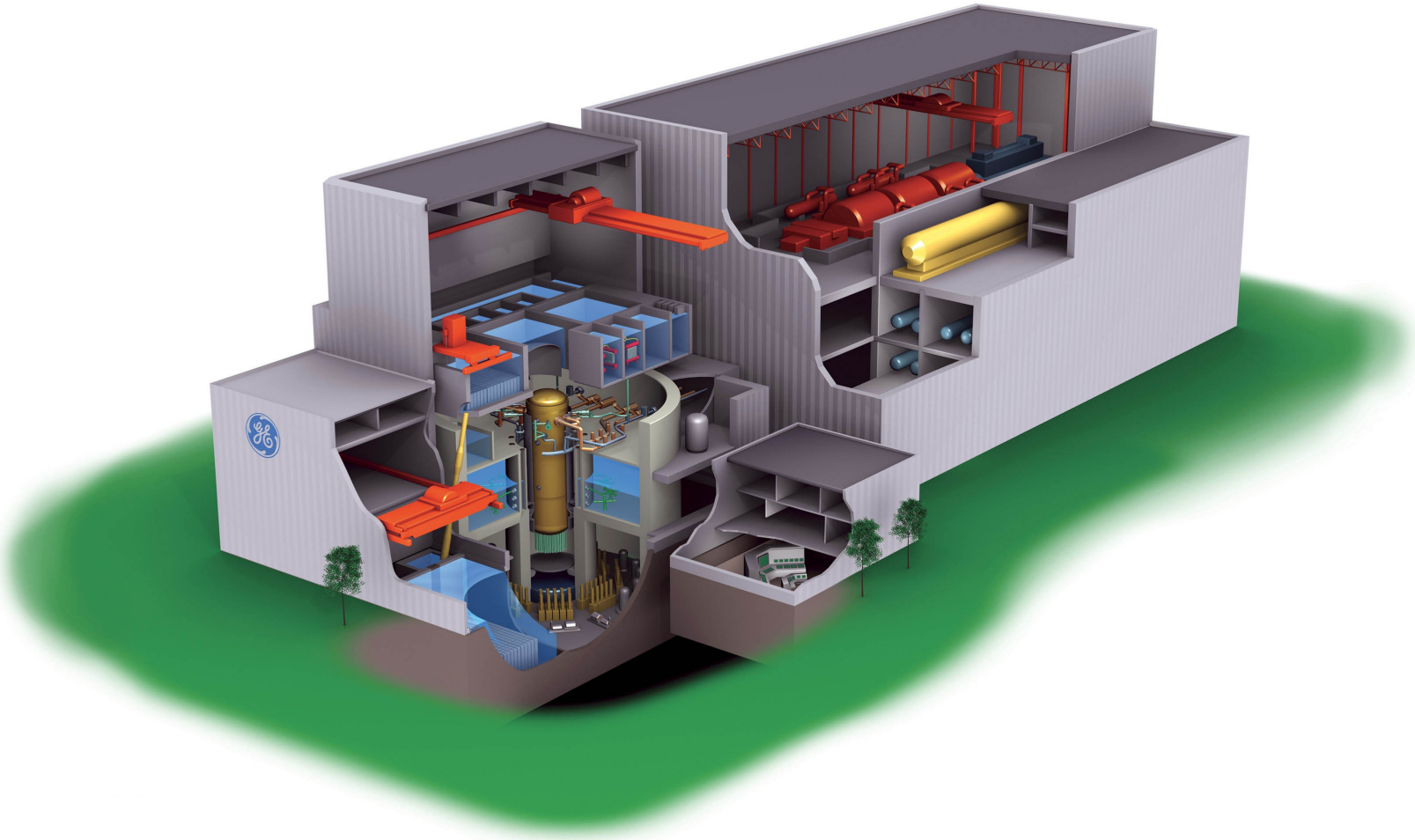
- AREVA/Framatome ANP—EPR Evolutionary Power Reactor
  - (1,600 MWe)
  - Redundant safety systems
  - European version being constructed in Finland
  - USA certification expected by 2010



Gen III+: The AP-1000



Gen III+: The ESBWR



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Significant financial investment

- $5.2 billion for purchase of Westinghouse
- $5.2 billion financial commitment to NRG to build 2 ABWRs at South Texas site
- Multi-hundred million $$$ investment by major vendors (AREVA, Westinghouse, GE) in design certification by the NRC.
- Private equity investment? (e.g., sale of BNFL America to Energy Solutions)
- Favorable financial analyses by OECD, University of Chicago, and many others

Entergy's look at the MIT economic study

New Nuclear (LWR, $/MWH)		$67
- Reduce Construction Cost, $2,000 to $1500/KW	- $12	55
- Reduce Construction Time, 5 to 4 Years	-2	53
- Reduce O&M plus Fuel, $15 to 13/MWH	-2	51
- Reduce Cost of Capital, 15% to 12%	-9	42
- Increase Capacity Factor (90%)		-2
	40	

Carbon Tax Effect ($/MWH)	$0/tn	$50/tn	$100/tn	$200/tn
Pulverized Coal	42	54	66	90
CCGT (Low Gas $3.77/MCF)	38	43	48	59
CCGT (Moderate Gas $4.42/MCF)	41	47	52	62
CCGT (High Gas $6.72/MCF)	56	61	67	77

Courtesy of Dan Keuter

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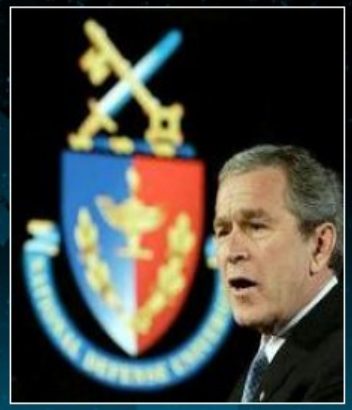
Global Nuclear Energy Partnership

Key GNEP Program Elements

- Expand use of nuclear power
- Minimize nuclear waste
- Demonstrate recycle technology
- Demonstrate Advanced Burner Reactors
- Establish reliable fuel services
- Demonstrate small, exportable reactors
- Enhanced nuclear safeguards technology



"To build a secure energy future for America, we need to expand production of safe, clean nuclear power"

President Bush, 06/2004

Global Nuclear Energy Partnership

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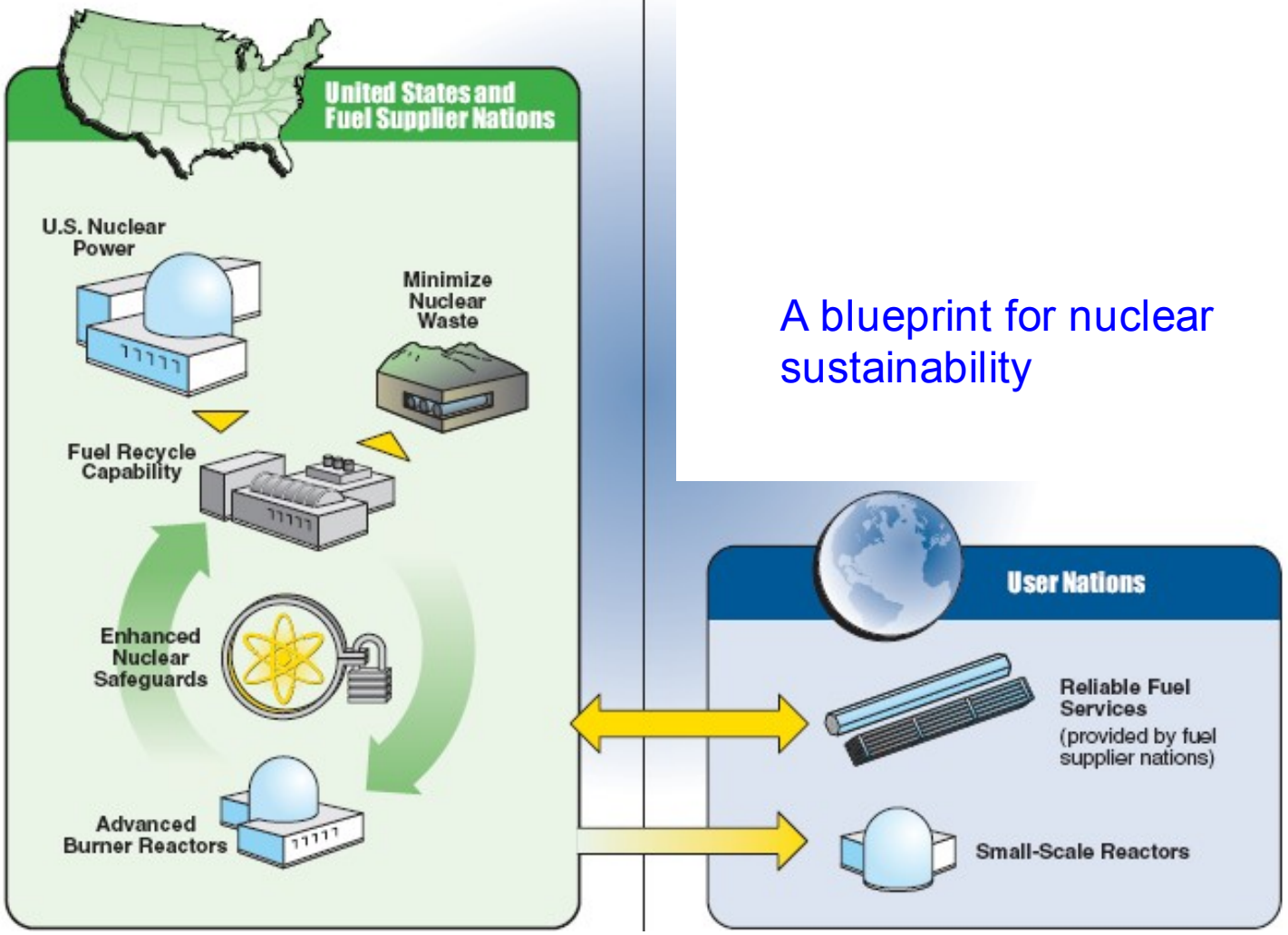
Global Nuclear Energy Partnership (GNEP)



A blueprint for nuclear sustainability

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Source: www.gnep.energy.gov

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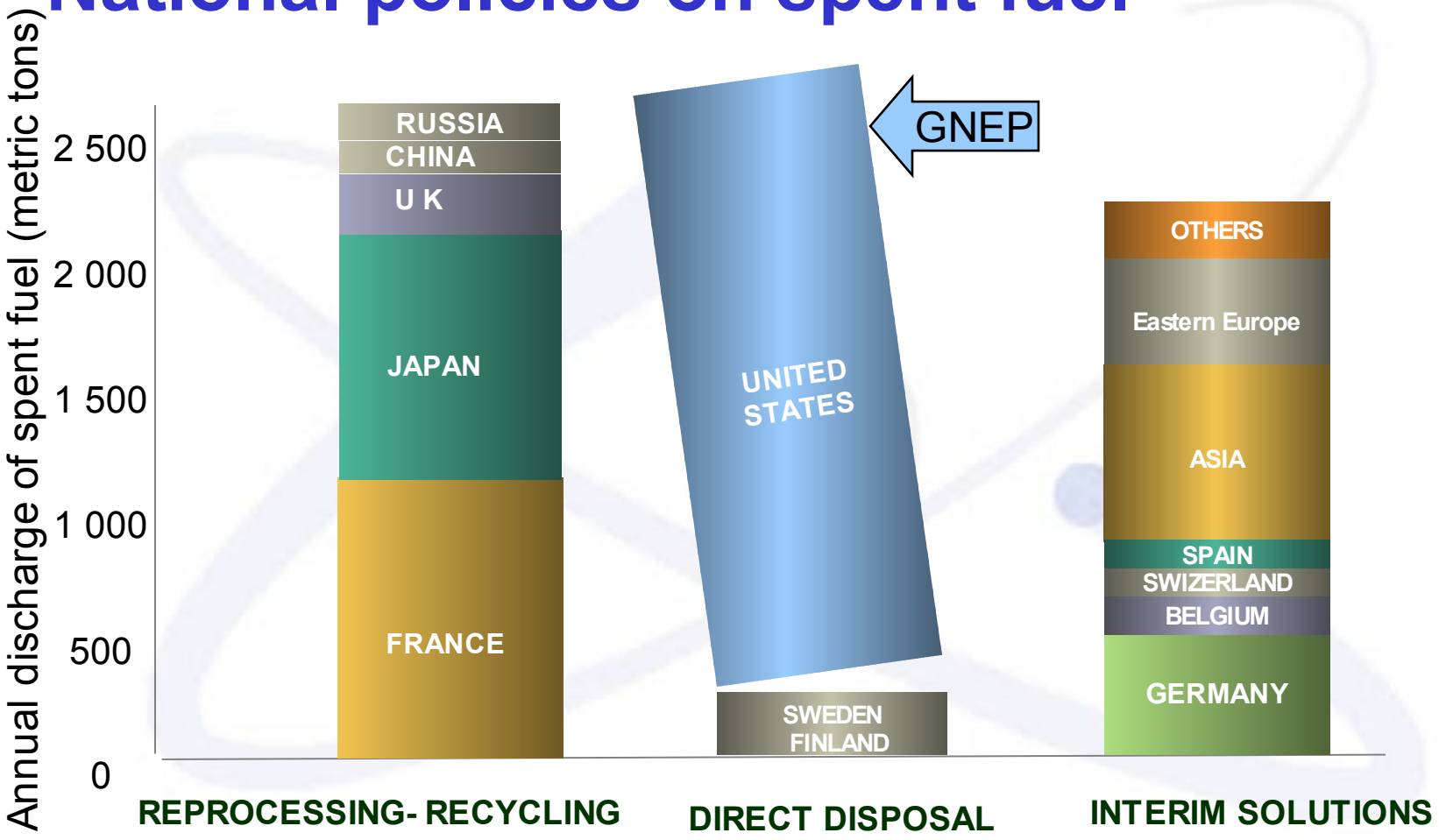
National policies on spent fuel



Courtesy Areva

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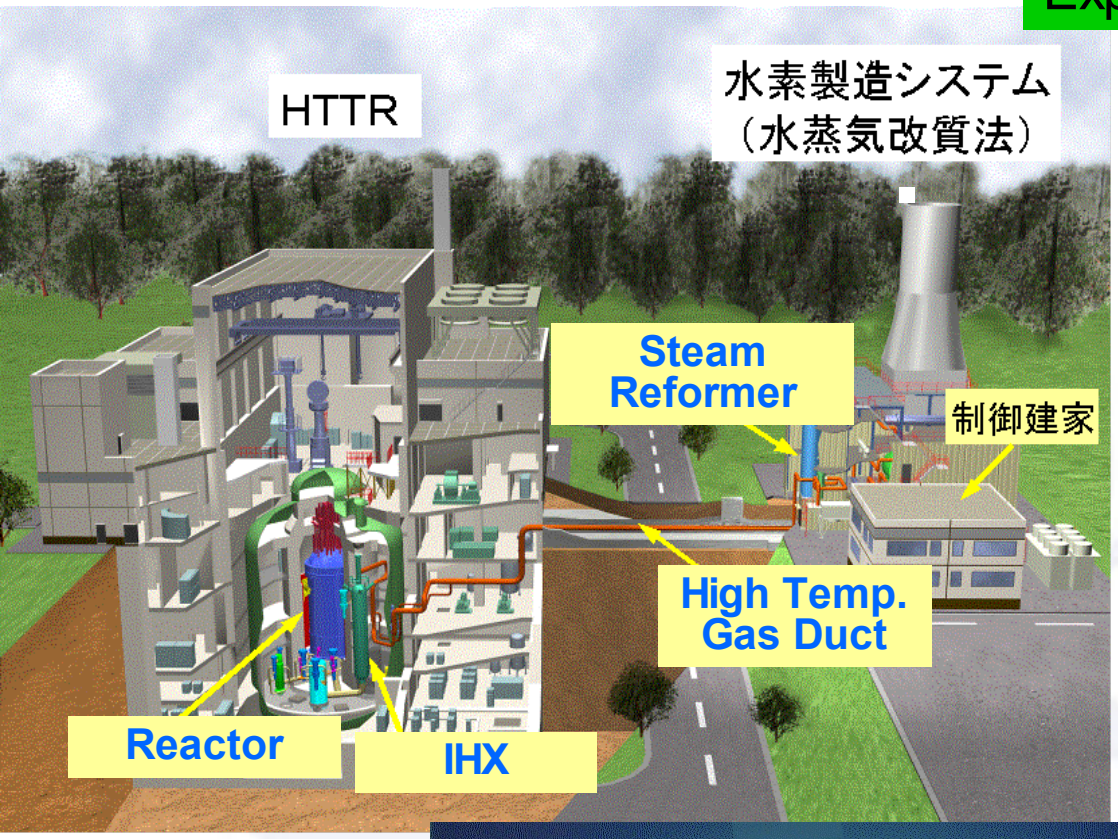
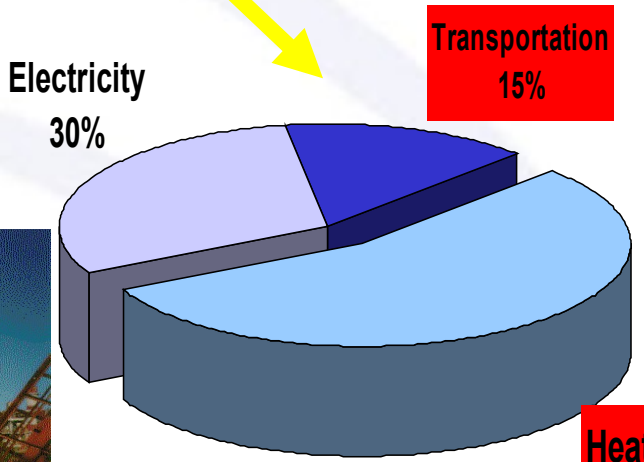
Non-electricity applications of nuclear energy

Expandable to other applications ✔



- Sea-water desalination
- Industrial and district heating
- Hydrogen production

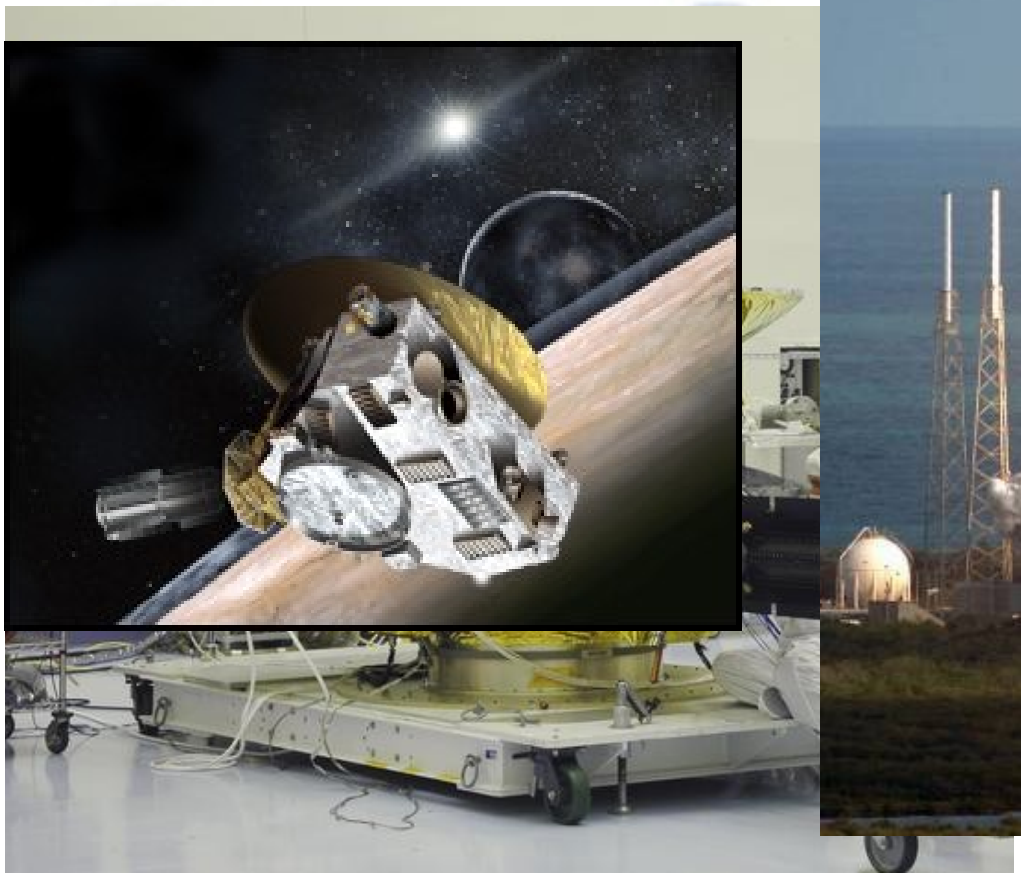


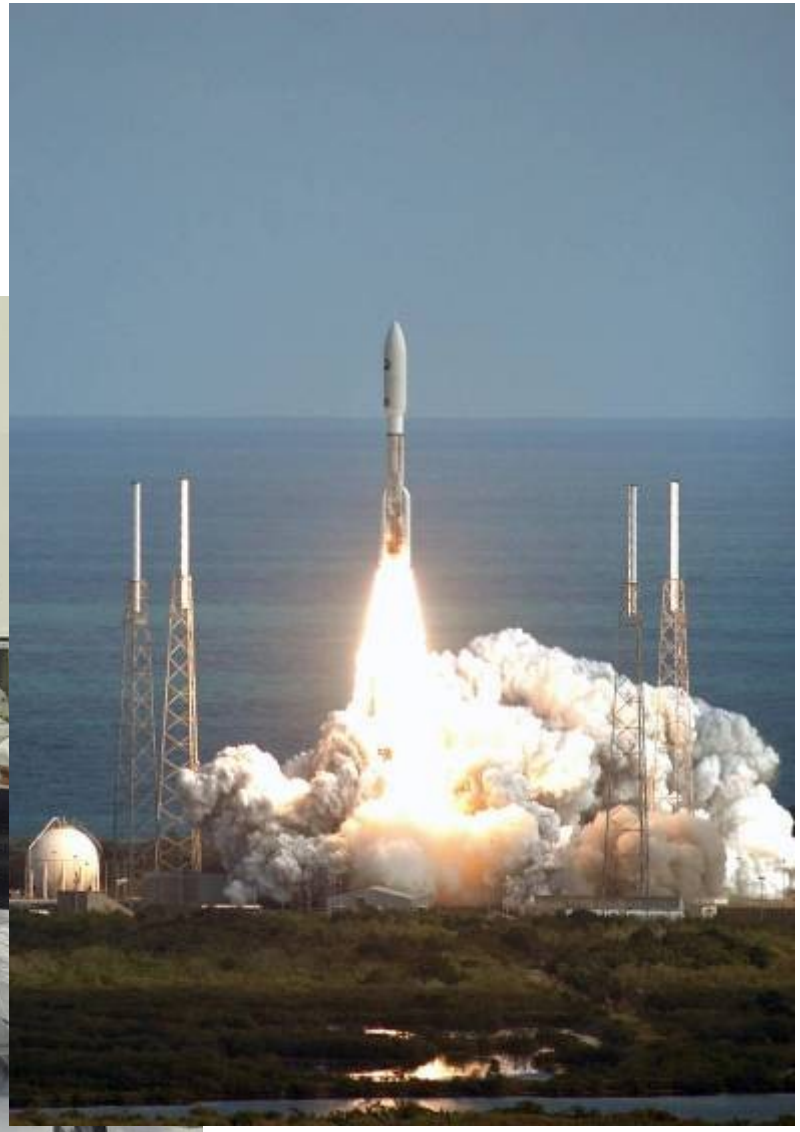
Kazakhstan, BN-350

Idaho Nati

Sokolov IAEA

Pluto/New Horizons launched on January 19, 2006





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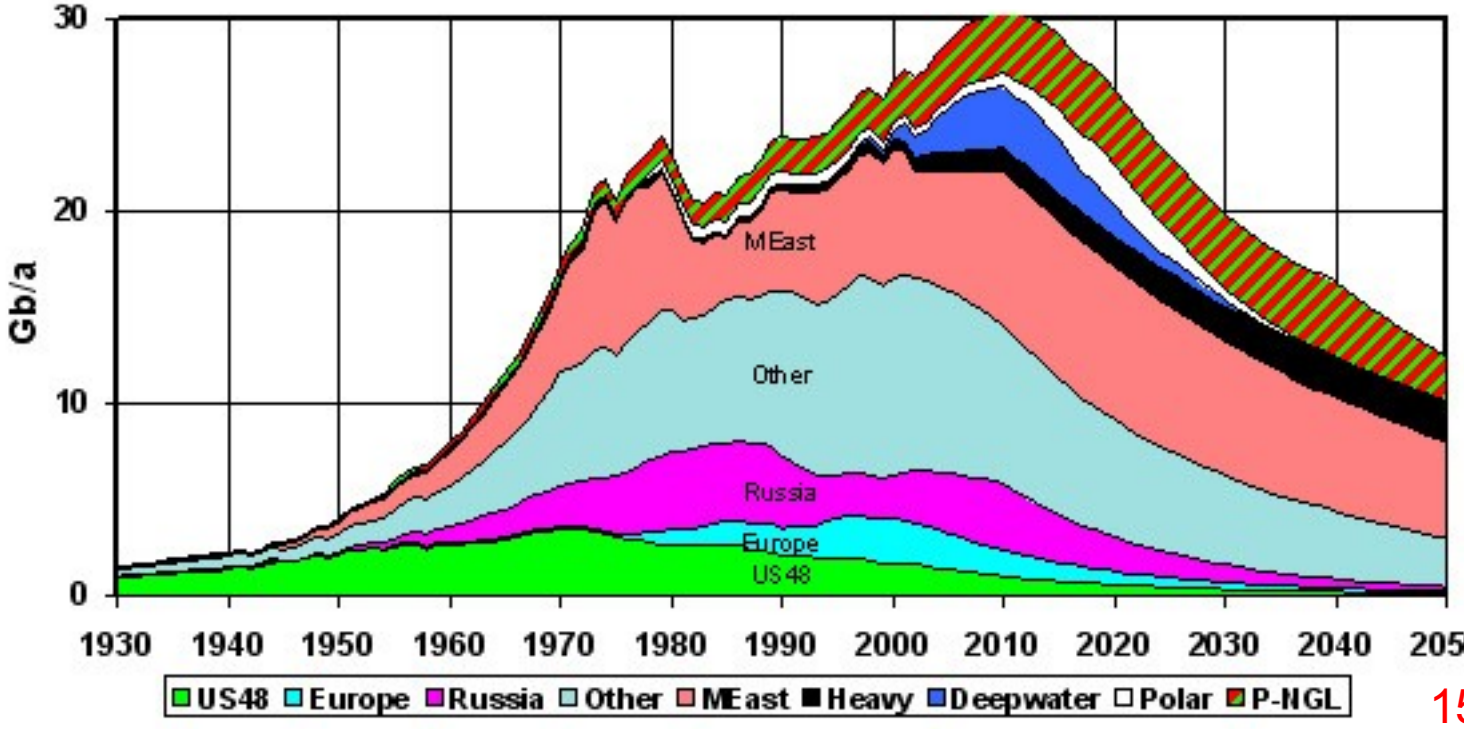
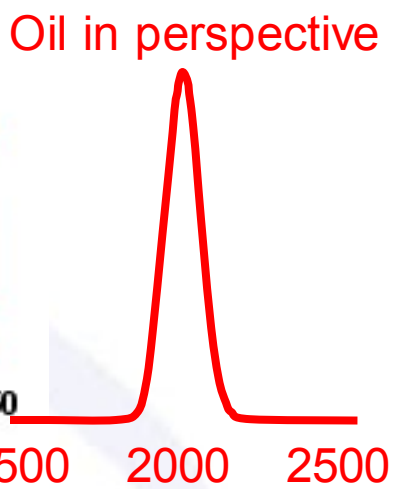
Ultimately the geologists have it right: Oil production will peak





Friday, April 21, 2006, spot oil prices hit $75/barrel—a new record

Also this week, President Bush complained to President Hu about ***China's*** increasing demand for oil

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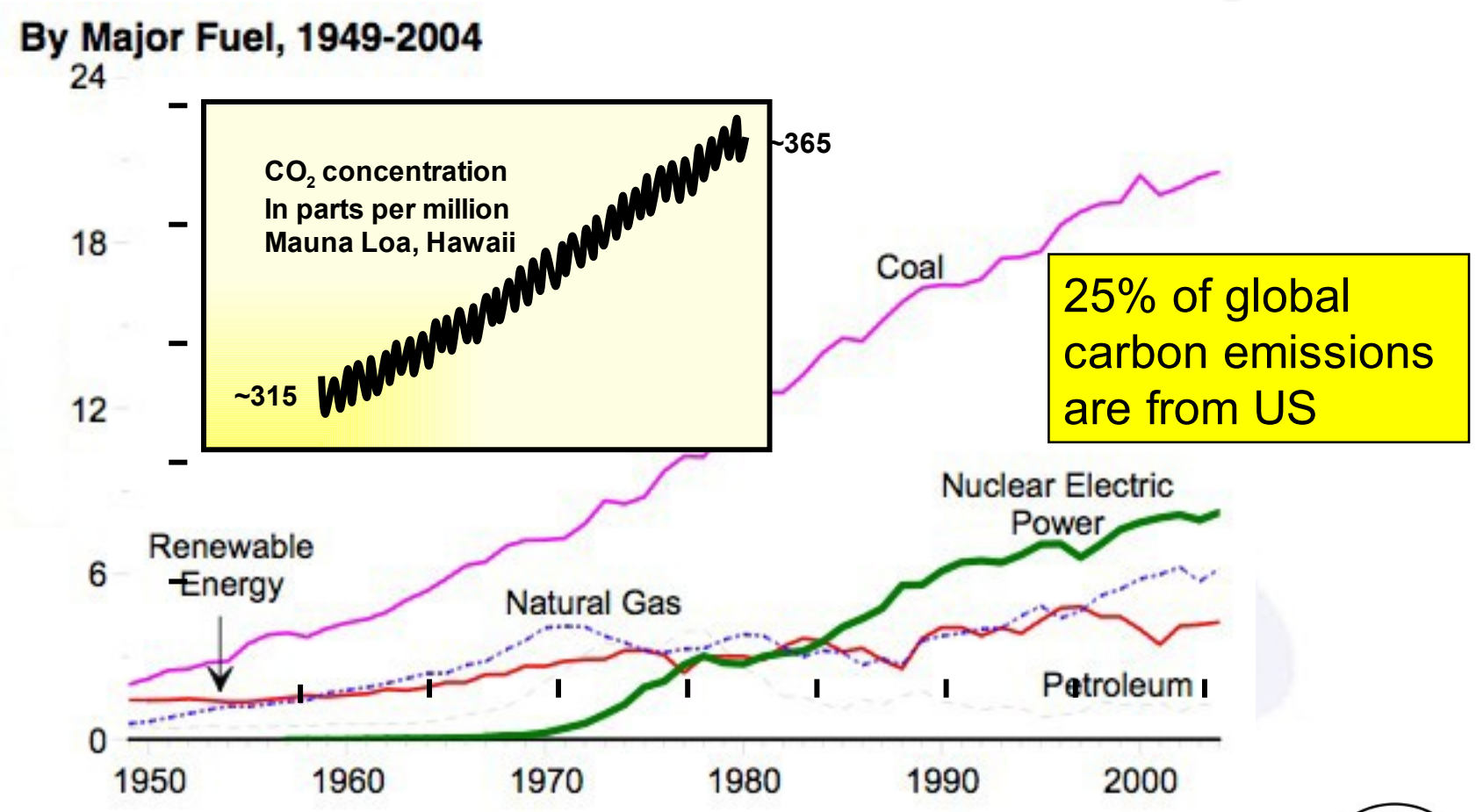
Carbon based fuel use is growing



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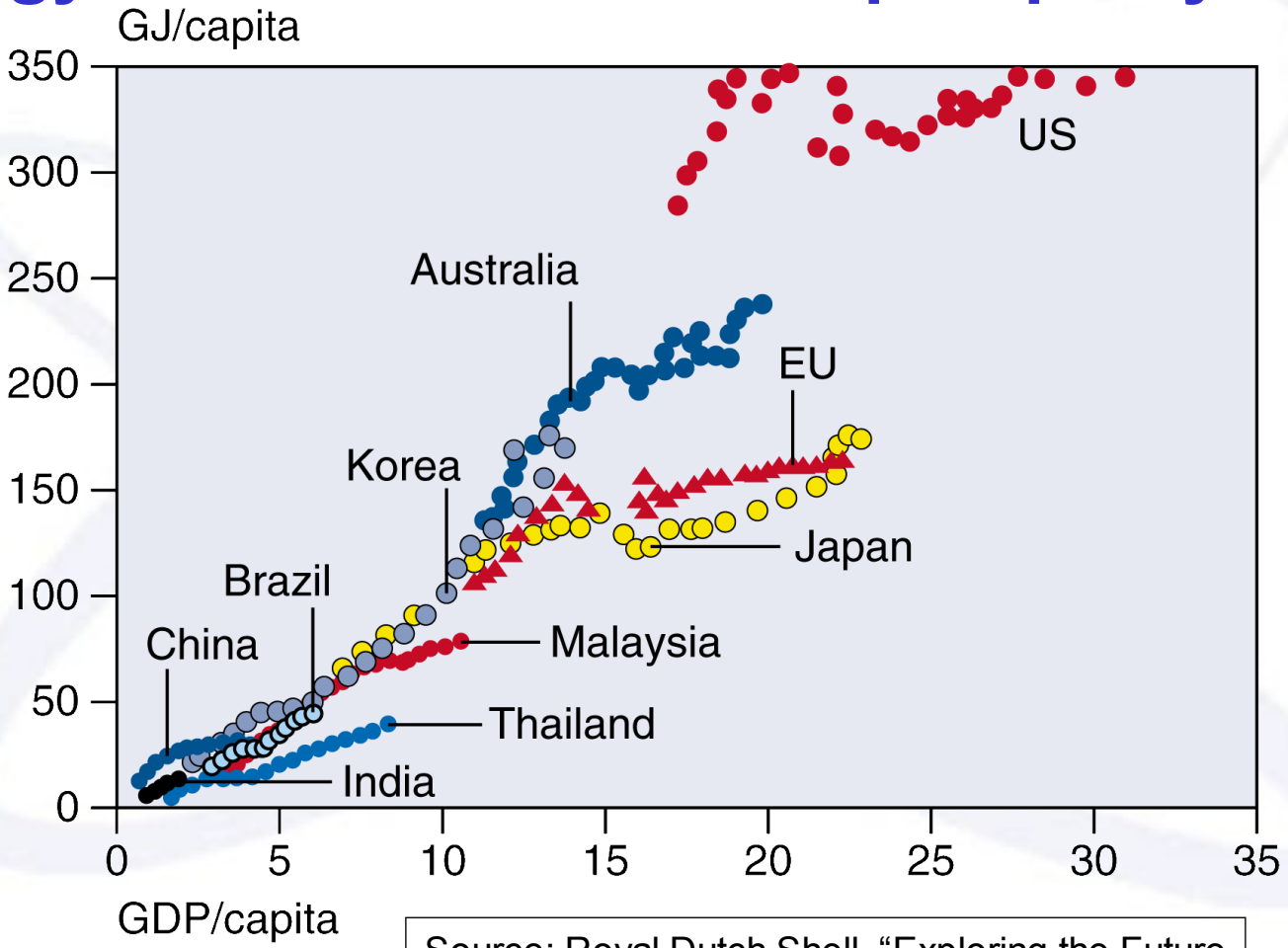
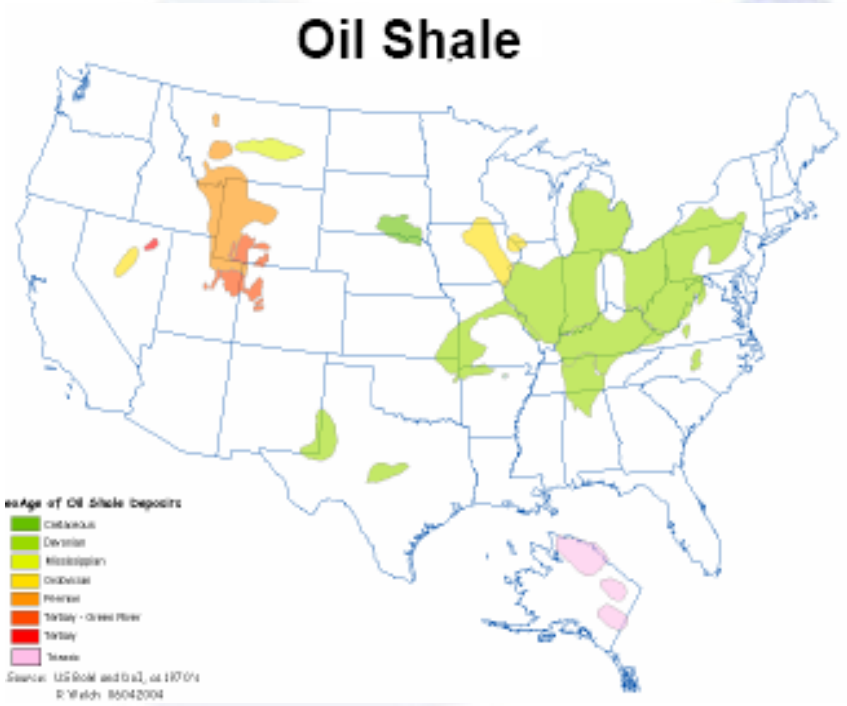
Energy is the fuel of national prosperity

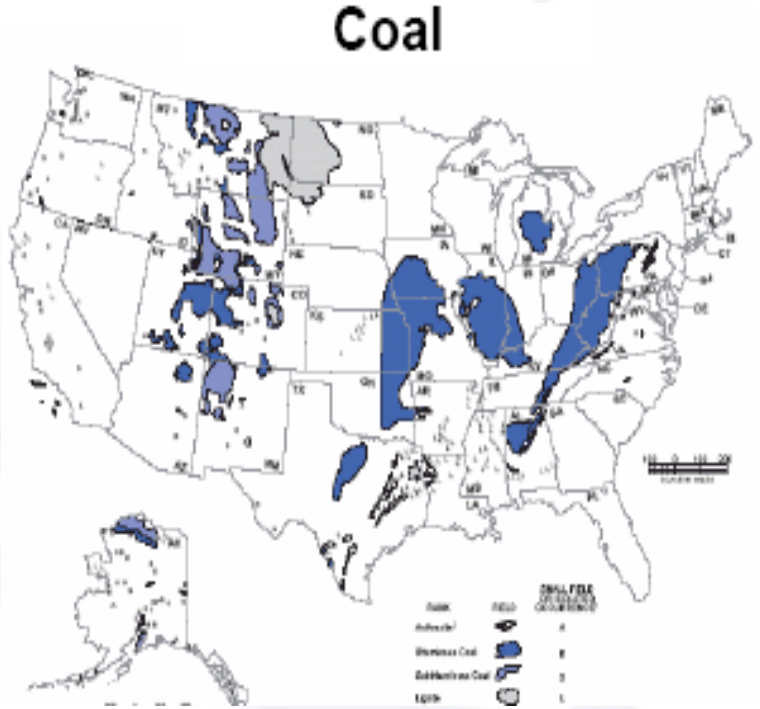


Source: Royal Dutch Shell, "Exploring the Future - Energy Needs, Choices and Possibilities

Resources in United States



~2 Trillion BOE



~800 Billion BOE

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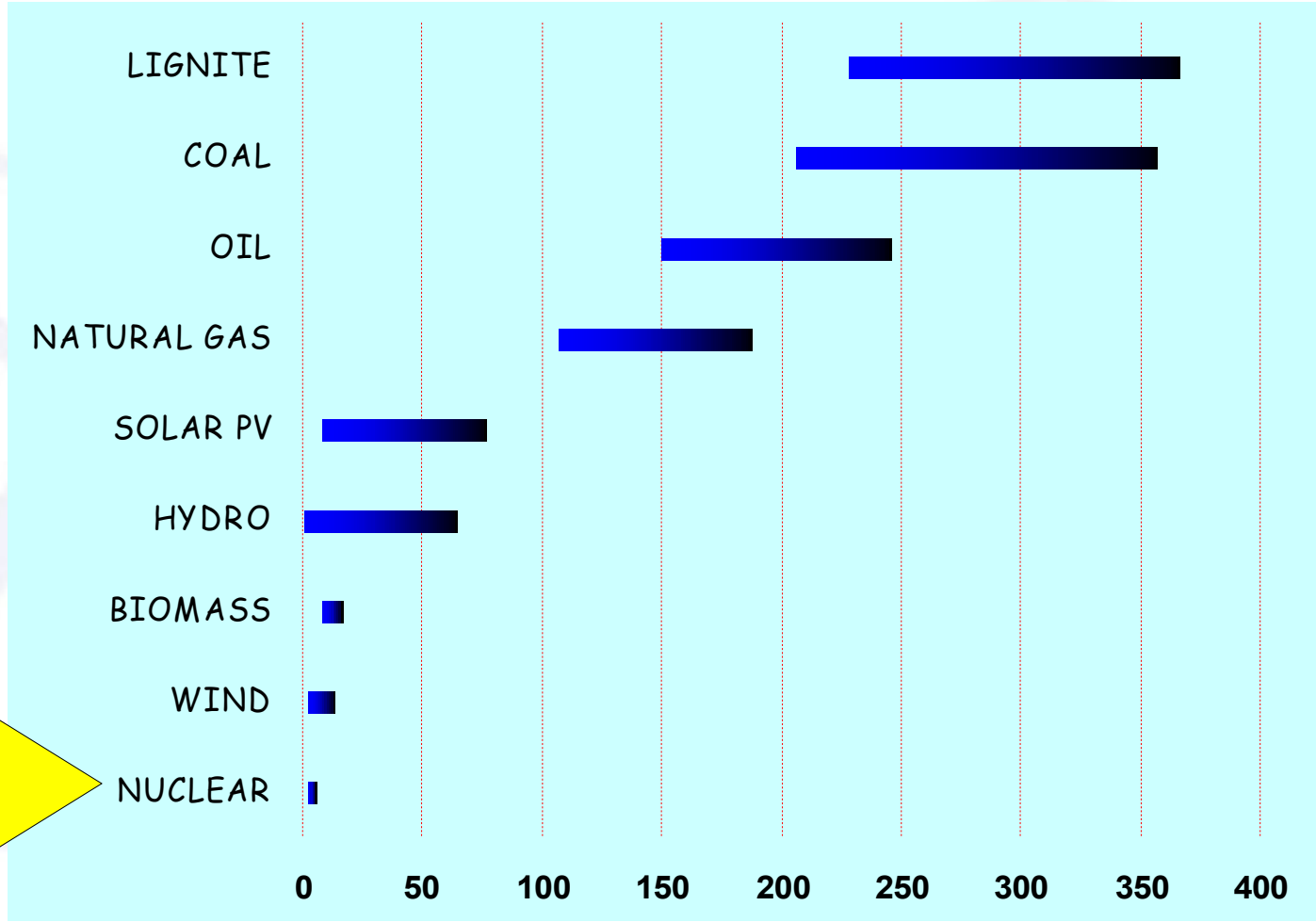
BOE – Barrels of Oil Equivalent

Source: EIA, 2005

Greenhouse gas (GHG) emissions

GHG
gC_{eq}/kWh



low carbon ✔

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Source: Sokolov, IAEA, 2005

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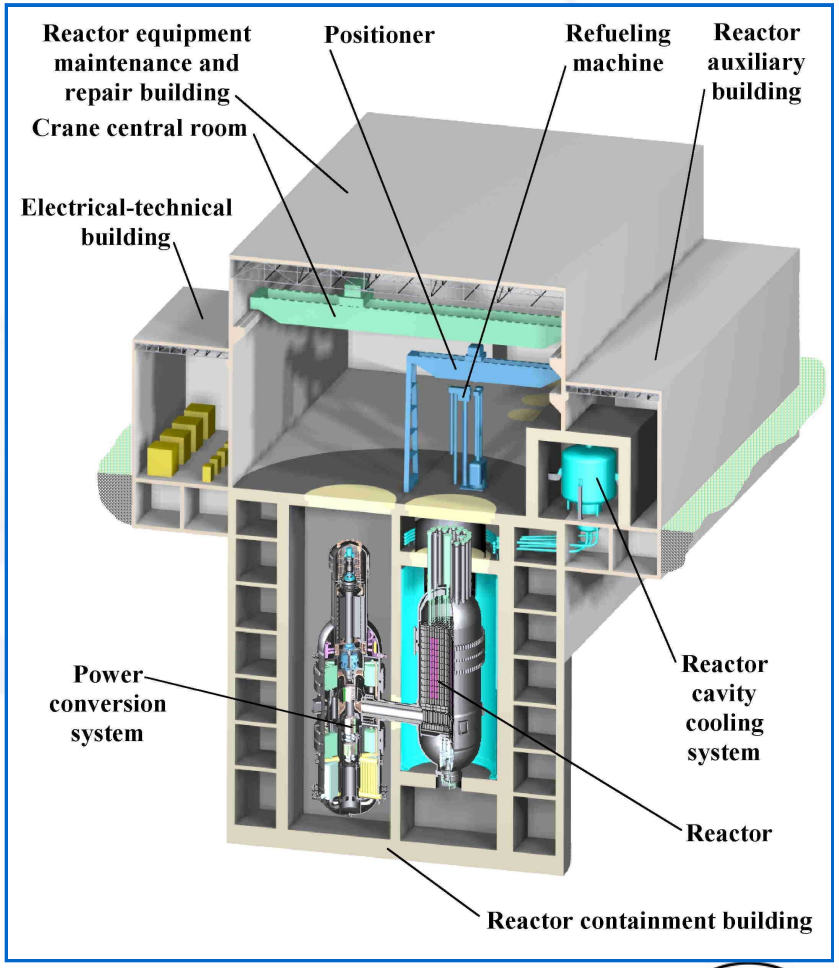
The Freedom Reactor

- **Modular Construction**
- **Low Cost**
  - Construction Time < 3 years
  - Capital Cost ~ $1120/kW ($n^{th}$-of-a-kind)
  - O&M + Fuel Costs < $15 / MWHr)
  - Low Staffing Levels
  - Low Decommissioning Costs
- **Proven Demonstrated Technologies**
  - 40 Years - Gas Reactor Experience
  - Core / Fuel Design - Fort St. Vrain
  - State-of-the-Art Large Turbine Design
  - New Compact Heat Exchangers



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Nuclear produced hydrogen may already be cost-competitive

- **H_2 currently made from natural gas by steam reformation**
  - At current ~$6.50/MBtu cost of NG, H_2 costs ~$1.50/kg or $11/MBtu
- **Production of H_2 from fission would cost ~$1.40/kg**
- **Could compete with natural gas today (at regulated utility capital rate)**
  - Increasing cost of natural gas and a possible CO_2 tax for fossil further increase advantage.

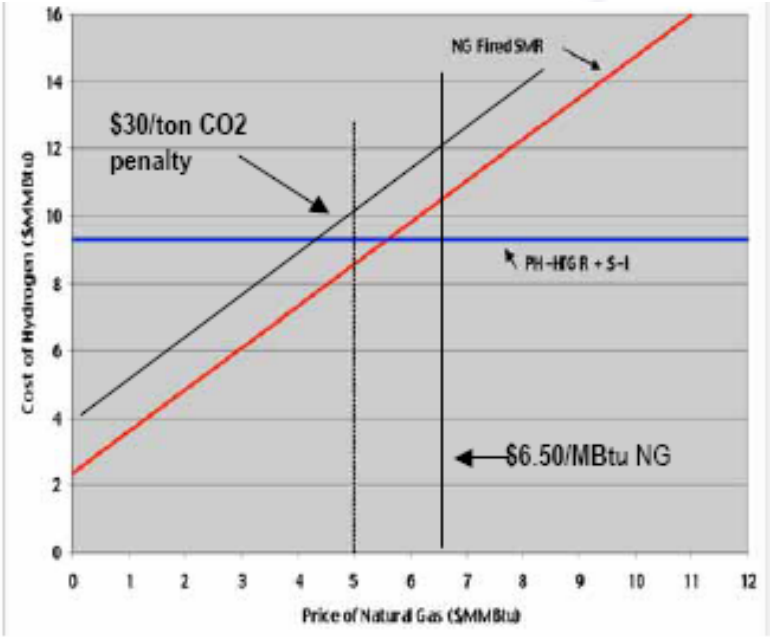

Figure courtesy of EPRI
$20/ton O_2 credit, no CO_2 penalty
Regulated utility capital cost rates used, 12.6% CRF

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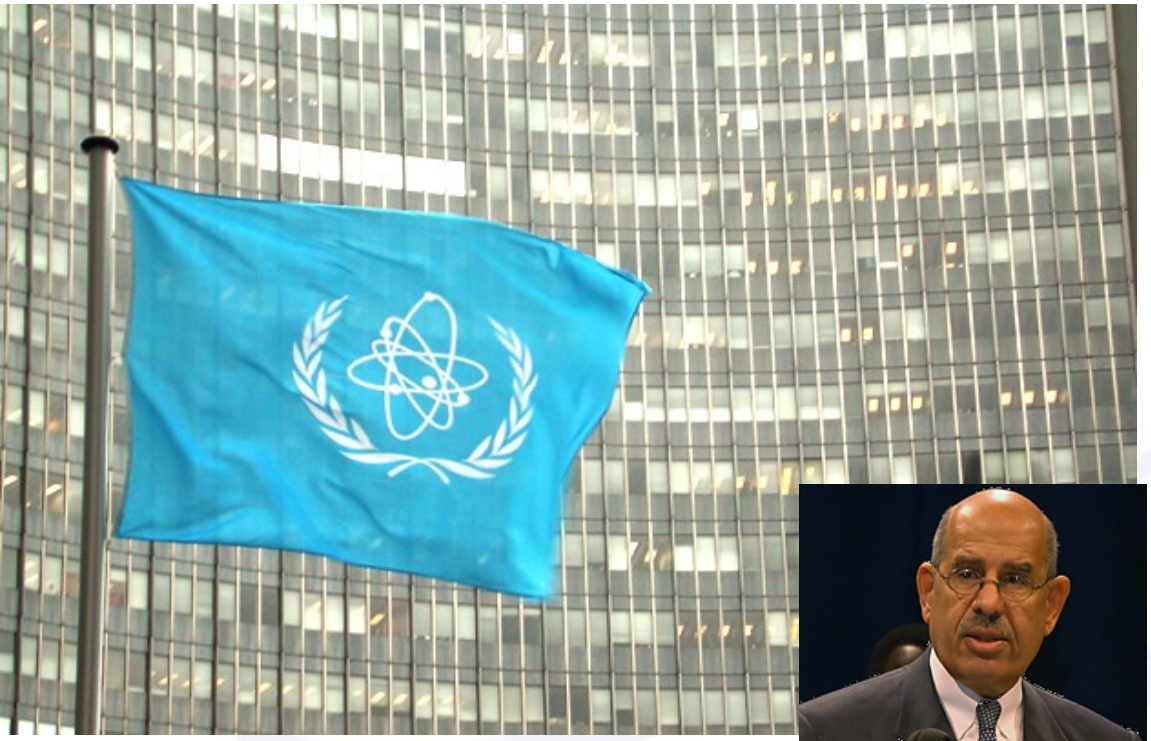
Conditions for nuclear to be a significant part of the 21st century energy mix

- Low carbon emission technology
- Affordable
- Expandable
- Sustainable
- Safe
- Accepted
- Doesn't leave a mess
- Consistent with national and international policy

Megatons to Megawatts



…atoms for peace.
2005 Nobel Peace Prize

- 1 out of 10 US light bulbs is powered by uranium from a former Soviet warhead
  - 6 trillion kW-hr
  - $12 billion cost
- Cost equivalent energy:
  - $600 billion in oil
  - $420 billion in gas
  - $43 billion in coal
- Energy equivalent:
  - 10 billion barrels of oil
  - 60 trillion cf natural gas
  - 3 billion tons of coal

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International Policy ✔

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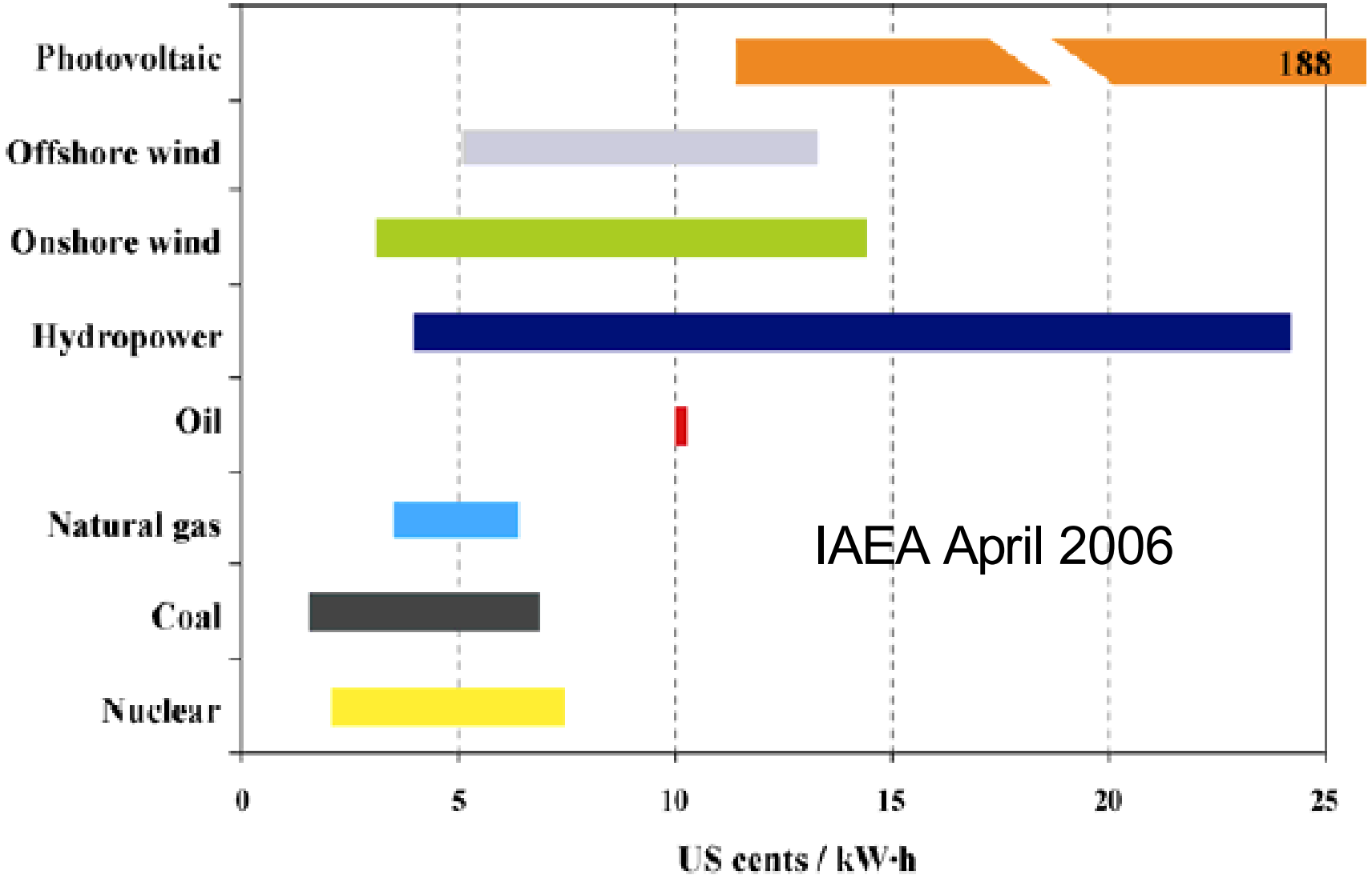
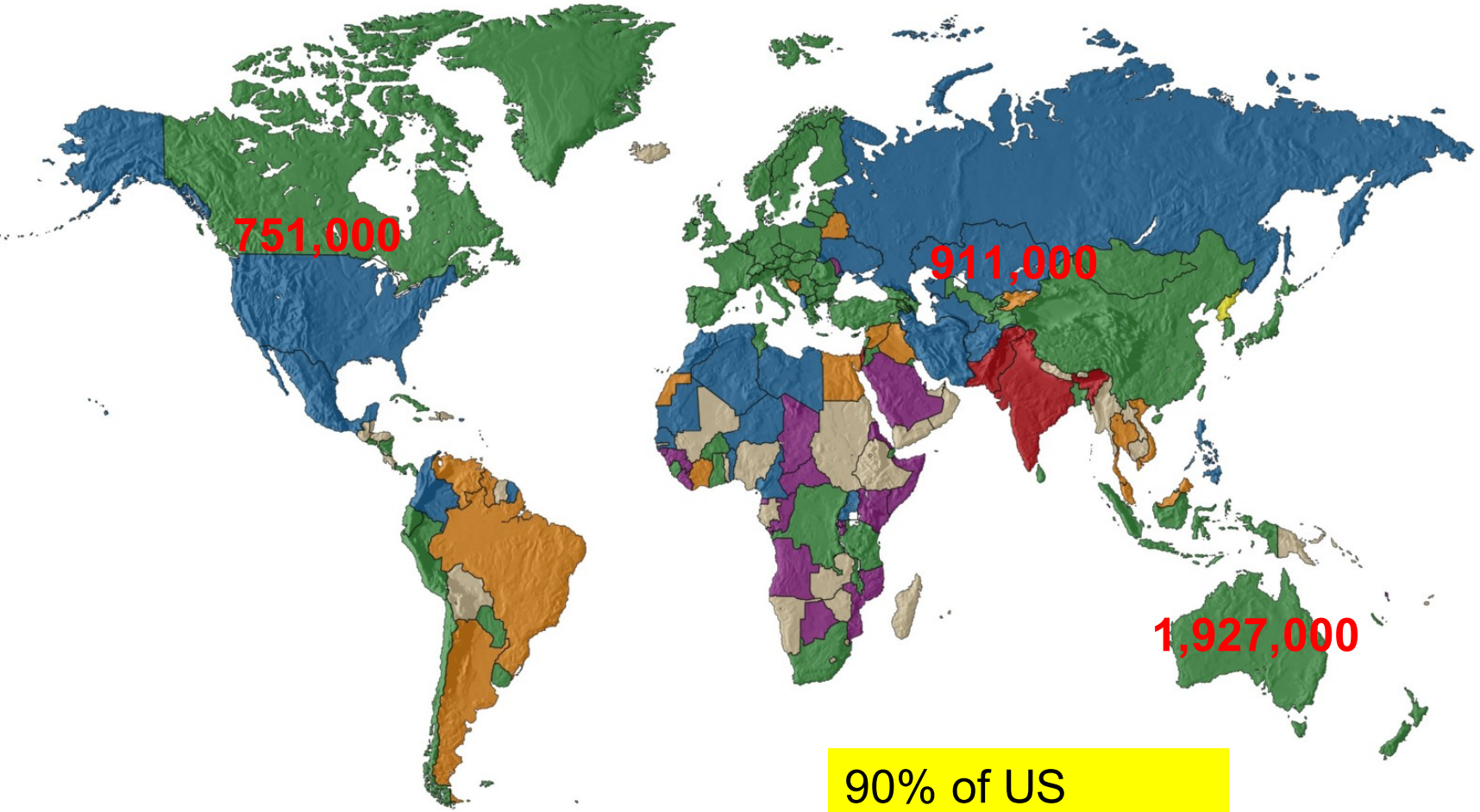
Results of 7 recent forward cost studies



Uranium resources are ample



90% of US enriched uranium is imported

INFCIRC/153 & AP in force
INFCIRC/153 & AP signed but not implemented
INFCIRC/153 Safeguards
Signed Small Quantity Protocol Declaration
NPT States without Safeguards Agreements
Non-NPT States with INFCIRC/66 Safeguards
"Withdrawn" from NPT (DPRK)

Safeguards Agreements Status as of 1 March 2005
Additional Protocol Status as of 1 March 2005

AMERICAN NUCLEAR SOCIETY

G-8 Ministers Statement

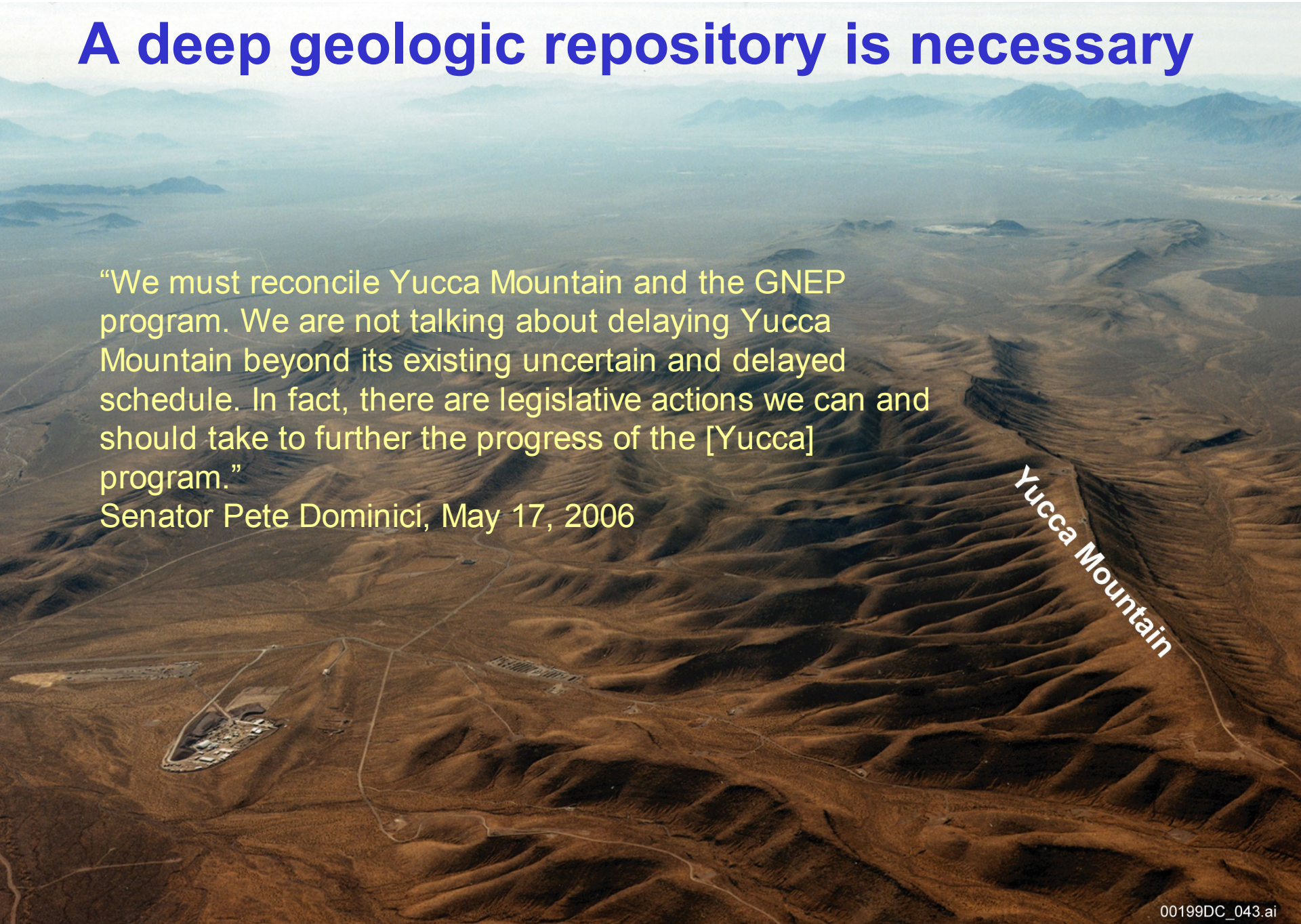
21 March 2006

International Policy ✔

"For those countries that wish, wide-scale development of safe and secure nuclear energy is crucial for long-term environmentally sustainable diversification of energy supply."

A deep geologic repository is necessary

"We must reconcile Yucca Mountain and the GNEP program. We are not talking about delaying Yucca Mountain beyond its existing uncertain and delayed schedule. In fact, there are legislative actions we can and should take to further the progress of the [Yucca] program."
Senator Pete Dominici, May 17, 2006



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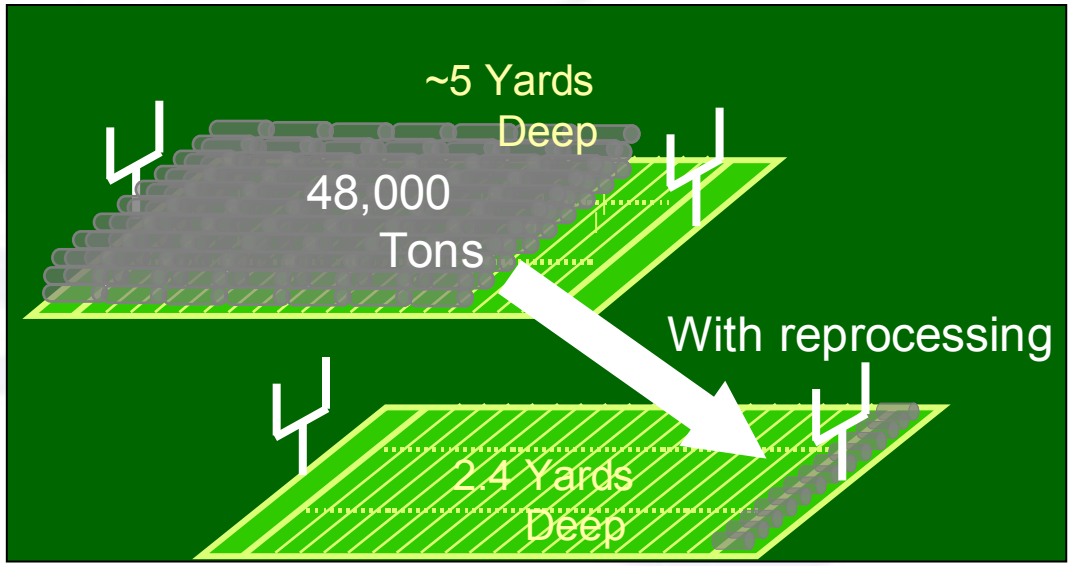
Total amount of used fuel generated is relatively small and readily manageable

Current high-level waste volume after 40 years of operations would fill an area about the size of a football field five yards deep

- ~48,000 metric tons
- ~½ ton per fuel assembly
- ~ 100,000 assemblies
- Only ~5% is waste



No environmental mess

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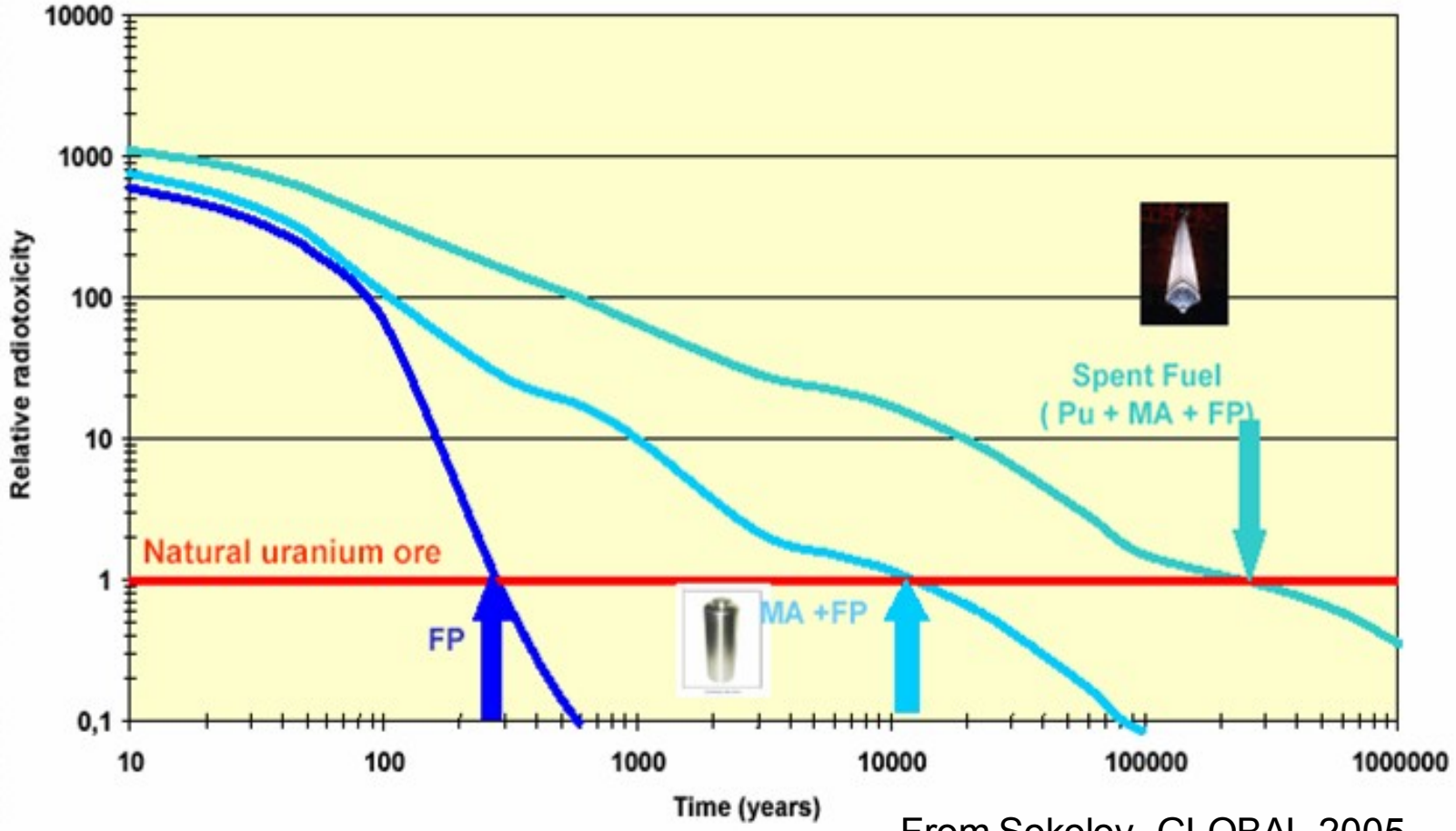
Reprocessing reduces future risk

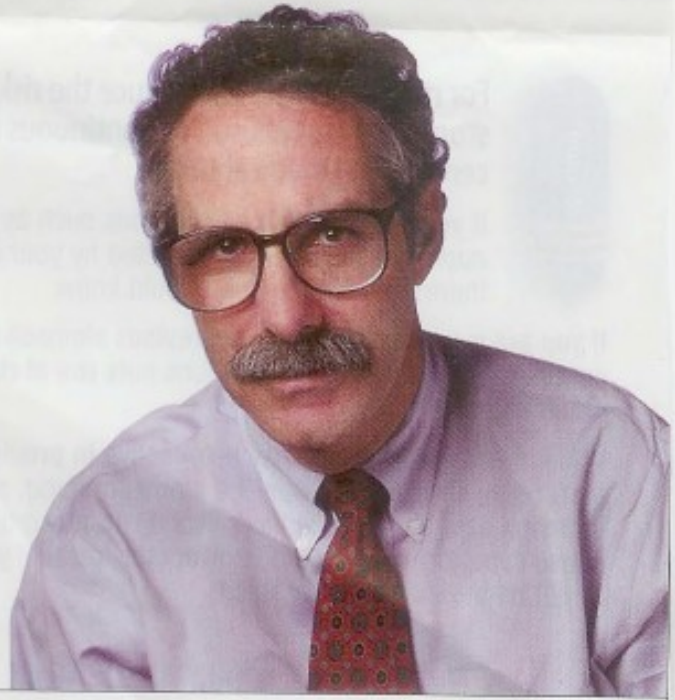


From Sokolov, GLOBAL 2005

Idaho National Laboratory

Supplying clean nuclear energy will not be easy

—ROBERT J. SAMUELSON



Newsweek

News. Trends. Voices.

"We Americans want it all: endless and secure energy supplies; low prices; no pollution; less global warming; no new power plants (or oil and gas drilling, either) near people or pristine places. This is a wonderful wish list, whose only shortcoming is the minor inconvenience of massive inconsistency."

Nuclear energy policy will remain in conflict

The leading nations of Europe, working with the United States, are preparing to offer Iran new assistance in building a light-water nuclear reactor for civilian use in return for Iran's ending activities suspected of being a cover for a weapons program, European and American diplomats said Tuesday [May 17]. New York Times

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Role of American Nuclear Society
and other international nuclear societies

- Provides forum to develop and apply technology to benefit all humanity
- Serves as credible voice for exchange of nuclear information

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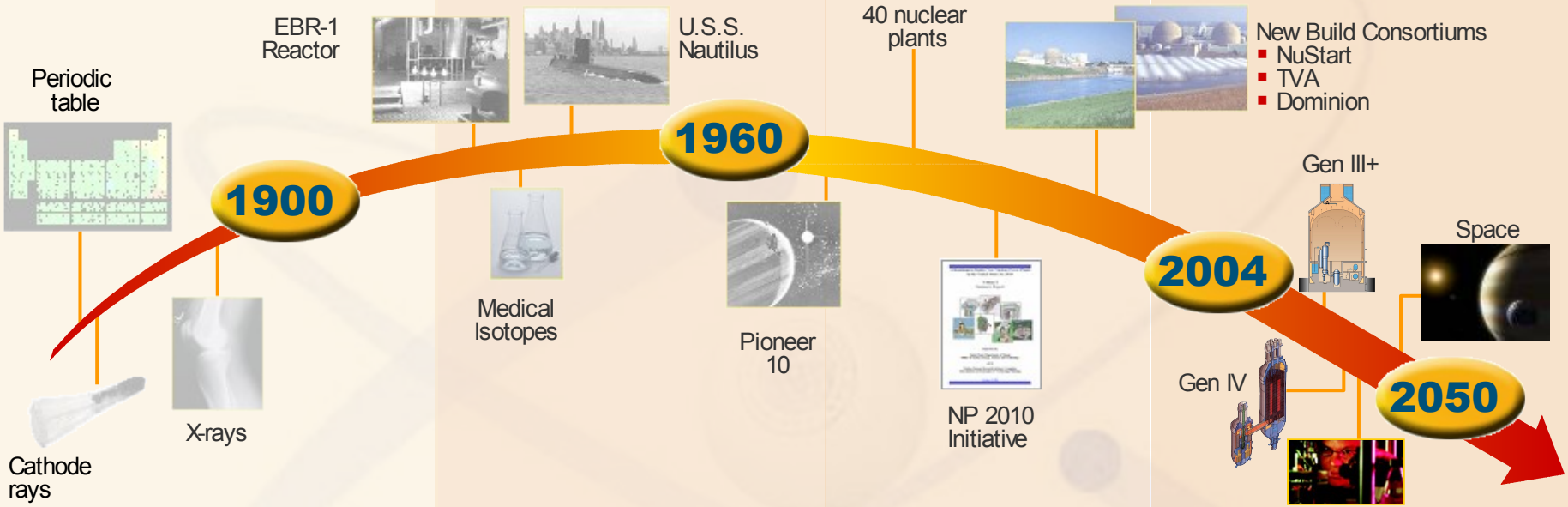
Tomorrow's Vision Coming into Focus



The Faces of Tomorrow

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Sección Latinoamericana/ANS

Resurgimiento Nuclear en Los Estados Unidos

Harold McFarlane

27 Junio 2006

Idaho National Laboratory