Nuclear Energy:
Poised for Expansion

2006 International High-Level Radioactive Waste Management Conference

"Global Progress Toward Safe Disposal"

Las Vegas, Nevada
May Day 2006

Harold McFarlane

Deputy Associate Laboratory Director for Nuclear Programs
Idaho National Laboratory

Vice President / President-Elect
American Nuclear Society

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Why nuclear is green / Why it's not green enough

- Safe
- Potentially sustainable
- Minimal air emissions
- Readily expandable
- Minimal solid waste
- It's now a "cool" conversation topic
- Strong environmental endorsements
- Economically competitive

- Extractive industry
- Lingering nonproliferation issues
- *Safe, effective disposition of spent nuclear fuel not yet demonstrated*

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What's driving nuclear expansion

- Rapid increase in global energy demand
- Rising importance of carbon free energy sources
- Policy shifts
- Outstanding performance
- Economics
- Menu of new products
- Desire for energy security

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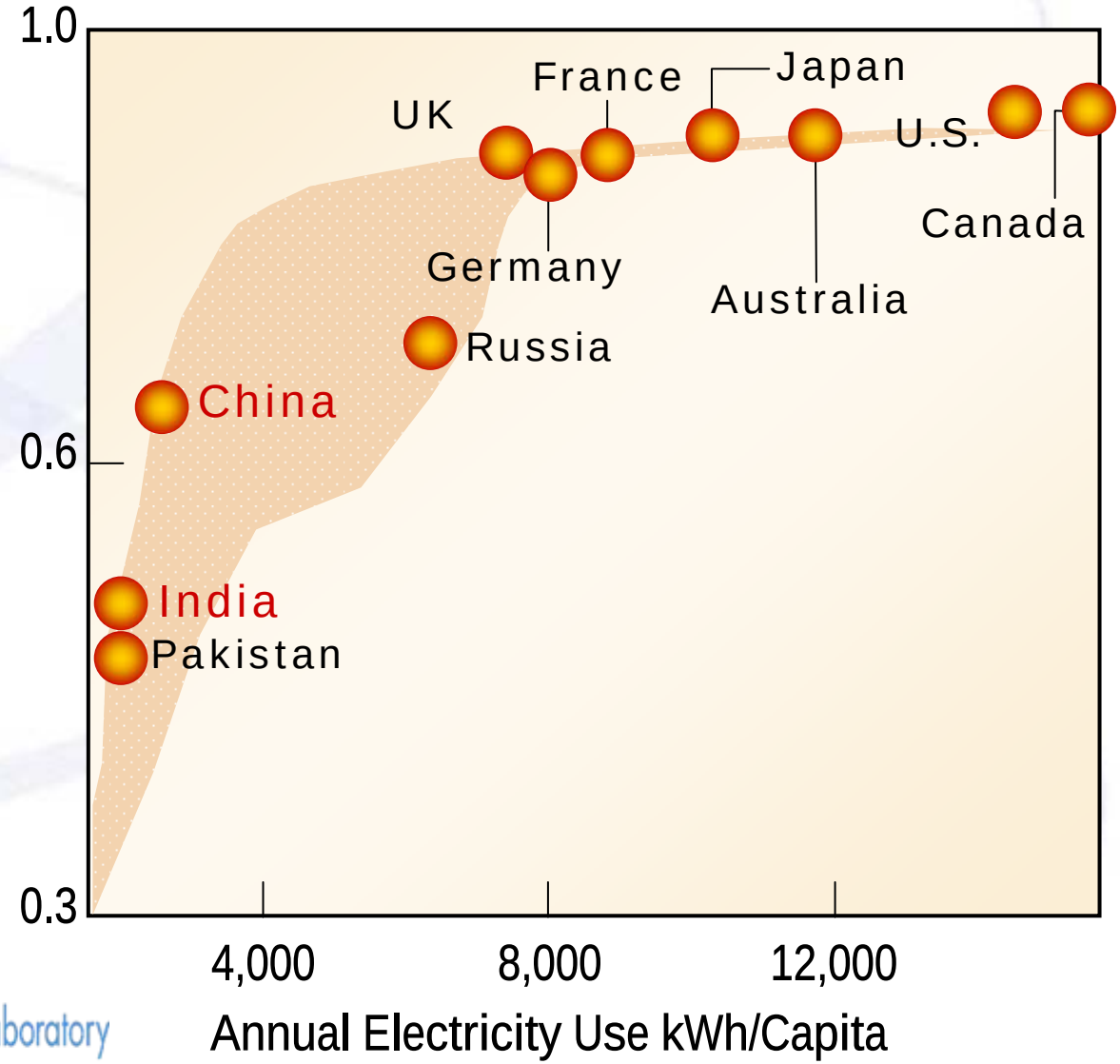
Access to energy essential to quality of life

80% of the world's population is below 0.8 on the UN's Human Development Index (HDI)

Prosperity

Education

Life span



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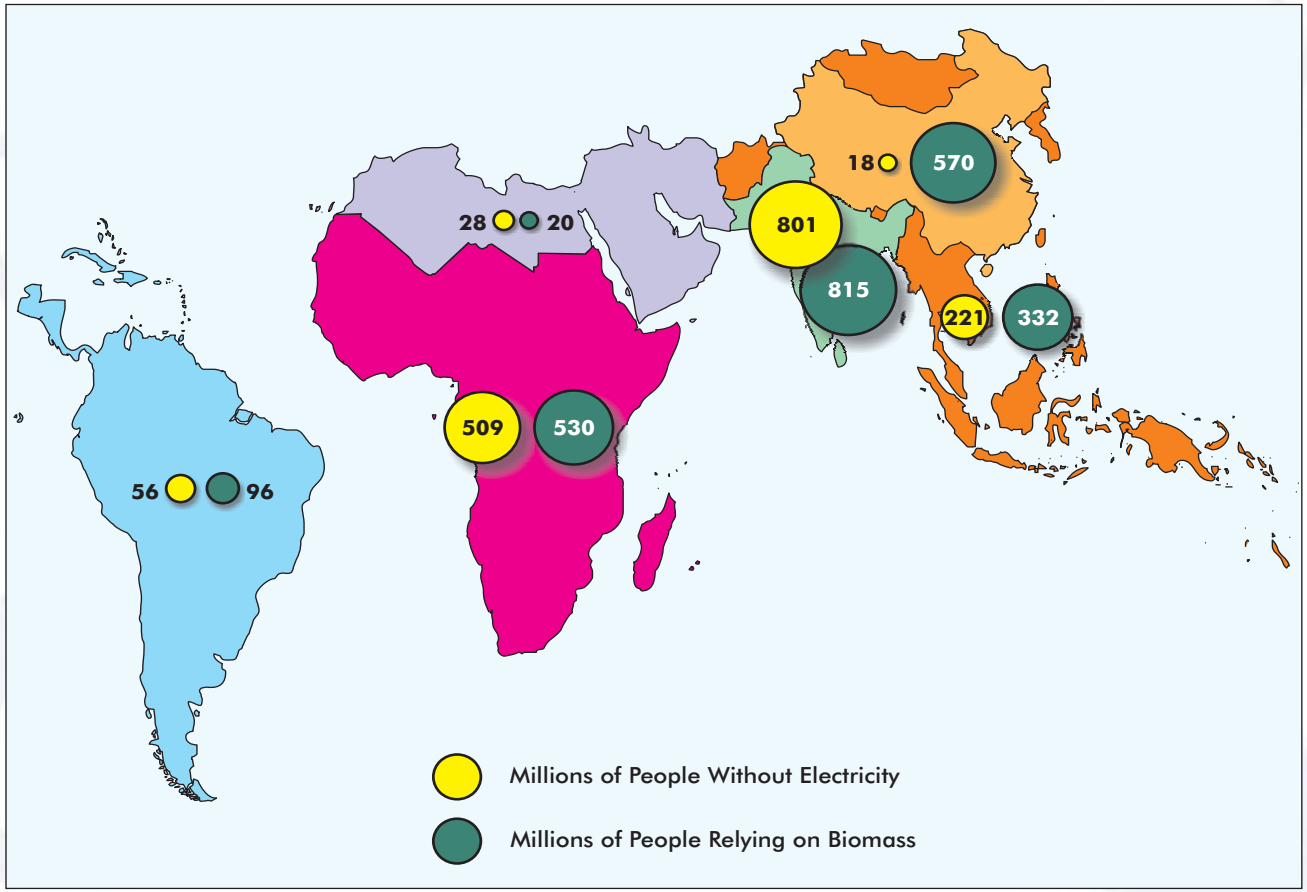
Map of Global Energy Poverty



1.6 billion people have no access to electricity, 80% of them in South Asia and sub-Saharan Africa

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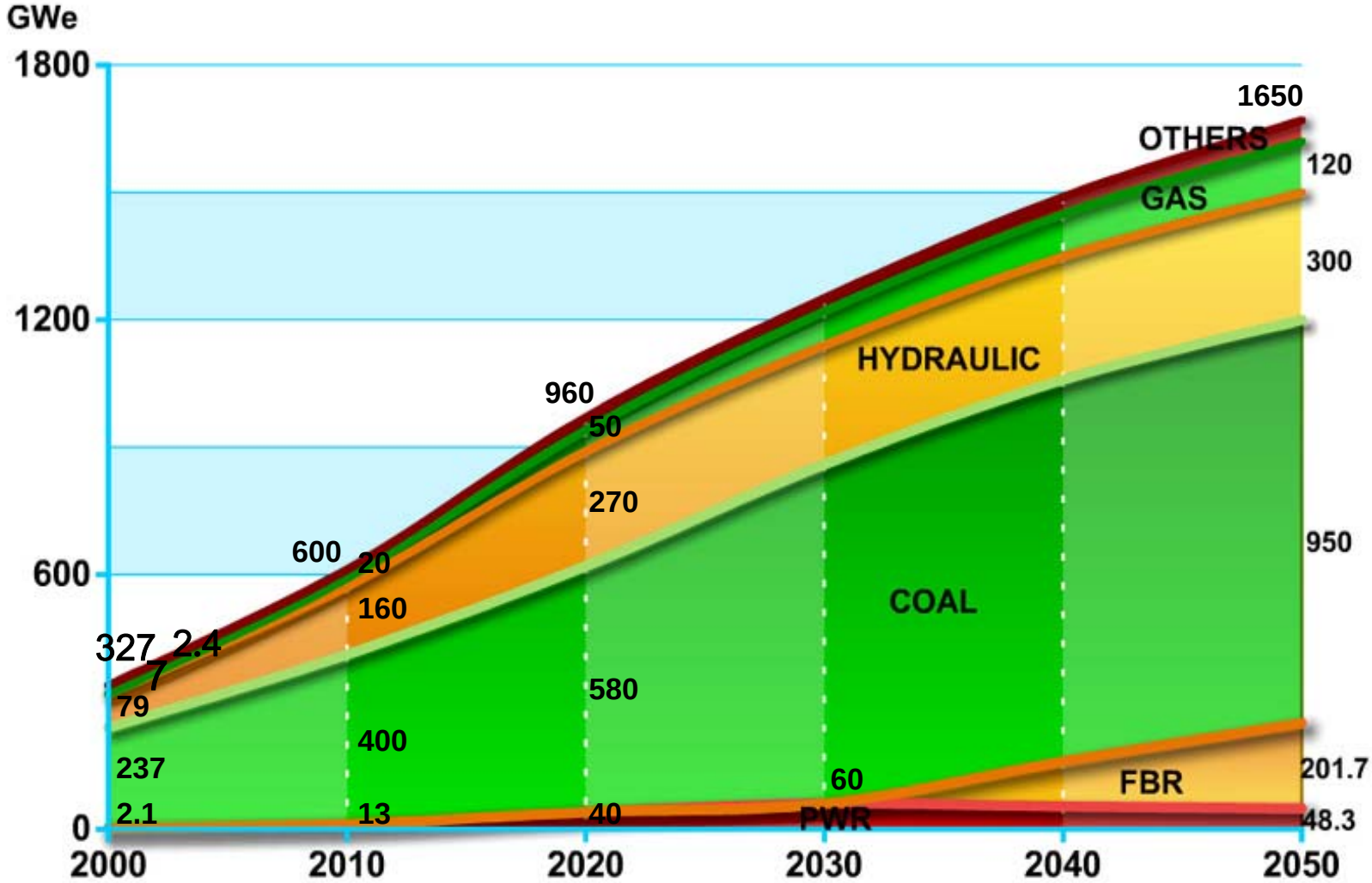
China's electric development plan



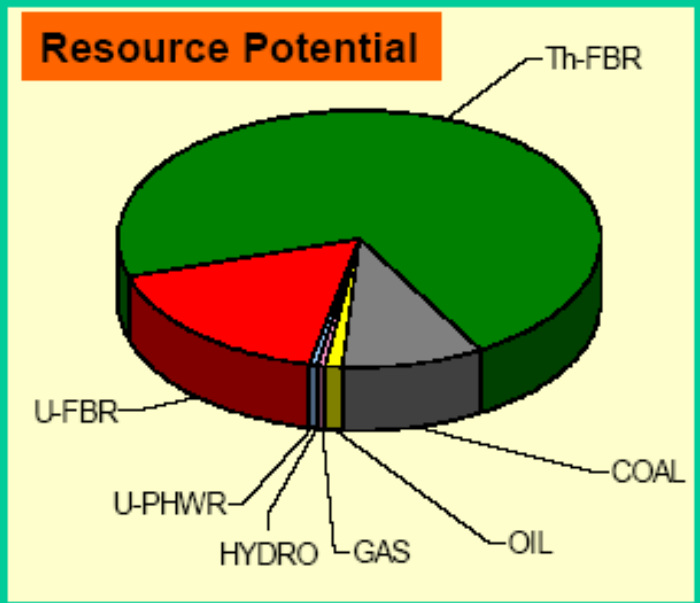
Electric Capacity Development Envisaged In China

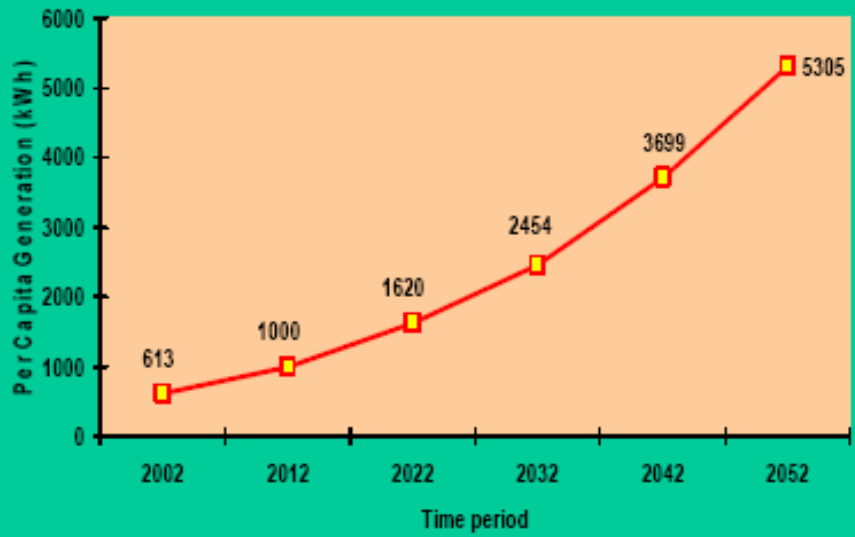
Indian Energy Growth Scenario

	2003-04	2052
➢ Electricity Generation (GWe)	112.0	~ 1344
➢ Nuclear Energy Share (GWe)	2.72	~ 275
➢ PHWR (GWe)	2.10	~ 0

➢ Faster Growth is needed to reach the target

➢ FBR with Closed Fuel Cycle is inevitable





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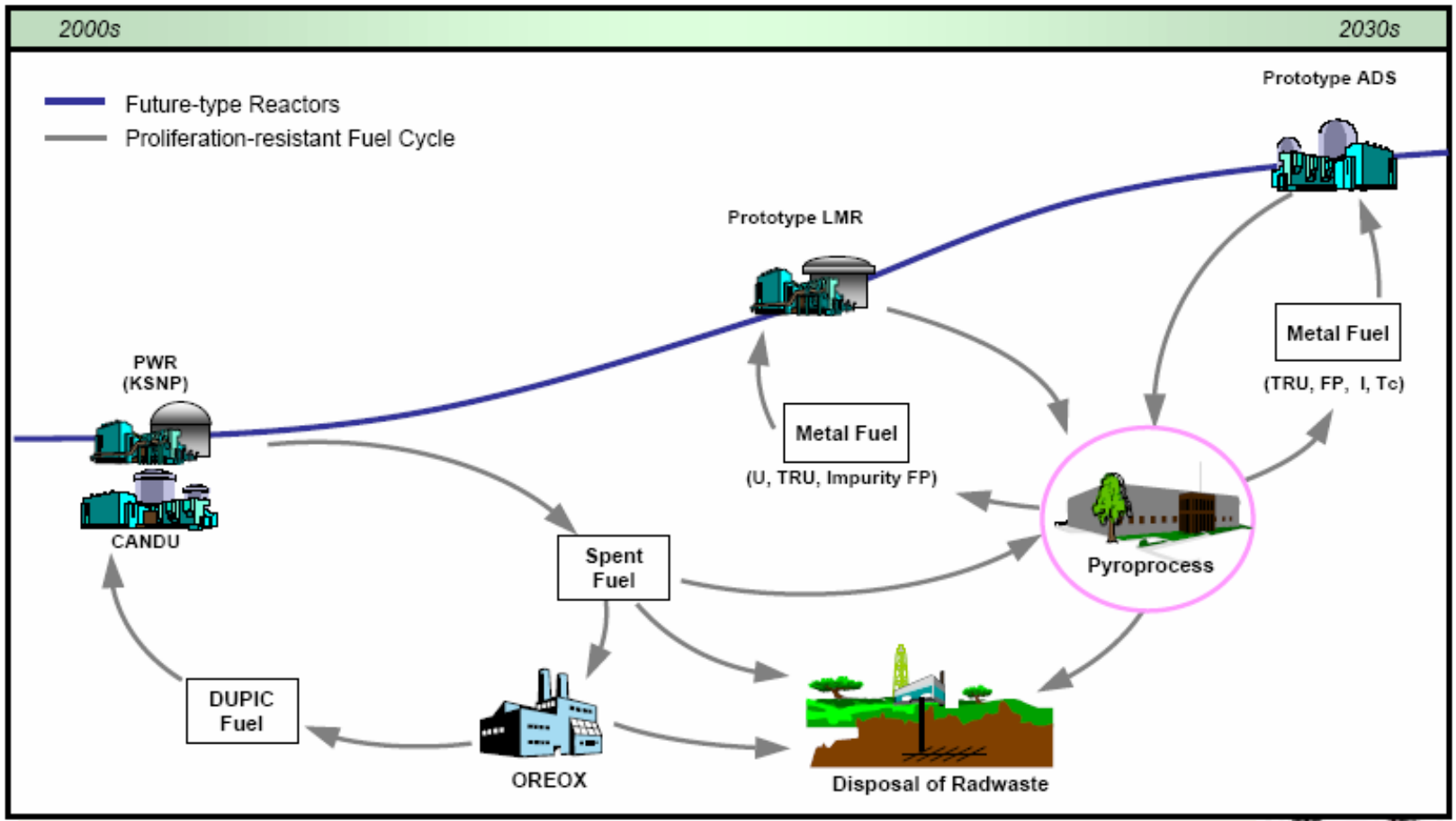
Baldev Raj, GLOBAL 2005, October 2005

South Korea

Prospect of Advanced Nuclear Fuel Cycle : KIEP-21

"K : Korea, I : Innovative, E : Environmentally friendly, P : Proliferation resistant"



GLOBAL 2005 International Conference, Tsukuba, Japan

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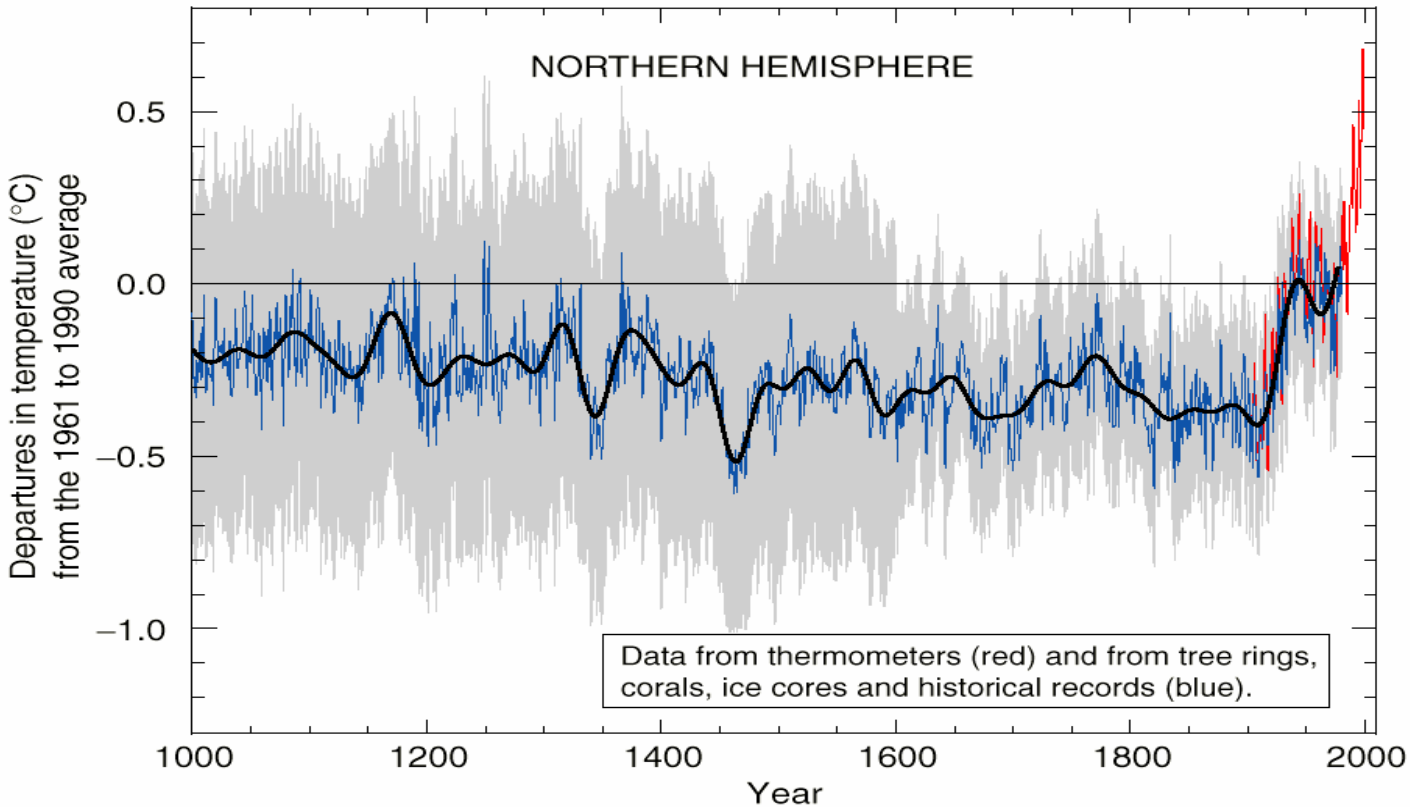
Prof. Jun Kai Lee, October 2005
(Ph.D. Princeton 19XX)

Current unit expansion in Asia/Europe

Country	Operating Units	Number of Units Under Construction	Near-Term Plan (GWe)	By (year)
India	14	8	29.5	2022
South Korea	20	6	26.6	2015
Russia	30	4	40	2020
Japan	52	3	15	2025
China	9	2	40	2020
Ukraine	8	2	22	2030
Pakistan	2	—	8.5	2030
Iran	0	1	—	—
Romania	1	1	—	—
Finland	4	1	—	—

Climate change is taking place



Estimated Change in Northern Hemisphere Temperature Since 1000 AD

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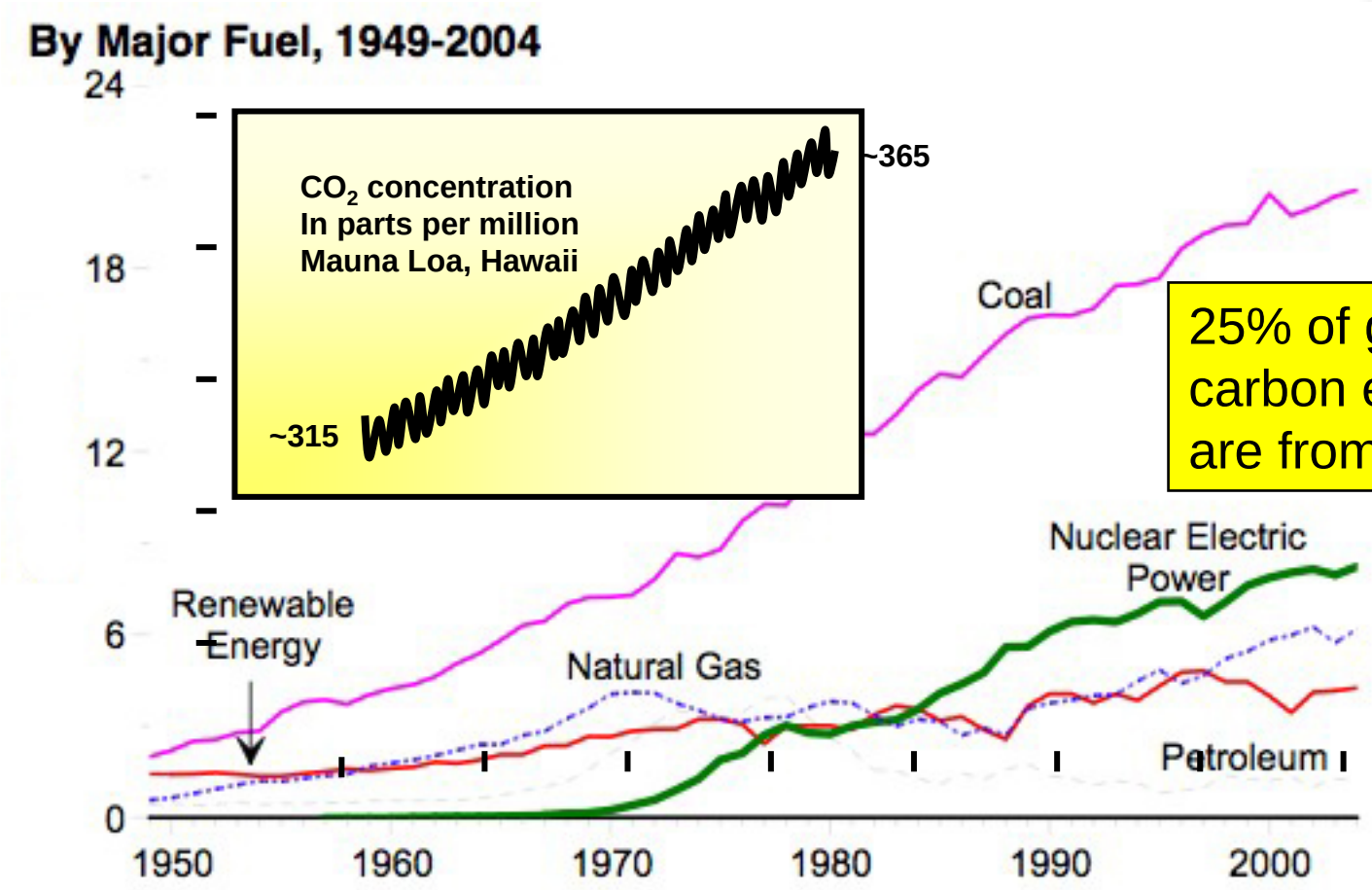
Carbon based fuel use is growing



25% of global carbon emissions are from US

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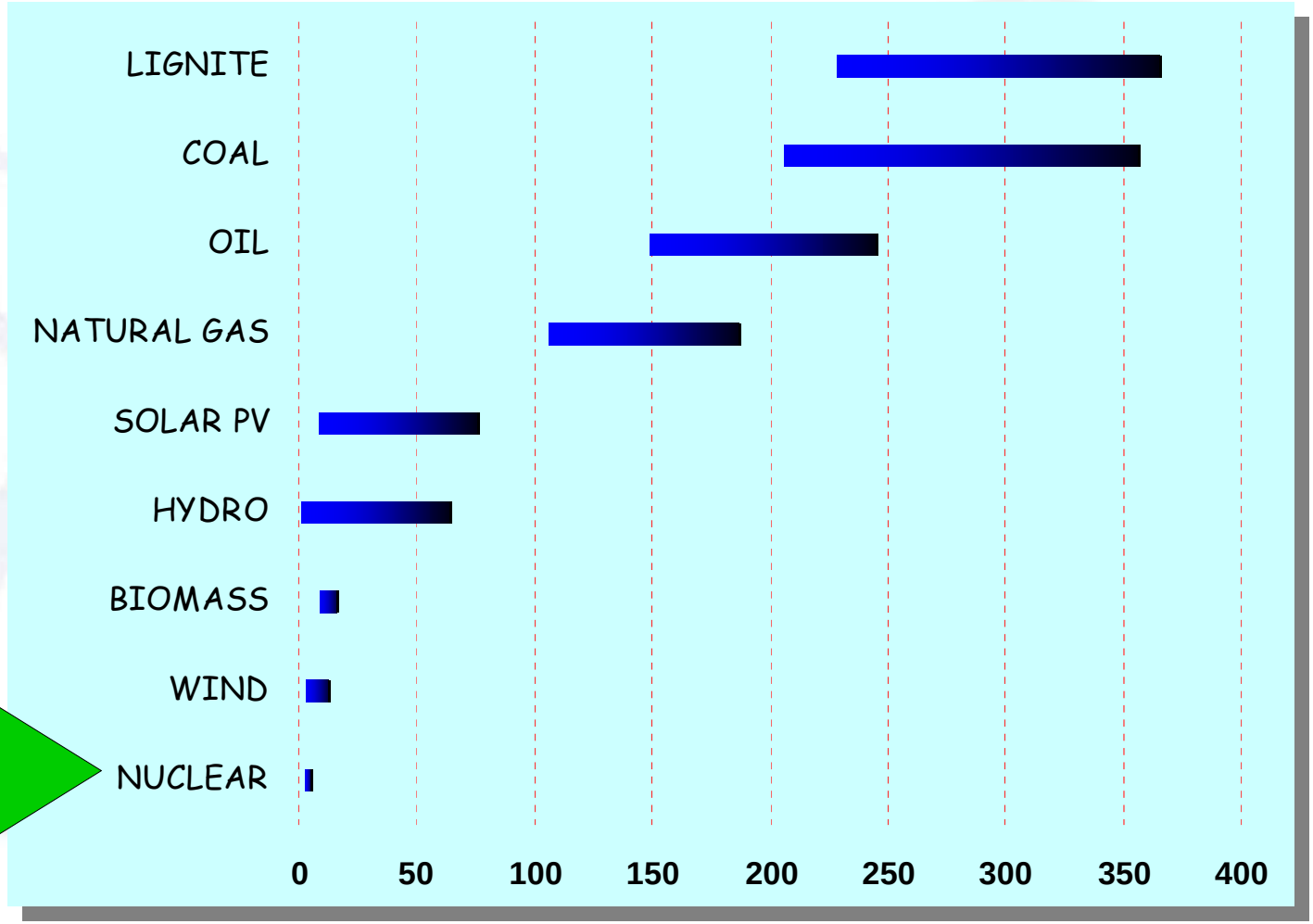
Greenhouse gas (GHG) emissions

GHG
gC_{eq}/kWh



low carbon ✔

Source: Sokolov, IAEA, 2005

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The Energy Policy Act of 2005

Energy Policy Act of 2005

Nuclear

New Plant Construction

- Loan guarantees
- Risk assurance
- Production tax credit
- Price-Anderson
- Decommissioning funds

R&D

- Next generation nuclear plant
- Nuclear hydrogen production
- Advanced fuel cycle initiative
- Nuclear engineering program
- Medical isotopes

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

Key provisions for R&D

Next generation nuclear plant	• $1.25B • Test 2 advanced designs of INL
Nuclear hydrogen production	• $200M • Demonstrate production of hydrogen
Advanced fuel cycle	• $580M • More proliferation-resistant fuel
University nuclear engineering program	• $56M • Recruit and educate students in nuclear science and technology
Medical isotope assurance	• Clarifies procedures for licensing the export of HEU • Ensure a robust, affordable supply of isotopes to U.S. medical community

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accepted ✔

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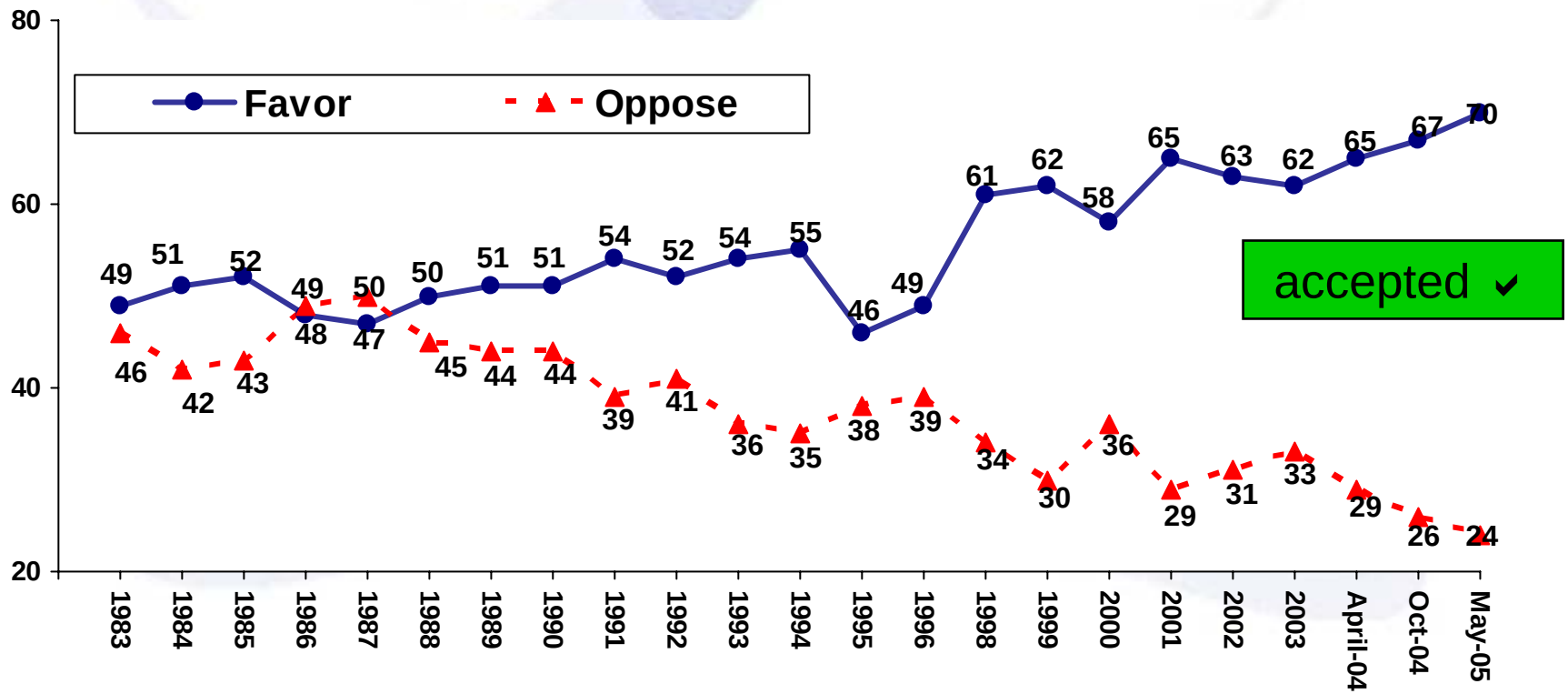
Nuclear Energy widely favored in USA



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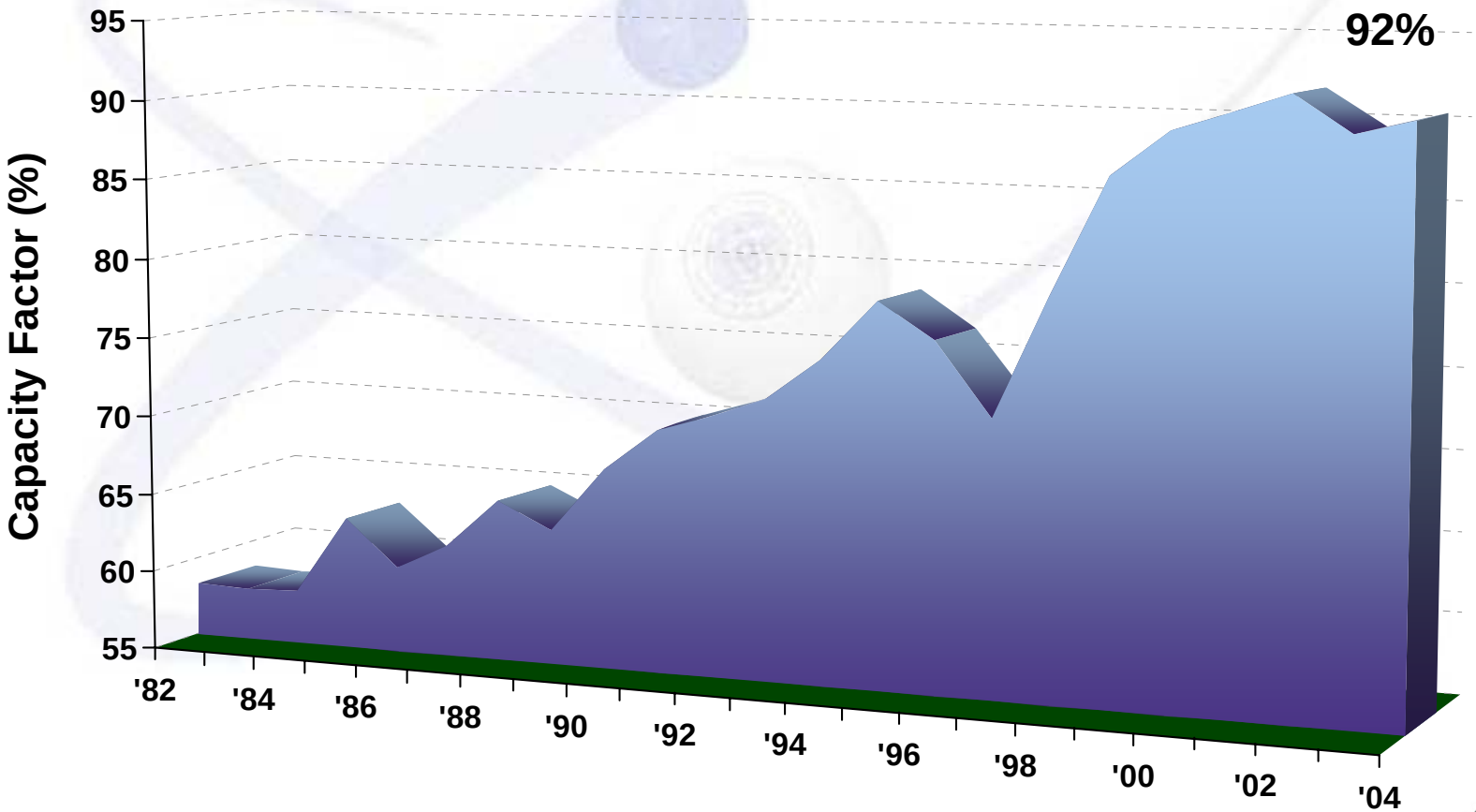
Nuclear power's proven performance



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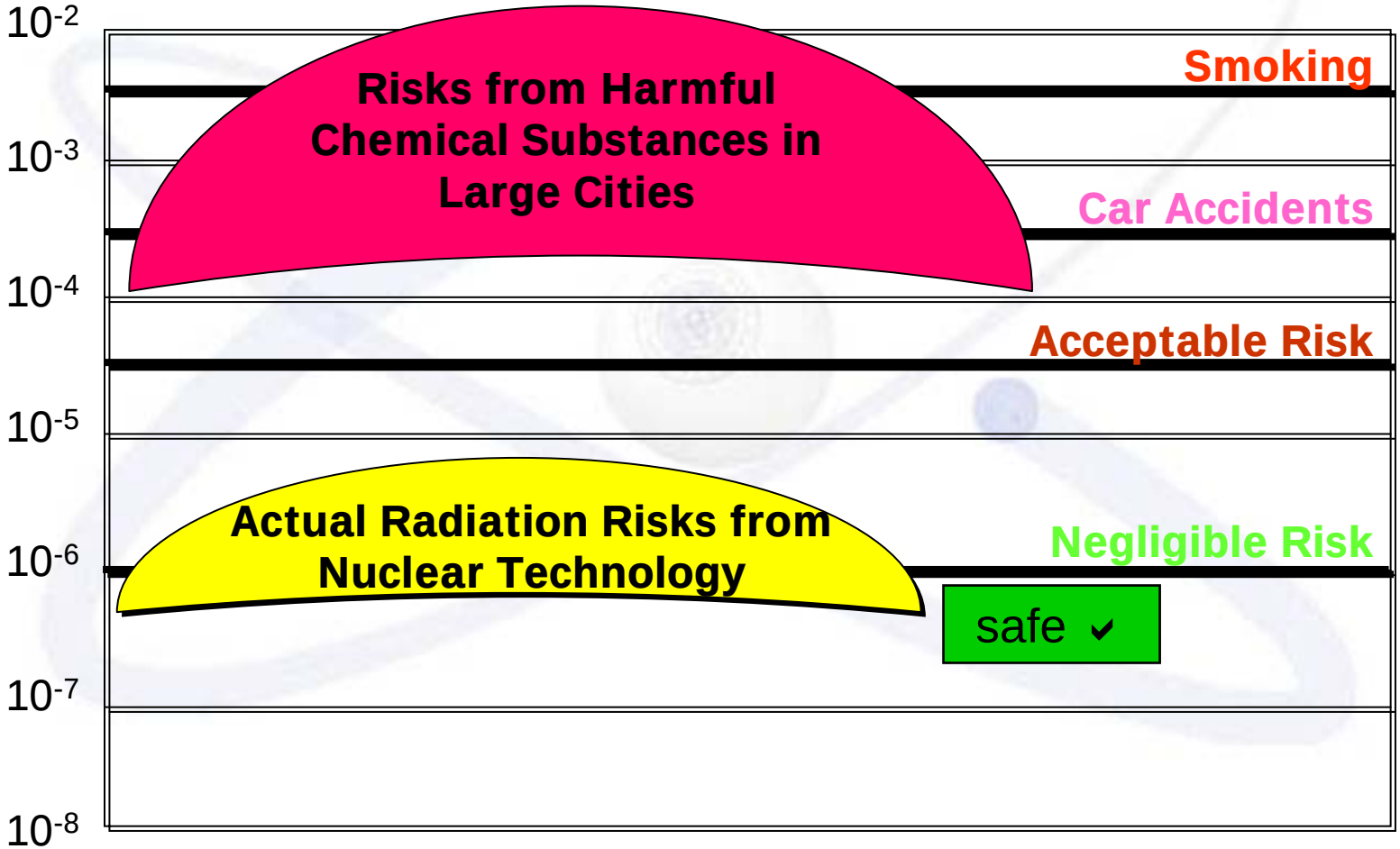
Source: Energy Information Administration/Nuclear Regulatory Commission

Nuclear technology has low risk



Sokolov, IAEA

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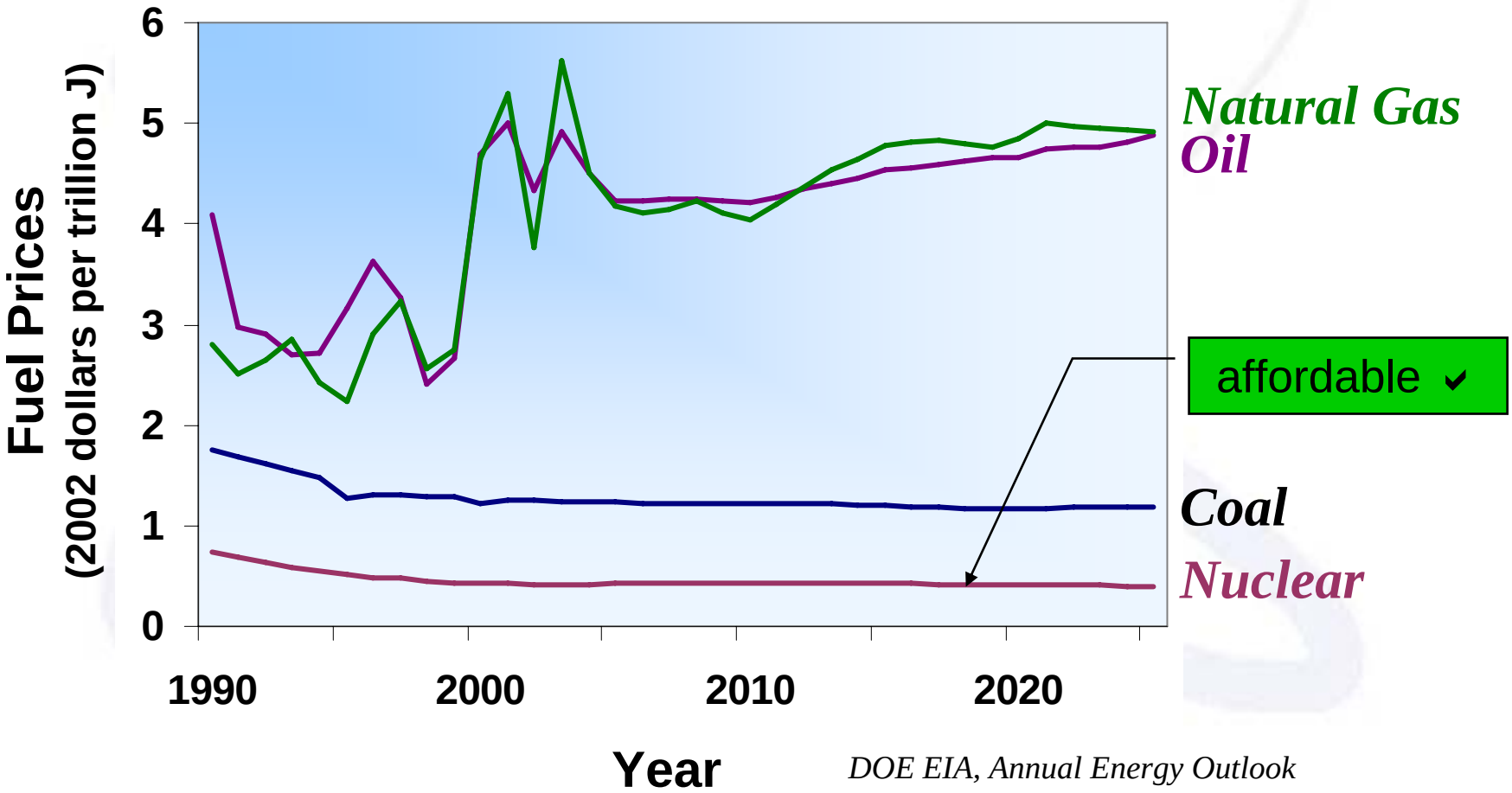
20th Anniversary of Chernobyl

safe ✔

- Impact reports released this year
  - IAEA: 4000 deaths based on World Health Organization study
  - Greenpeace: 95,000 deaths
  - Immediate deaths: 28
  - Most physical impacts were avoidable!
    - No evacuation plan or action
    - No quarantine of milk supply (iodine exposure—virtually all observed cancers are thyroid)
  - Mental health impact for 600,000 people
- 11 more RBMK reactors still in operation

U.S. fuel prices to electricity generators



DOE EIA, Annual Energy Outlook 2004, Figure 73

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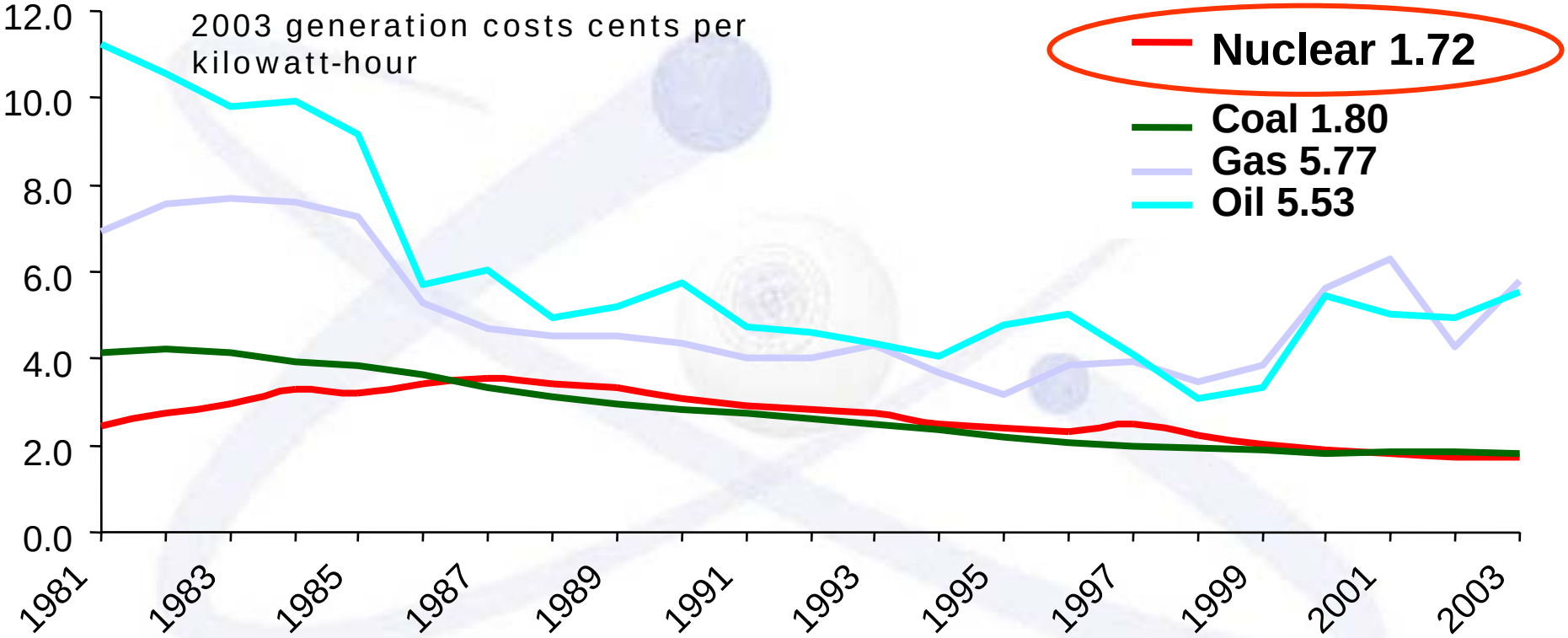
Nuclear energy is competitive



Nuclear is the lowest cost of all (except hydro)

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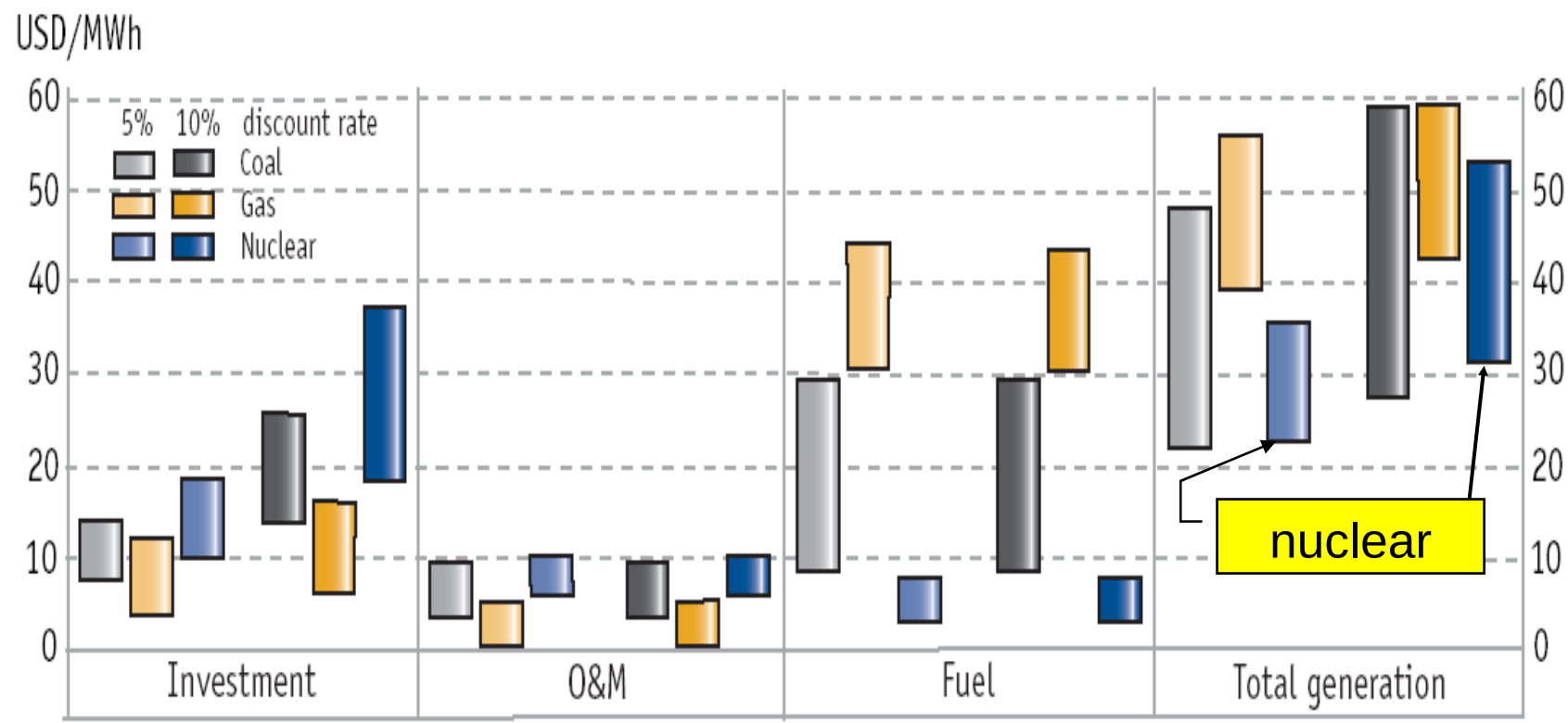
Nuclear Energy Institute

Projected future cost of generating electricity: 2005 update (OECD)

Figure 3.10 – Range of levelised costs for coal, gas and nuclear power plants (USD/MWh)



Source: NEA and IEA

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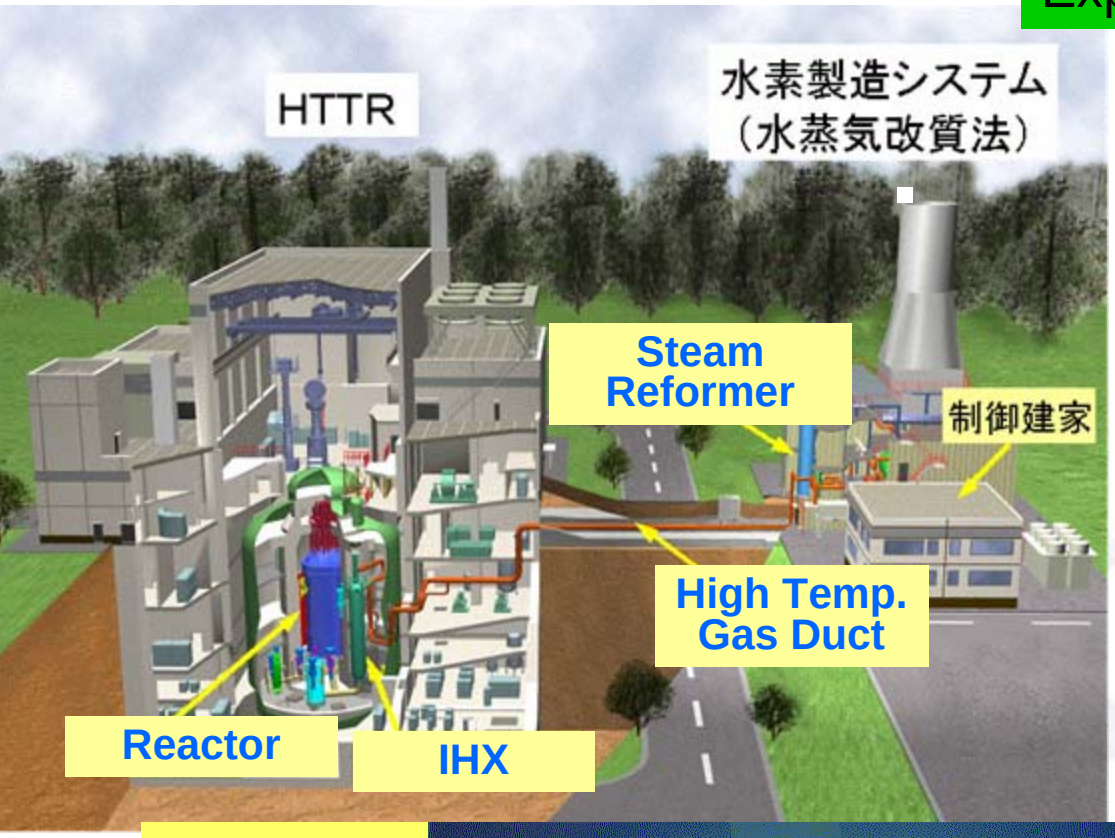
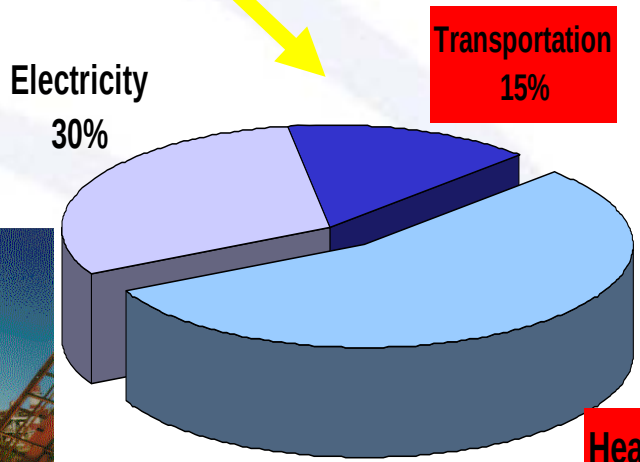
Non-electricity applications of nuclear energy

Expandable to other applications ✔



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



Sokolov IAEA

Kazakhstan,
350

Most oil production in the “Golden Triangle” in the Middle East

From Simmons & Company, International

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."

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United States New Generation

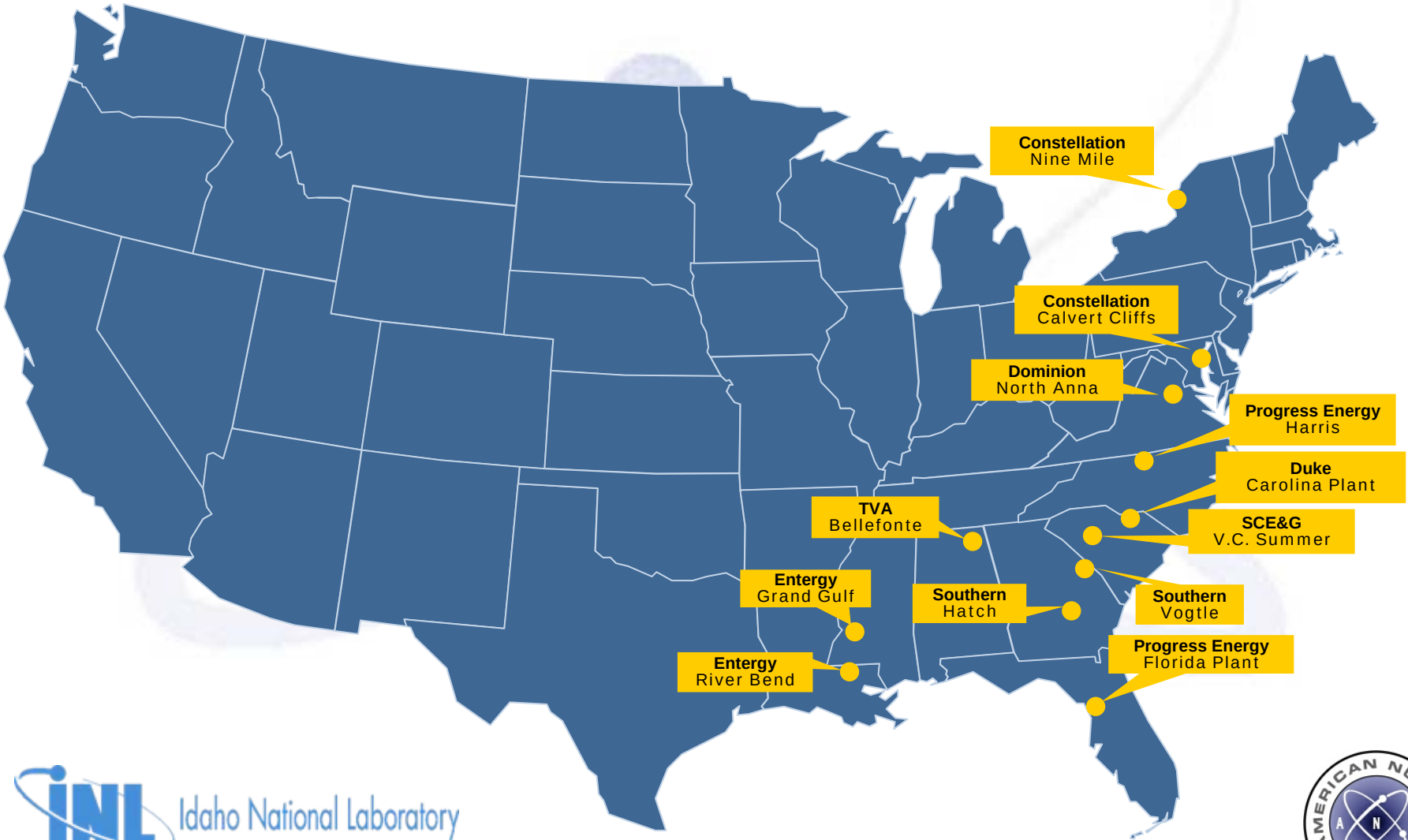
Utilities

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

Technologies

- AREVA/Framatome ANP
- Westinghouse
- General Electric

U.S. Nuclear Industry—First Movers



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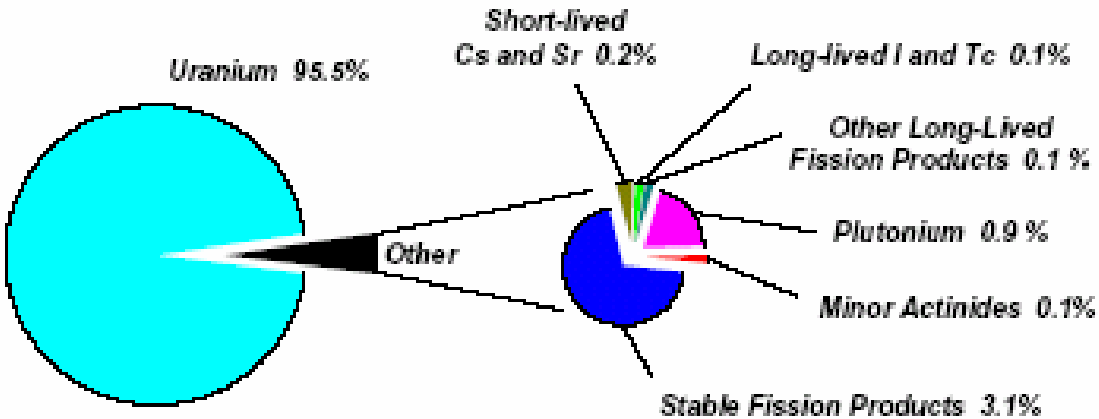
Composition of Spent Nuclear Fuel



(Standard PWR 33GW/t, 10 yr. cooling)

<u>1 tonne of SNF contains</u>:

955.4 kg U
8.5 kg Pu

<u>Minor Actinides (MAs)</u>
0.5 kg ^{237}Np
0.6 kg Am
0.02 kg Cm

<u>Long-Lived fission Products (LLFPs)</u>
0.2 kg ^{129}I
0.8 kg ^{99}Tc
0.7 kg ^{93}Zr
0.3 kg ^{135}Cs

<u>Short-Lived fission products (SLFPs)</u>
1 kg ^{137}Cs
0.7 kg ^{90}Sr

<u>Stable Isotopes</u>
10.1 kg Lantanides
21.8 kg other stable

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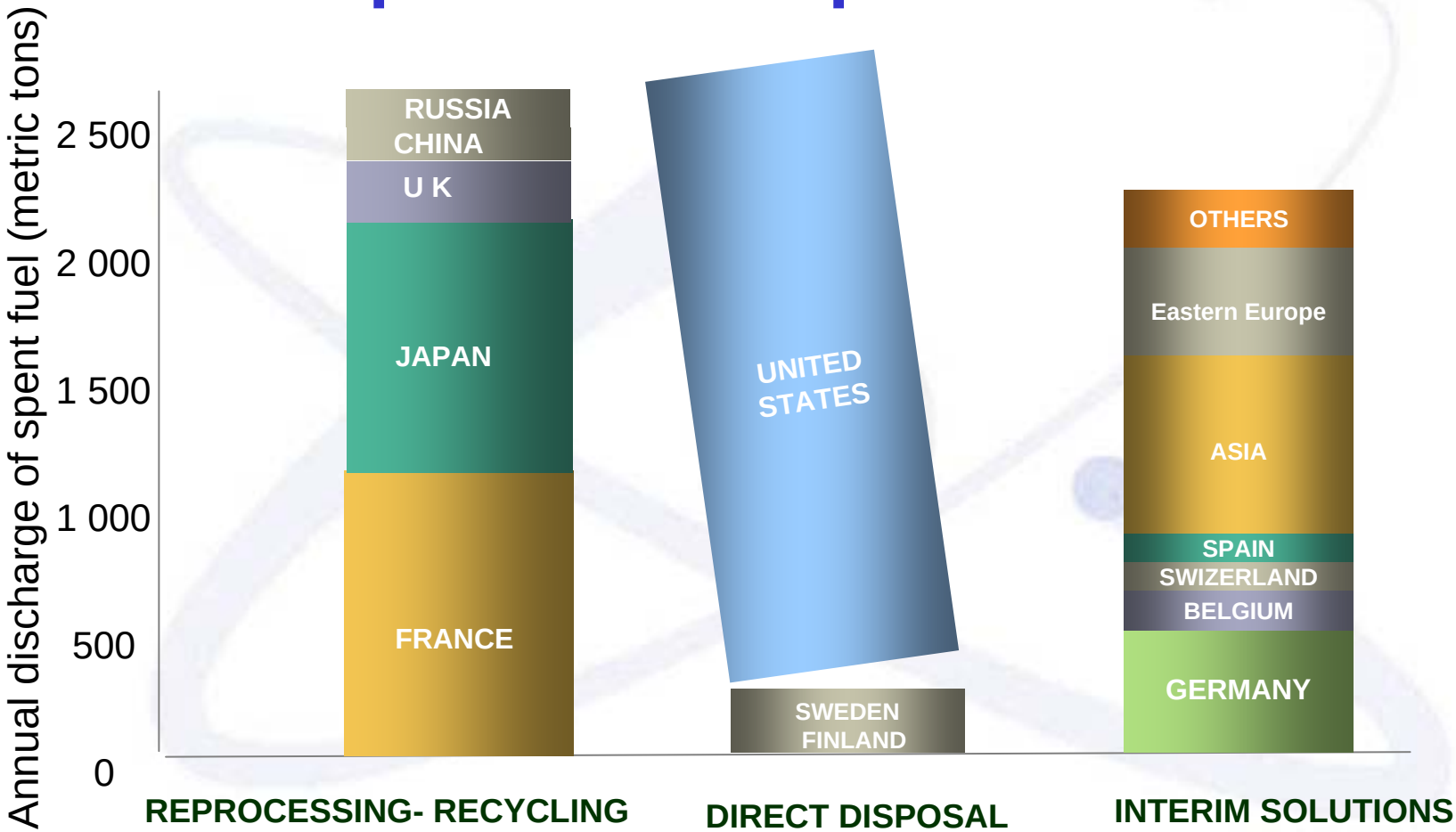
Courtesy of Max Salvatores

Arms race environmental legacy

- In the US, massive reprocessing preceded planning for management of the environmental effluents
  - 685,000 curies of ^{131}I were released between 1944 and 1947
  - 350,000 m^3 of high level liquid waste is stored in steel tanks in the states of Washington, Idaho and South Carolina
- In the USSR, environmental releases from reprocessing in the secret cities of Mayak, Tomsk-7 and Krasnoyarsk-26 resulted in record releases of radioactive material—more than the Chernobyl reactor accident.
  - In 1957 a waste tank explosion ejected 2 million curies up to 1000 feet and contaminated some 23,000 m^3 of land
  - Lake Kurachi contained an inventory of 120,000,000 curies in 1995.
    - Dust from the receding shoreline contaminated land for 75 miles downwind in 1967

Big environmental mess

National policies on spent fuel



Courtesy Areva

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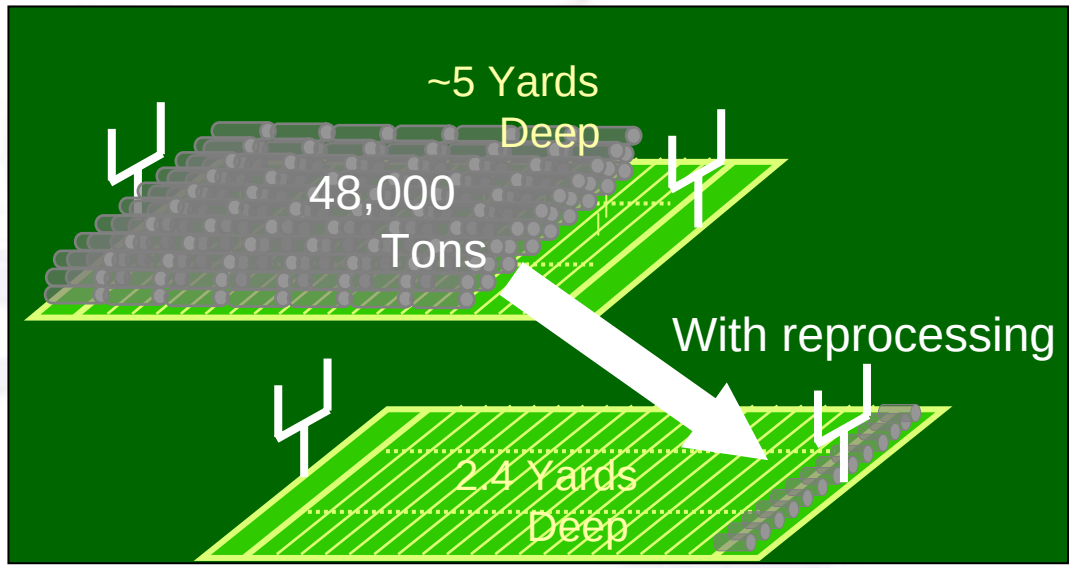
Total amount of used fuel generated is relatively small and readily manageable

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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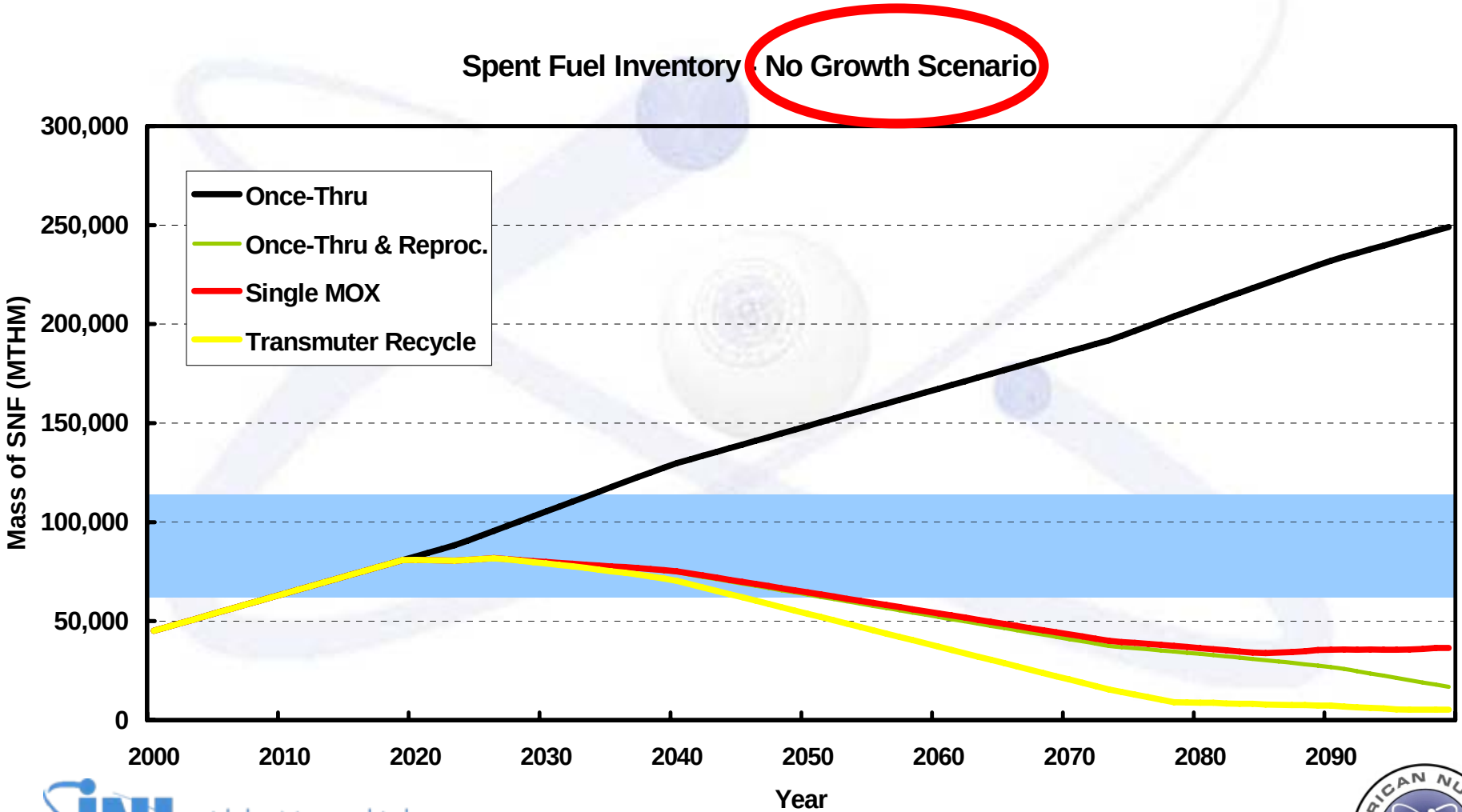
Reprocessing needed for growth



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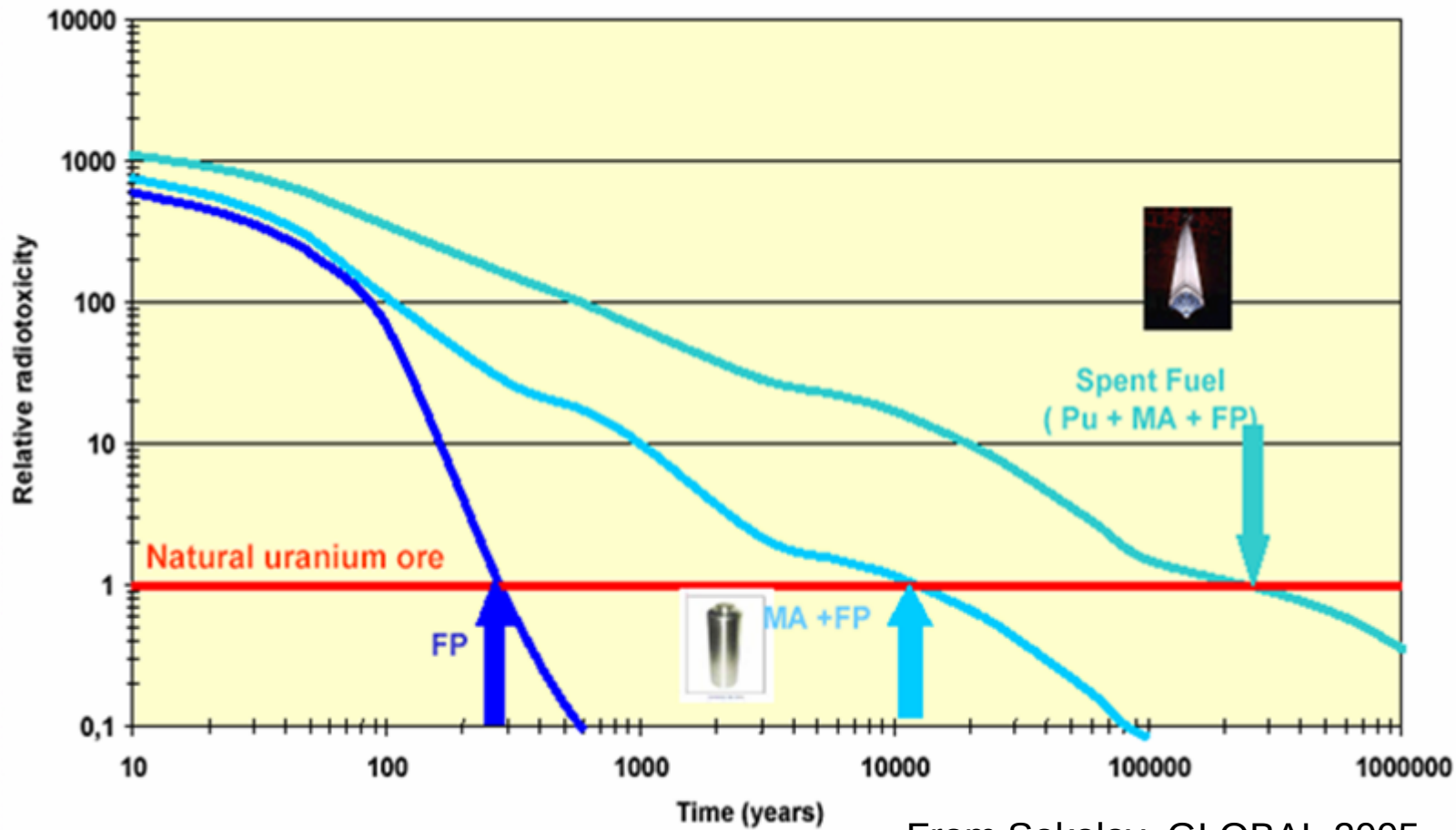
Reprocessing reduces future risk



From Sokolov, GLOBAL 2005

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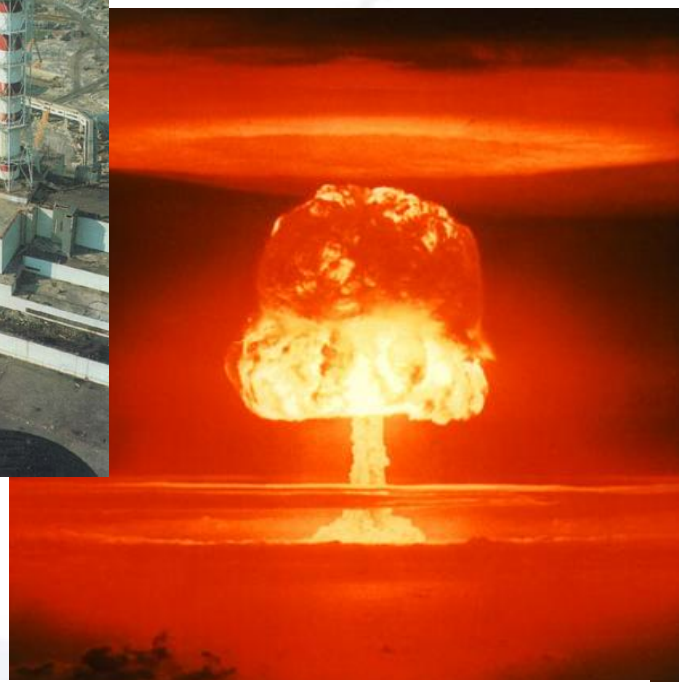
Nuclear energy policy remains in conflict



If we're to get in step with the world effort to reduce greenhouse gases, we are going to need to rely more, not less, on carbon-free nuclear energy."
New York Times editorial April 26, 2006.

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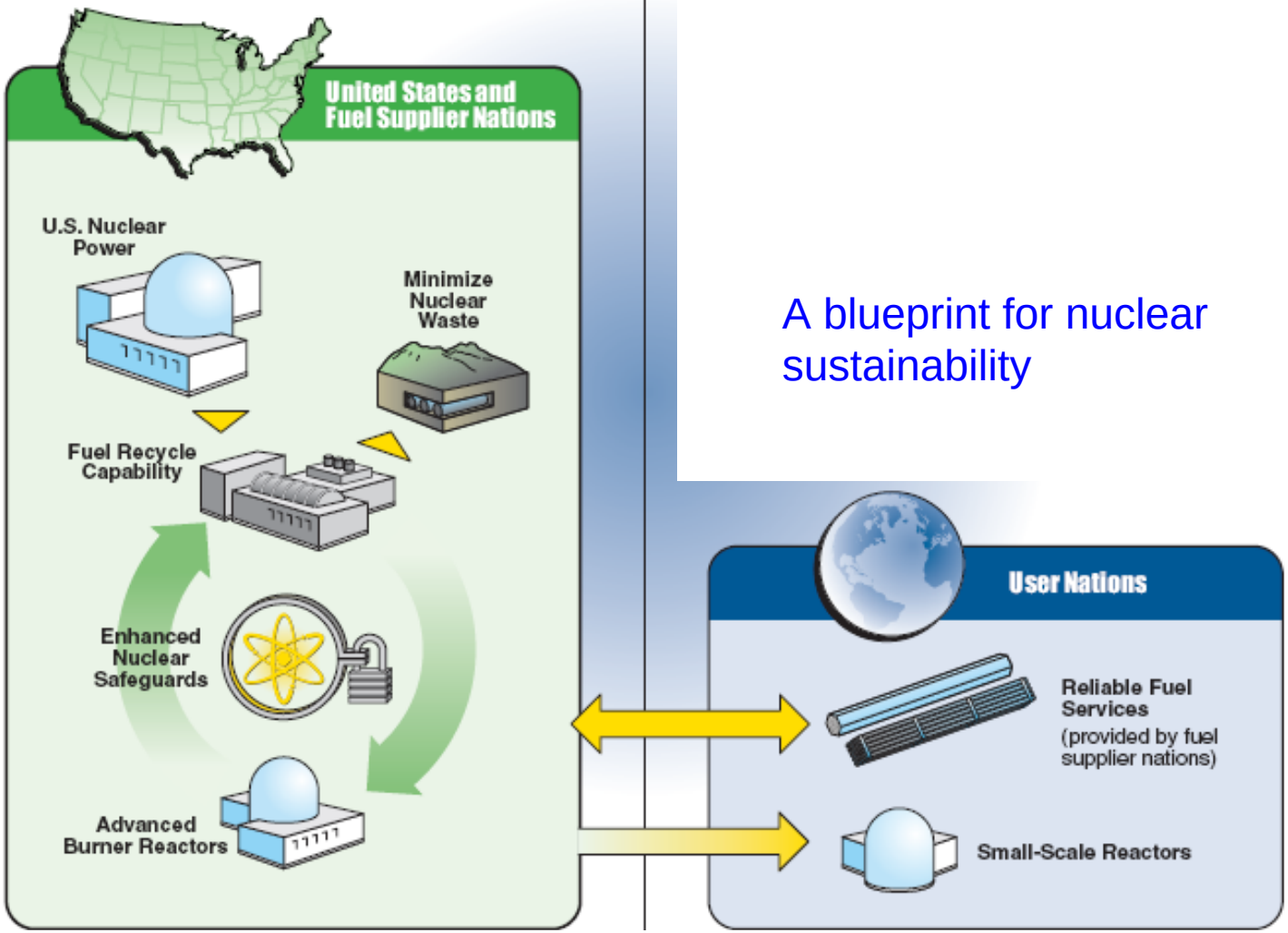
Global Nuclear Energy Partnership (GNEP)



A blueprint for nuclear sustainability

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Source: www.gnep.energy.gov

Role of American Nuclear Society

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

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2006 HLW Management

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