Wisconsin Legislature Special Committee on the Future of Nuclear Power

Societal Responsibilities

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September 29, 2006

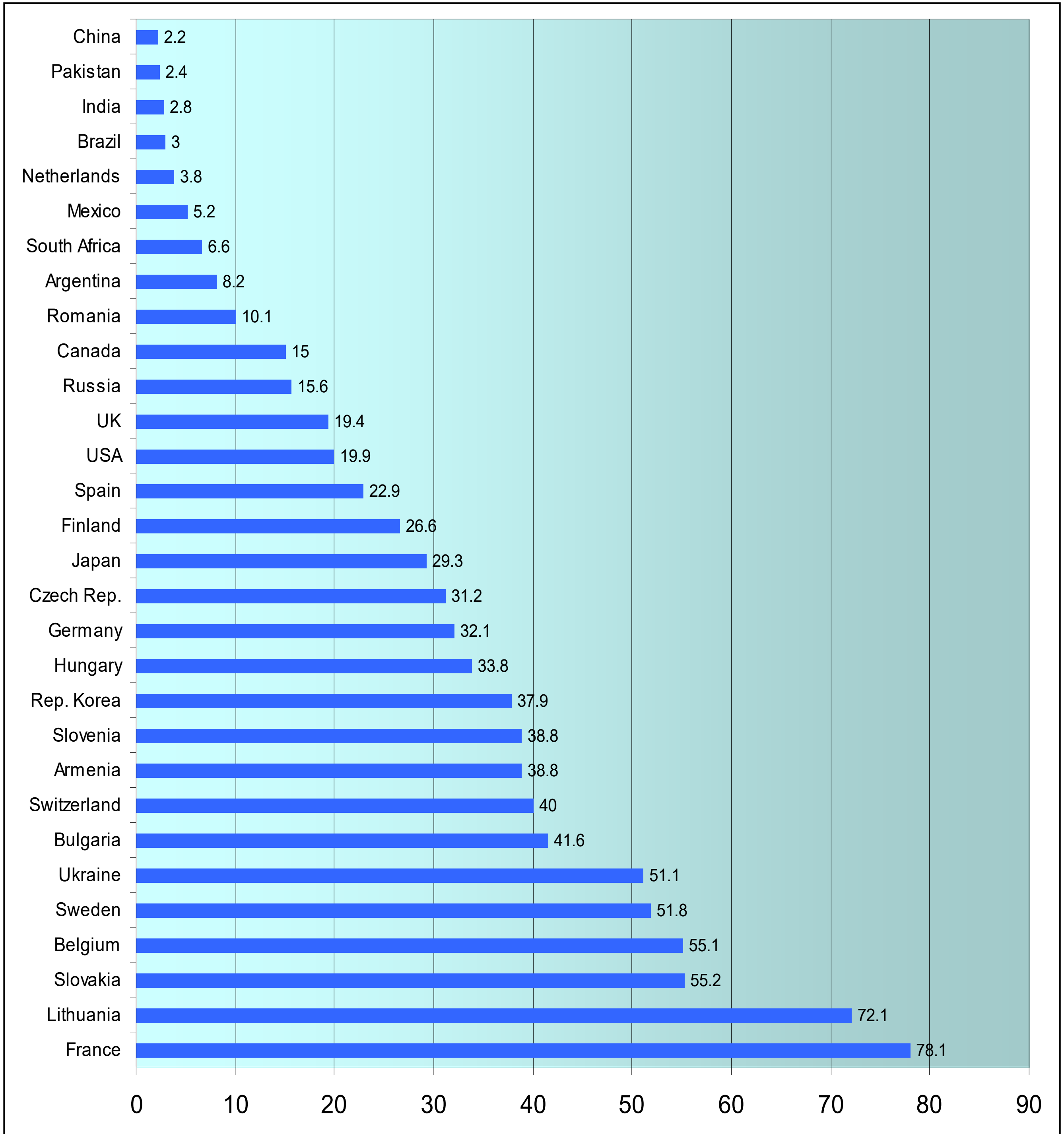
NUCLEAR MATERIALS MANAGEMENT POLICY GOALS

- Protection of Present & Future Generation's
  - Safety
  - Security
  - Safeguards
    - International
    - Intra-national
  - Environment
- While Meeting Societal Energy Needs

NUCLEAR MATERIALS MANAGEMENT POLICY DRIVERS

Dynamic Interaction Over Time of:

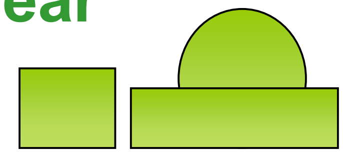
- **Technology**
- **Economics**
- **Sociological/Psychological Perspectives**
- **Democratic Government Processes**
    - **Legislative**
    - **Executive**
    - **Judicial**
- **Politics**



Nuclear Power Share of Electricity Production (2004)

Power and Waste: 1000 MWe/a

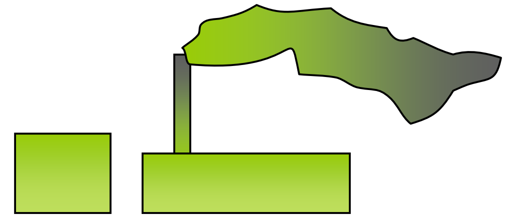
Nuclear



- Fuel: 27 t UO_2 or if reprocess
- 35 t HLW
- 310 t ILW and
- 460 t LLW

Note- 27 t of fuel fills a space approximately 8'X7'X12'

Coal



- Fuel: 2.6 million t
  - 5 x 1400 t trains a day
- 6.5 million t CO_2
- 900 t SO_2
- 4500 t NO_x
- 320,000 t ash
  - 400 t toxic heavy metals

Ethics: International Conventions

- US-NAS (1955)
  - Safety before cost
  - protection of environment
- IAEA (1989, 1995, 1999)
  - Safety Principles
  - Waste Convention
- OECD/NEA (1995)
  - Workshop
  - Collective Opinion

Ethical Principles in Waste Disposal

- **Intergenerational Equity**
  - “fairness to future generations”
- **Intragenerational Equity**
  - “fairness across current generations”
- **Others**
  - Sustainability
  - Precautionary Principle
  - Polluter pays

Intergenerational Equity Issues

- **Minimise burdens**
  - Financial, technical and institutional
- **Protect at same (or higher) level**
  - Guidance for dose or risk criteria
- **Judgement Trade-offs Are Necessary**

Intragenerational Equity Issues

- Risk levels relative to other activities
  - Risk-based regulation - rare!
- Social and economic impacts
  - Proper use of society's resources

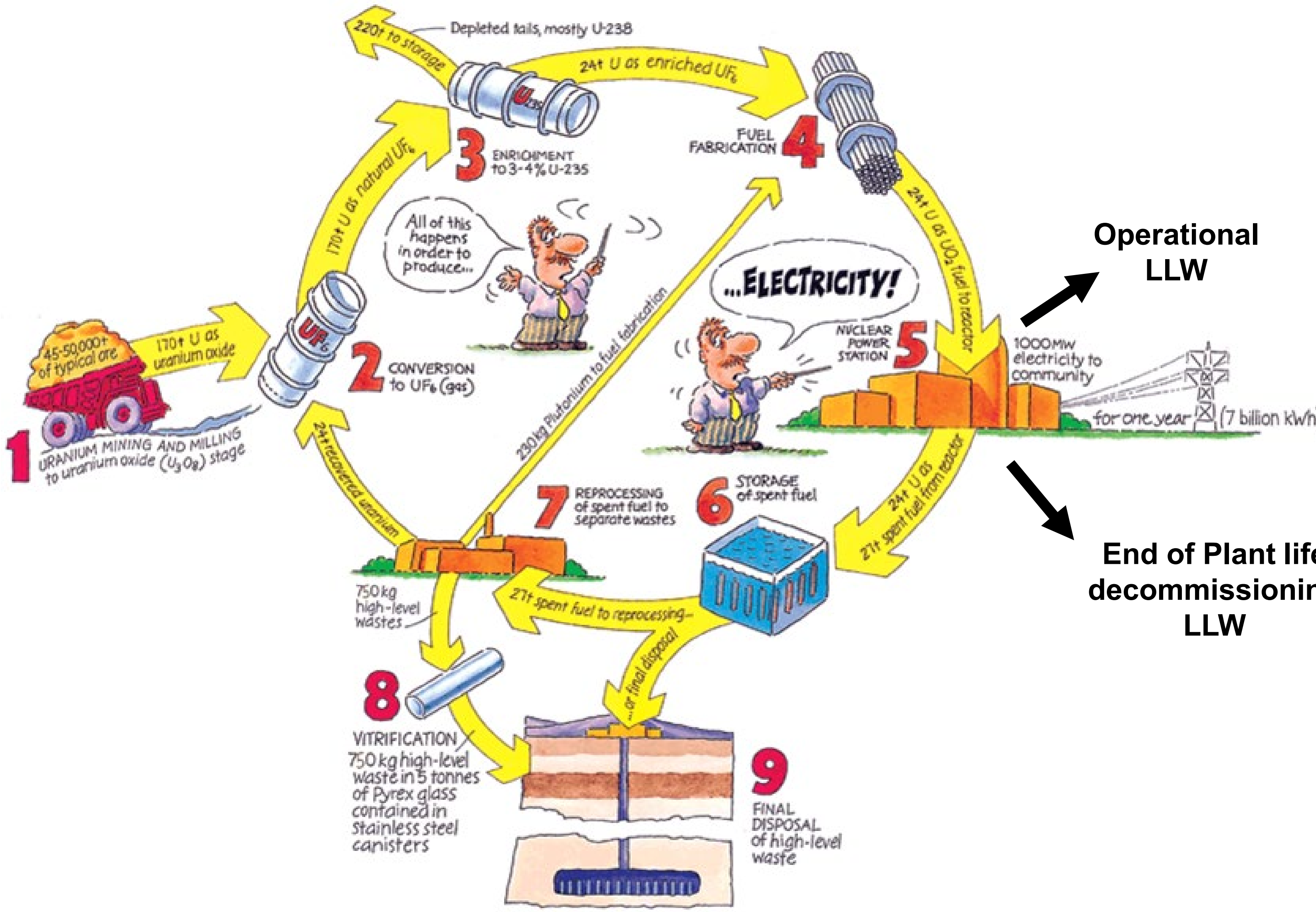
  Spatial distribution of risks and benefits
  - Siting debate national and international
- Public involvement
  - Not just one way information flow!

Ethical Positions

- Sustainability
  - don't pass on undue burdens
  - same safety for future generations as today's
- Precautionary principle
  - no irreversible harm unless compelled
  - don't do it if we don't understand it
- Chain of obligation principle
  - use resources to provide for present needs
  - prioritise present hazards over hypothetical future hazards

Are we equitable in the resources we devote to radwaste, and the standards we apply, compared to other environmental issues?

Nuclear Fuel Cycle



Operational LLW

End of Plant life decommissioning LLW

Nuclear Materials to Manage

- **Fissile materials from weapons dismantling or separated from fuel reprocessing**
  - **plutonium:**
  - **enriched uranium (HEU)**
- **Irradiated reactor fuel**
- **Vitrified high-level waste (HLW)**
- **Greater than Low Level Waste (> Class C)**
  - **reprocessing wastes (fuel assembly parts & TRU)**
- **Low Level wastes (US Classes A, B & C)**
  - **reactor operational wastes**
  - **decommissioning wastes**

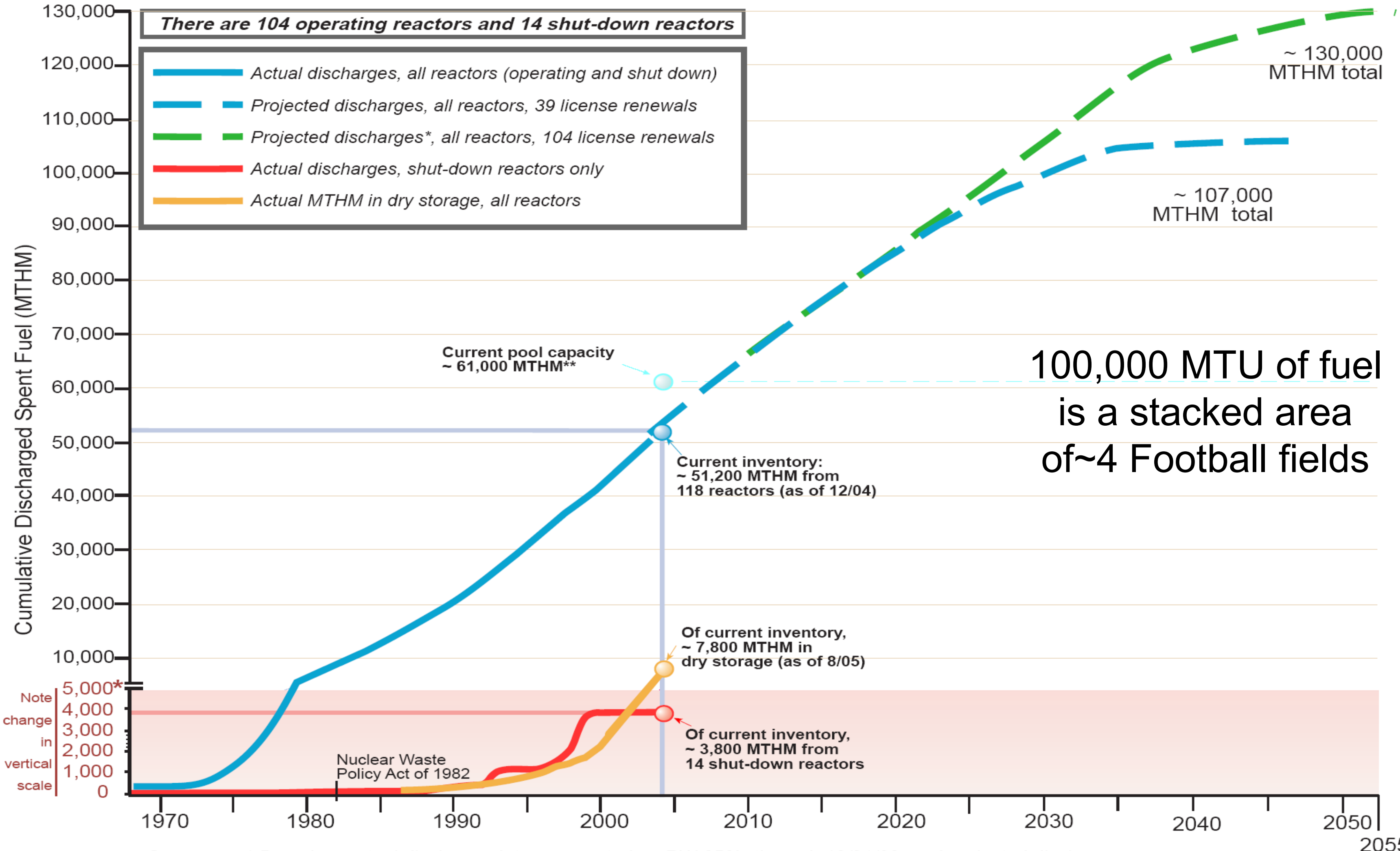
Reactor Operation Low Level Wastes

- The operation of nuclear reactors produces irradiated spent fuel (HLW/SNF) and operational wastes (LLW Classes A,B & C) from activities such as cleaning the reactor cooling systems, decontamination of equipment, filters and activated components (control and instrumentation rods).
- Packaged, Transported to Licensed Disposal Sites under NRC, DOT, EPA and State Safety, Environmental and Security Regulations.
- Paid for by the Waste Producer

Reactor Decommisioning Wastes

- The majority of waste generated by decommissioning is LLW Classes A,B & C (majority of cooling circuit, excluding some reactor internals which are potentially > Class C).
- Most Structures are Class A LLW or BRC
- A 1000 MW(e) PWR or BWR produces ~ 10,000 t of decommissioning wastes
- Paid for by The Waste Producer

Commercial Spent Nuclear Fuel



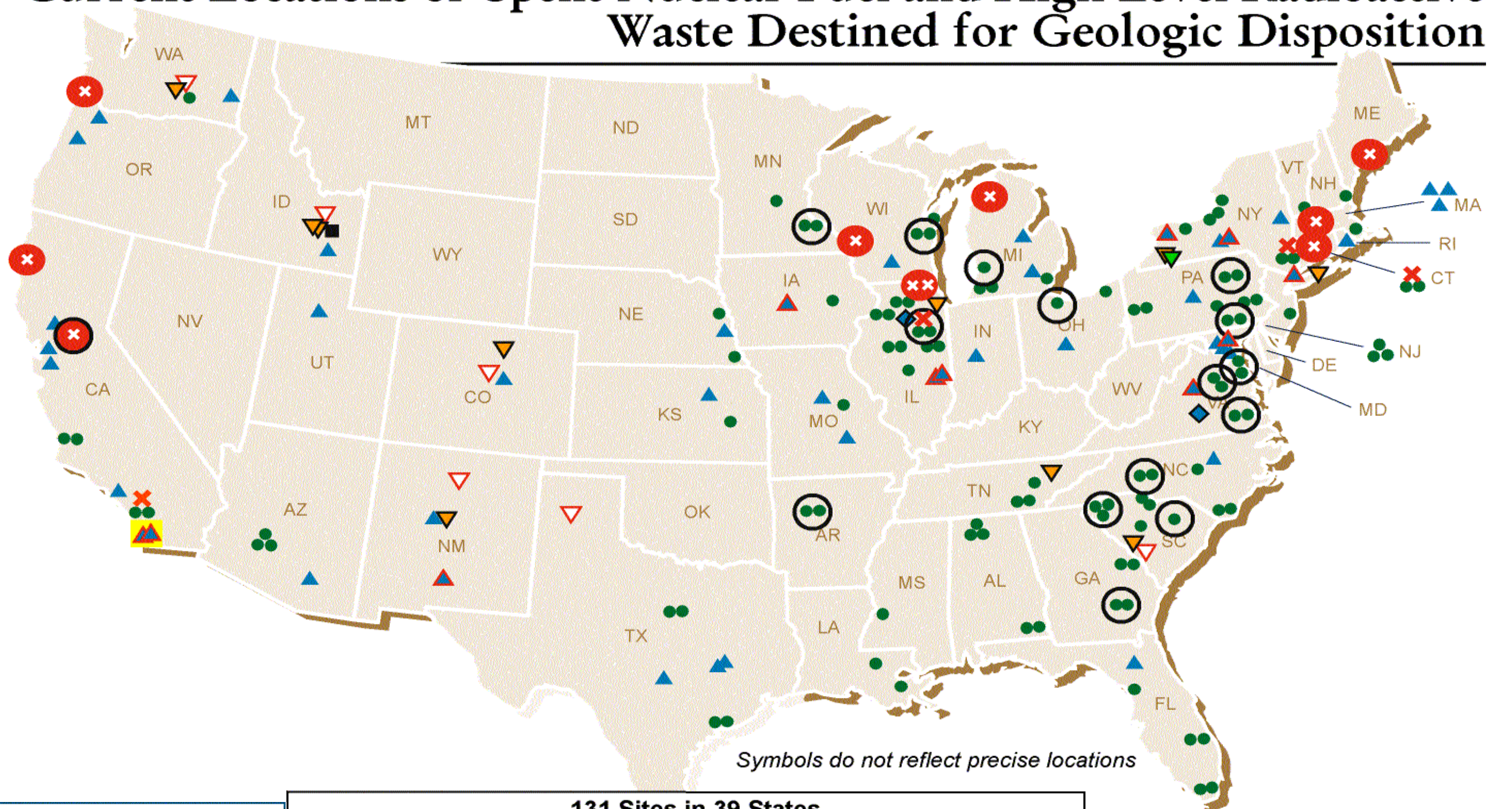
100,000 MTU of fuel is a stacked area of~4 Football fields

Sources: * Based on actual discharge data as reported on RW-859's through 12/31/02, and projected discharges, in this case 2003-2055, based on 104 license renewals.
**Based on pool capacities provided in 2002 RW-859 (less FCR) and supplemented by utility storage plans.

Discharge Curves 122805.FH10

As of December 2005

Current Locations of Spent Nuclear Fuel and High-Level Radioactive Waste Destined for Geologic Disposition



Waste Quantities Projected through 2046 (in Metric Tons, except for HLW)

Commercial SNF	up to 105,000
DOE-Owned SNF	2,500
including:	
Naval Reactor Fuel	*65*
Foreign Research Fuel	*16*
Surplus Plutonium	50
HLW Glass (canisters)	~22,000

131 Sites in 39 States

Commercial Reactors *including:*
- *operating reactors, and*
- *shutdown reactors at operating sites, and*
- *shutdown reactors at shutdown sites where SNF could be removed after repository opening*

Commercial SNF Pool Storage (Away-From-Reactor)

Commercial Dry Storage Sites

Highly Enriched Uranium at Shutdown Site

Research Reactors *including:*
- *operating reactors, and*
- *shutdown reactors with SNF on site*

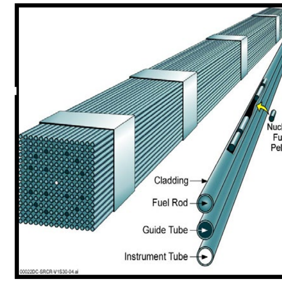
DOE-Owned SNF and HLW

Commercial HLW

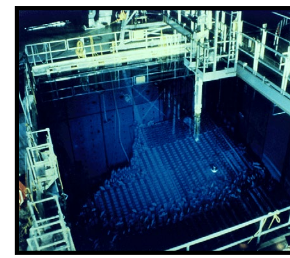
Surplus Plutonium

Naval Reactor Fuel

As of January 10, 20

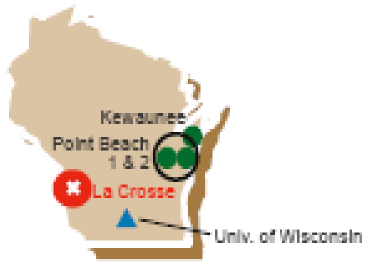


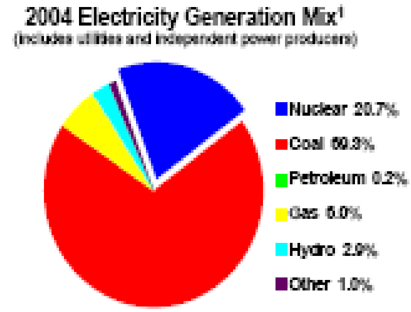
Commercial Spent Nuclear Fuel


Wet Storage


Dry Storage

WISCONSIN

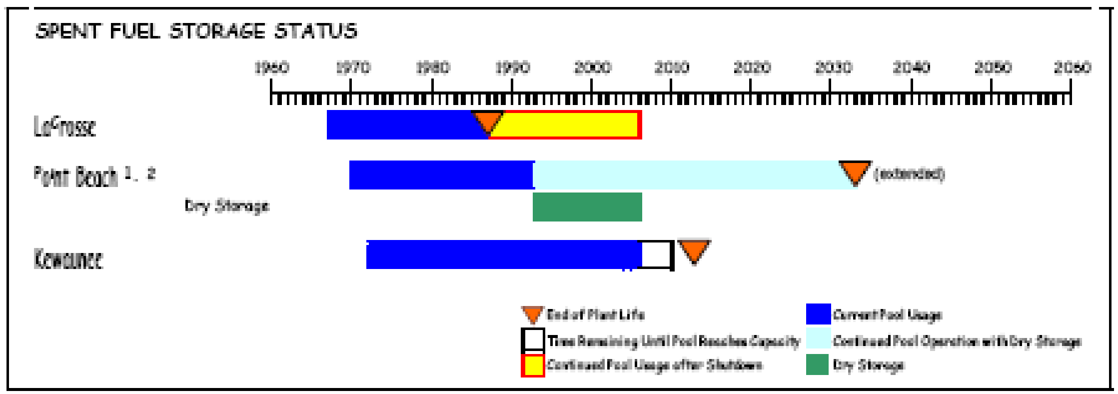




- Operating Commercial Reactors = 3 at 2 sites
- Commercial Dry Storage Sites
- Shutdown Commercial Reactors at Shutdown Sites = 1 at 1 site
- Operating Research Reactors = 1 at 1 site

Facility	Owner	License Period	Plant Output/Type[2]
Univ. of Wisconsin	University of Wisconsin		TRIGA
LaCrosse	Dairyland Power Cooperative	1967-1987	0 MWe/BWR
Point Beach 1[3]	Wisconsin Electric Power Co.[5]	1970-2030[6]	516 MWe/PWR
Point Beach 2[3]	Wisconsin Electric Power Co.[5]	1970-2033[6]	518 MWe/PWR
Kewaunee[3,4]	Dominion Energy Kewaunee[7]	1972-2013[6]	556 MWe/PWR

SPENT NUCLEAR FUEL INVENTORIES
Cumulative spent fuel (projected as of end-2005, per 2002 RW-859): **1,152 MTU**
of which: **38 MTU** is at shutdown reactor
amount currently in dry storage: **198 MTU**



NUCLEAR WASTE FUND
Cumulative payments as of December 31, 2005: **$314 million**

US Spent Nuclear Fuel Policy Development

- Government Technology Will Solve
  - 1957-U.S. Academy of Sciences :Geological Disposal
- Nuclear Expansion Accelerates
- 1972: Lyons Kansas Salt Site Selection Failure
- 1974: Energy & Economic Changes
  - Economic slowdown & High Interest Rates
  - Nuclear Energy Slows & Fuel Reprocessing Halted
- Environmental & Anti-Nuclear Movement
  - Three Mile Island
- New National Waste Policy Need Recognized

US Nuclear Waste Policy Development (1977-1982)

- **Congress Debates National Waste Policy**
  - **-Atmosphere of Federal Distrust**
  - **-Watergate & TMI**
- **Anti-Nuclear Groups Wanted no Off Site Fuel Storage/Reprocessing**
- **Utilities Wanted Off Site Storage**
- **States & Native Americans Wanted Site Disapproval Power**
- **East/West Regional Equity Issue**
- **Who should Pay, How Much & When Perform**
- **What Organization Should Implement**

Nuclear Waste Policy Act of 1982

Political Consensus Decisions Achieved

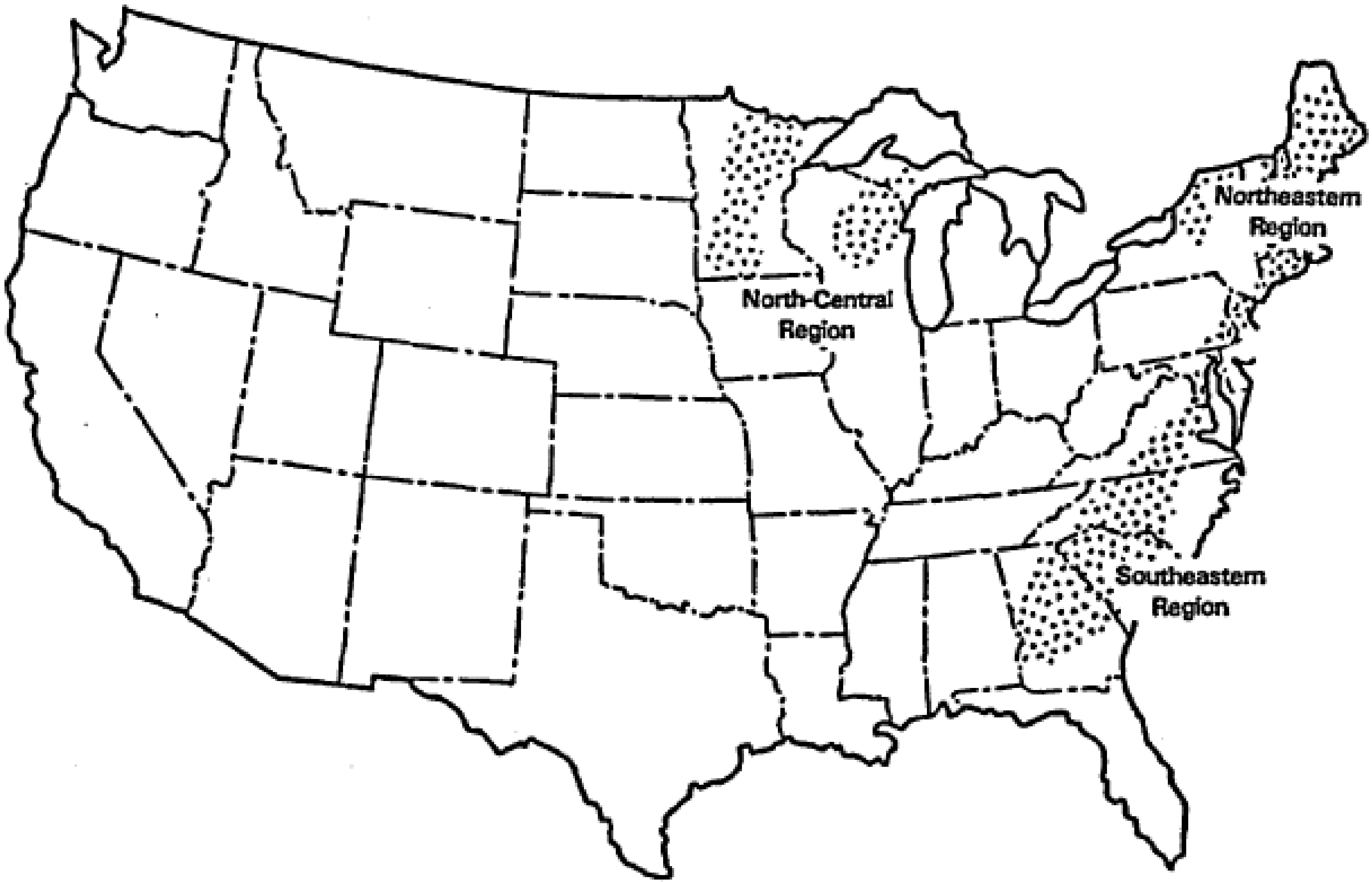
- **DOE to Build Two Deep Repositories**
  - **Independent Regulation by EPA/NRC**
  - **West and East Repositories for Regional Equity & Diversity**
  - **Develop Proposal for Storage Facility (MRS)**
- **Paid for by Waste Generators under legal contract**
  - **January 1998 Start Date**
- **Final Repository selected by scientific comparison to determine “best” site.**
  - **Three sites to be characterized underground**
- **Specific balance of power between Federal, State/Tribal, and Local Governments**

Initial Program Progress (1983-86)

- DOE Office Of Civilian Radioactive Waste Office Formed
- Open & Transparent Process Begins
  - Environmental Assessments of 9 Sites Issued & 3 Selected
- Second (Eastern) Repository Work Initiated
- Monitored Retrievable Storage Facility Recommended
- Budgets are Sufficient
- Public Concerns Increase with Siting Specificity

Crystalline Second Repository Program

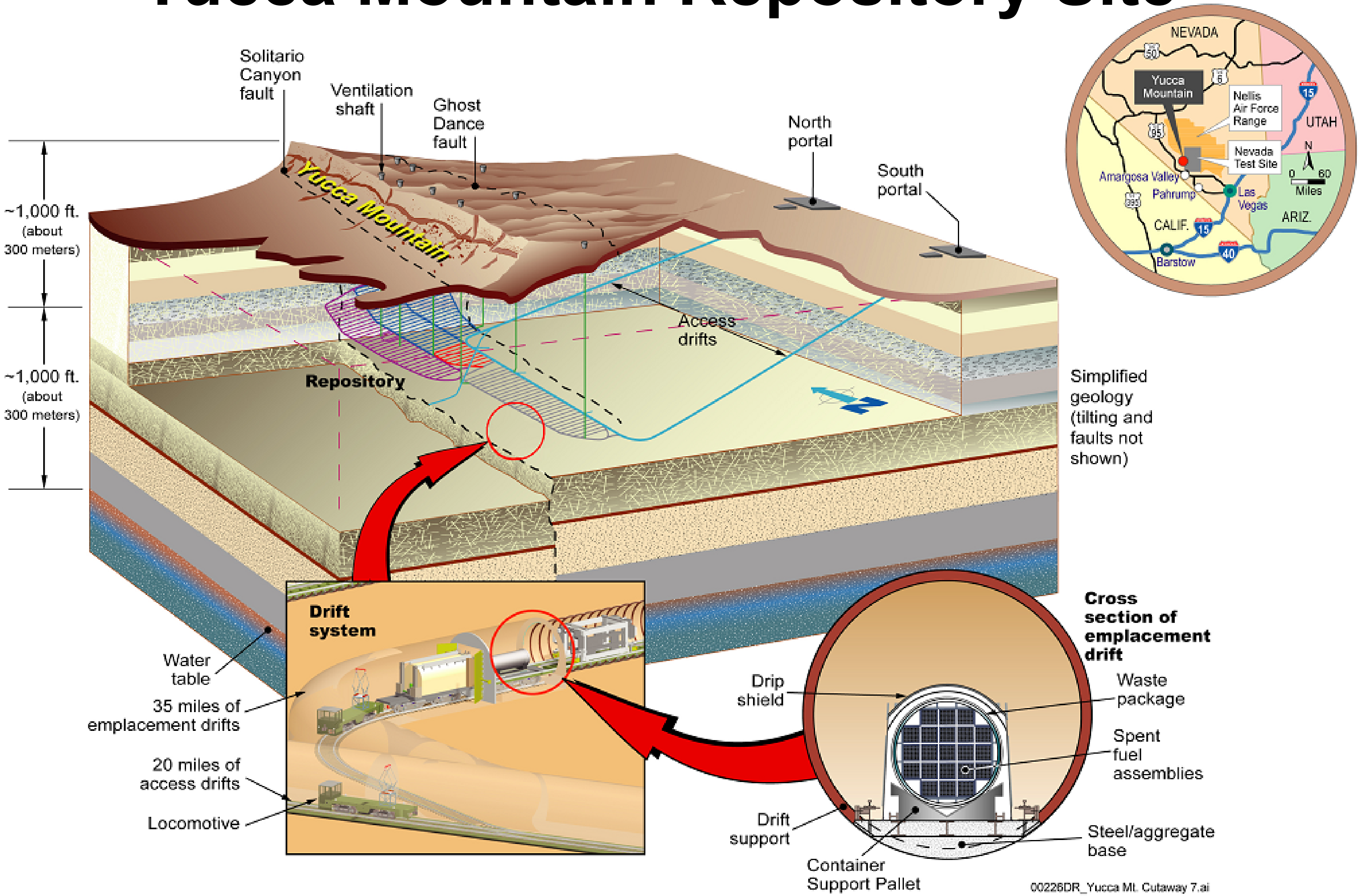
REGIONS BEING CONSIDERED FOR THE SECOND REPOSITORY



Nuclear Waste Policy Act, Amended 1987

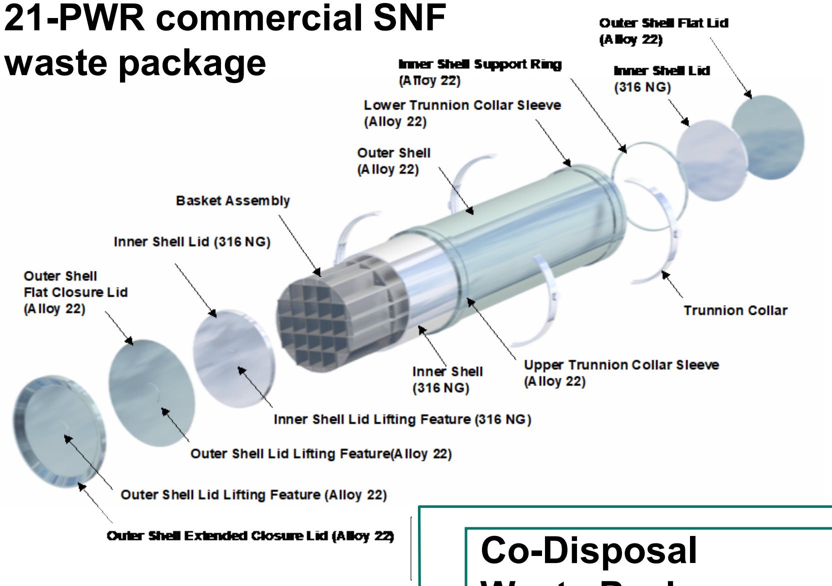
- Limited investigations to only Yucca Mountain
  - Second Repository Stopped & 2007 Report
- Established Nuclear Waste Negotiator
  - to find a State or Tribe volunteer to host a repository or monitored retrievable storage site
- Established the Nuclear Waste Technical Review Board
  - Additional independent oversight

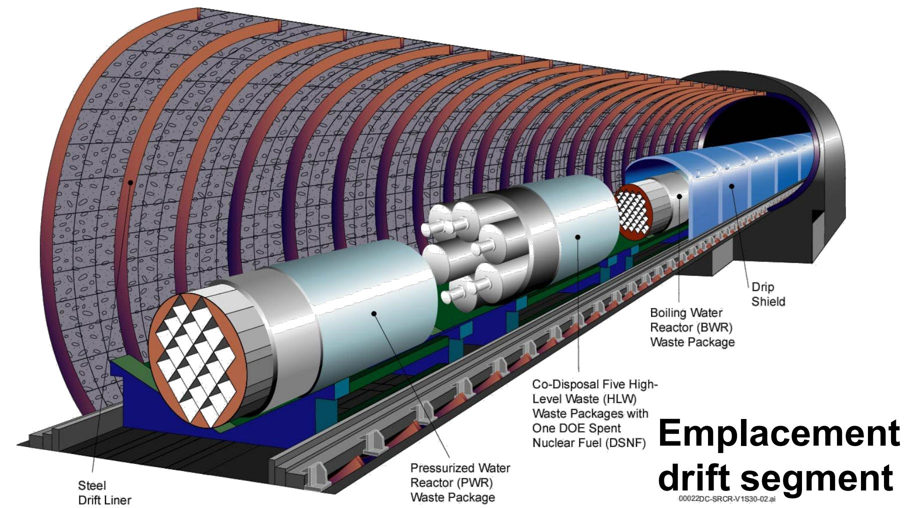
Yucca Mountain Repository Site



Yucca Mountain Waste Package Design

21-PWR commercial SNF waste package

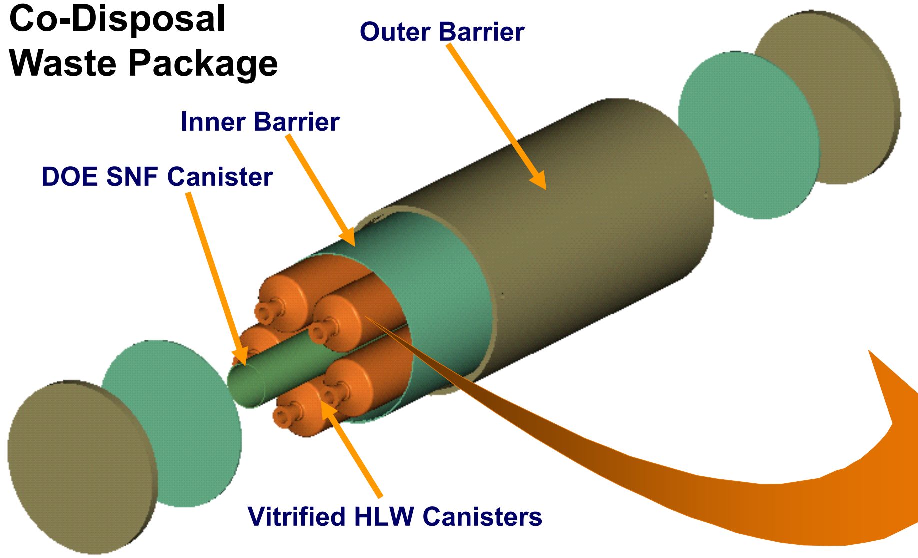


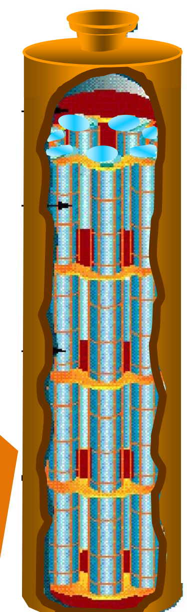


Emplacement drift segment

Waste packages contain canisters of defense high-level waste, commercial and DOE spent nuclear fuel, and dispositioned surplus plutonium.

Co-Disposal Waste Package

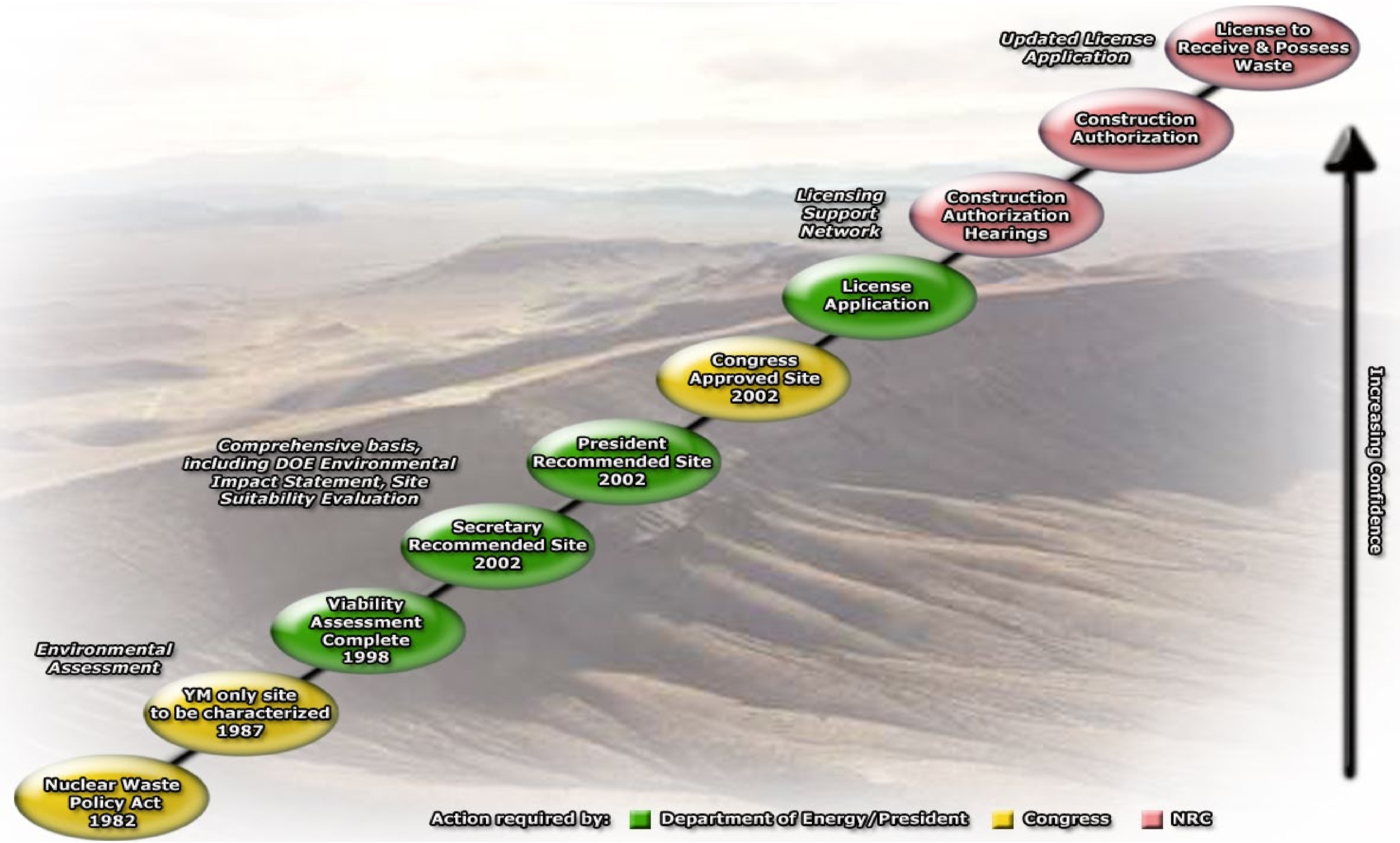




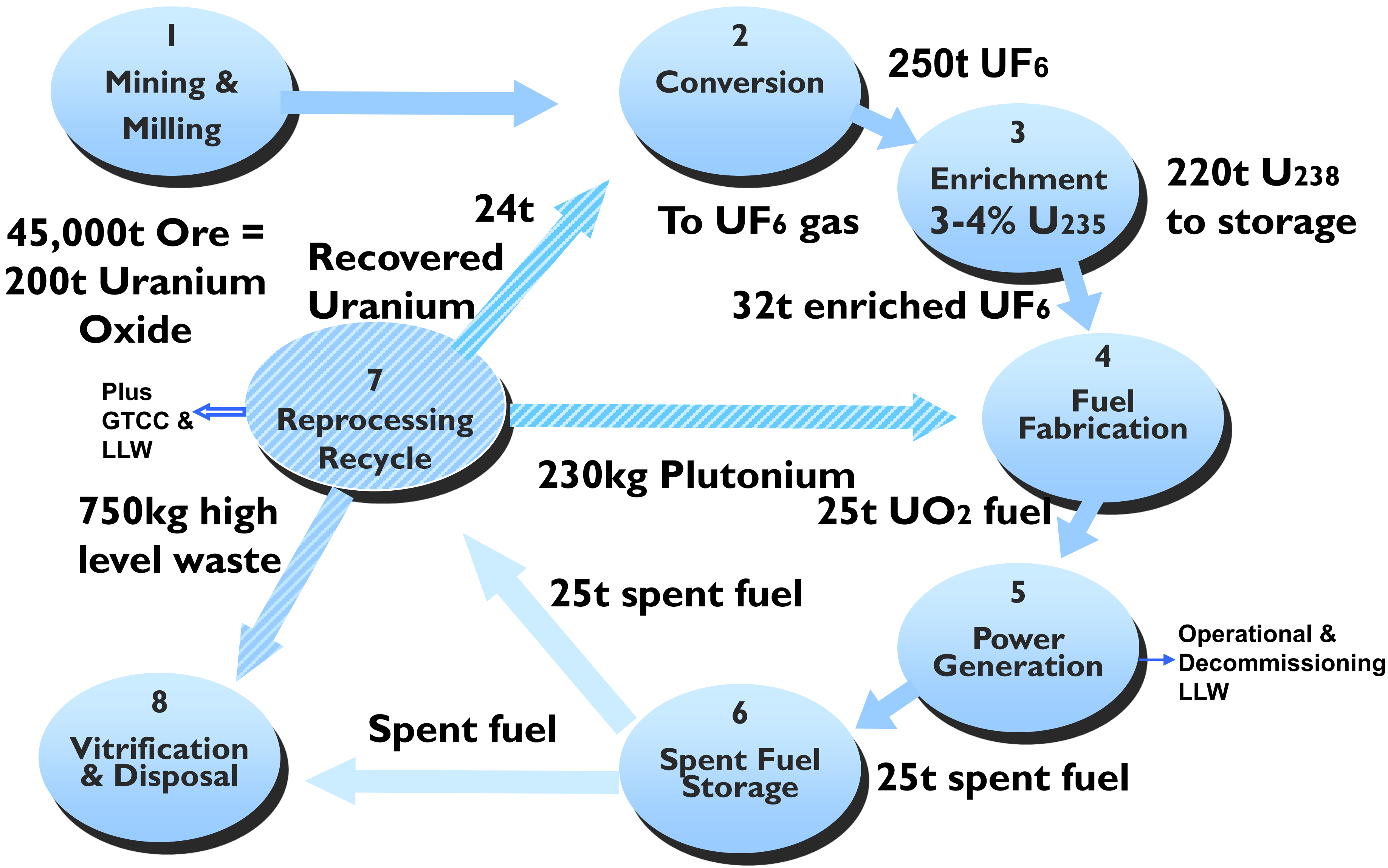
Immobilized plutonium and high-level waste canister

Note: Engineering enhancements underway.

Repository Program Steps

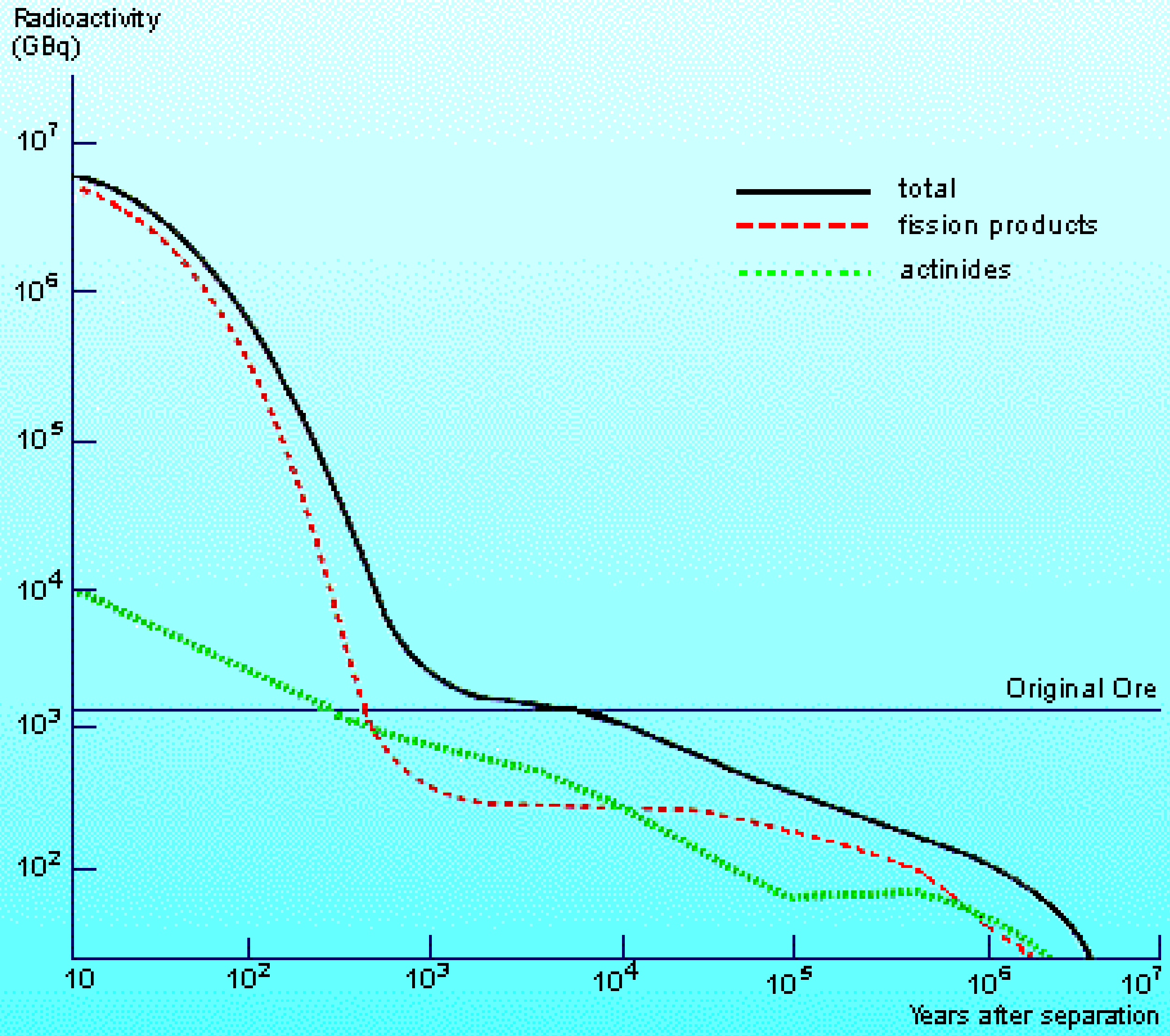


Nuclear Fuel Cycle



Decay in radioactivity of high-level waste

from reprocessing one tonne of spent PWR fuel

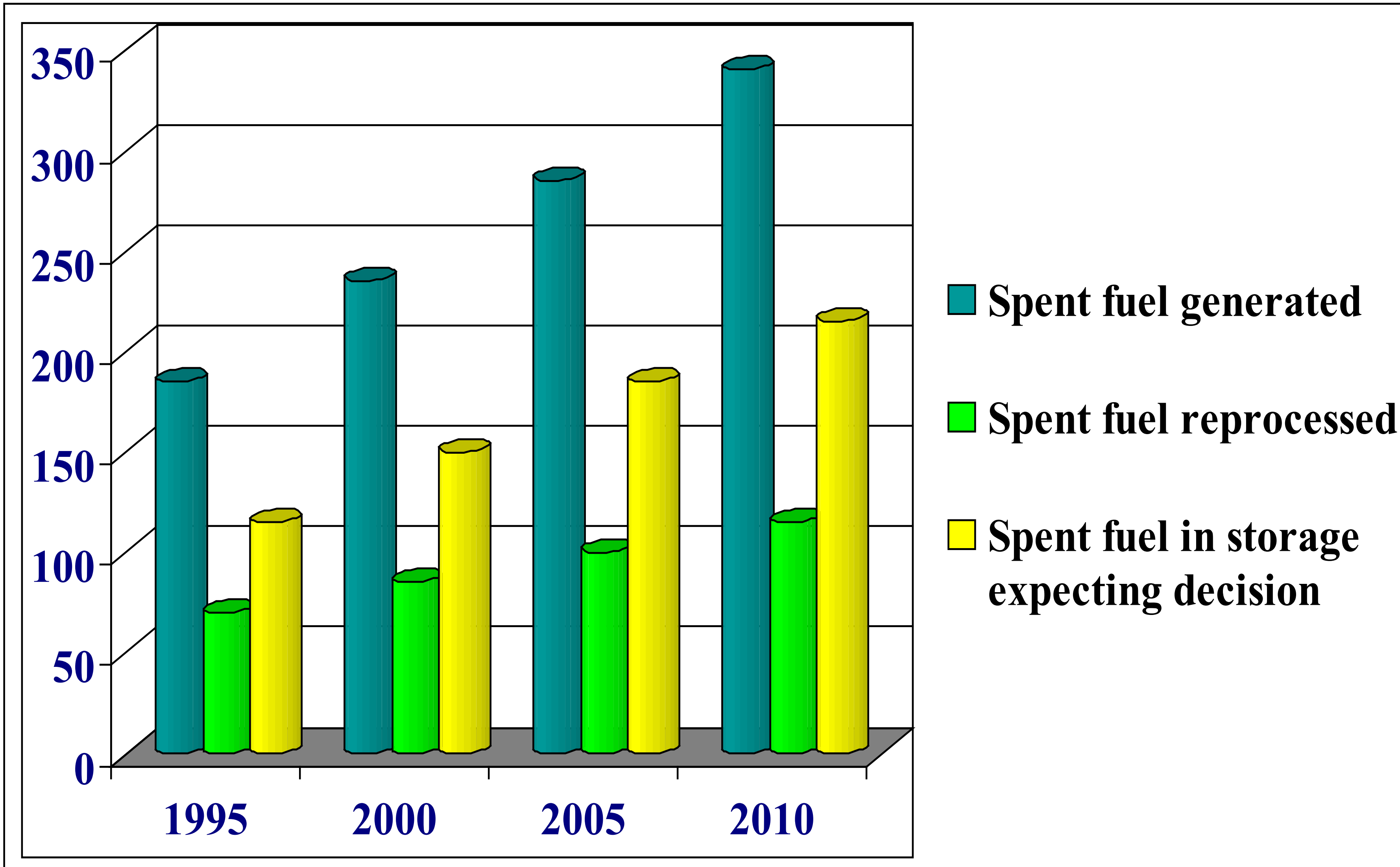


Gbq = 10^9 becquerel
The straight line shows the radioactivity of the corresponding amount of uranium ore.
NB both scales are logarithmic.
Source: OECD NEA 1996, *Radioactive Waste Management in Perspective*.

Reprocessing: policy issues

- Resource conservation
- Environmental impacts
- Prolifération concerns
- Transport concerns
- Economics !!!!!

Amount of SF worldwide: tHM x 1000



Proliferation Concerns

- Weapons Capable Materials
  - Plutonium (Pu)
  - Highly Enriched Uranium (HEU)
- Manage Sources
  - Pu - requires reprocessing
    - Production reactors
    - Power reactor spent fuel
    - Excess weapons materials
    - Dismantled or diverted weapons
  - HEU - requires enrichment
    - Enrichment plants
    - Excess weapons materials
    - Research reactor fuel
    - Naval reactor fuel

Security Concerns

- Physical protection
- IAEA safeguards
- Transportation
- Spread of sensitive technologies

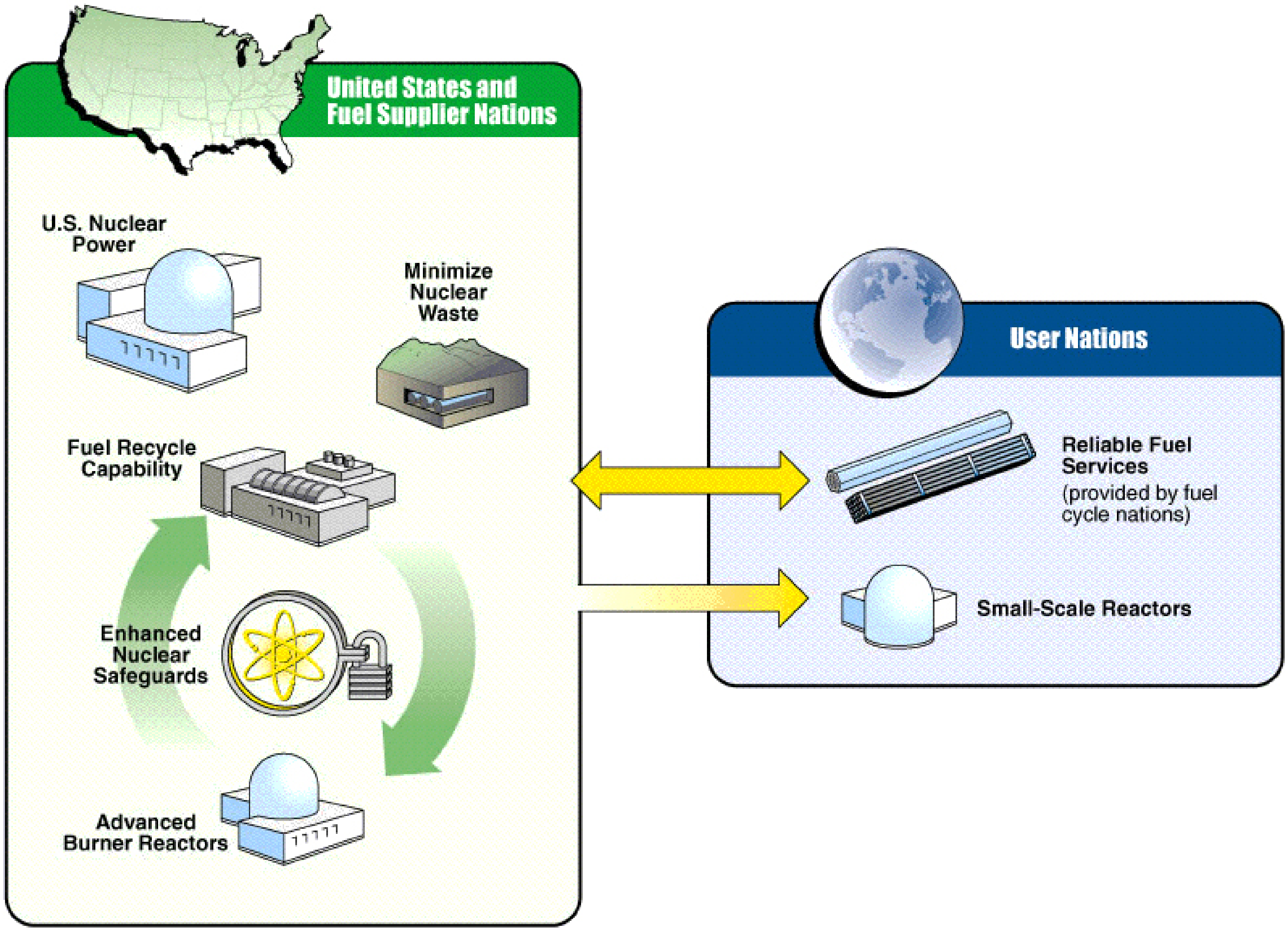
Energy, Security & Environmental Trends

- Greater energy demand
  - Developed countries
  - Developing countries
- Global warming
- Energy security
- Growth and spread of nuclear power may be imminent
- Closed fuel cycle seen as “Latent Proliferation” concern
- Pu Commerce a security concern
- History with DPRK, Iran, Pakistan . . .

Global Nuclear Future Vision

- Countries can have access to nuclear power at market prices
- Nuclear fuel supplies are assured at competitive prices
- Rationale for enrichment/reprocessing eliminated for all but select few under international control/oversight
- All excess weapons usable material (WUM) is secured, put in unattractive form, burned where sensible, and brought under international control in appropriate countries
- SNF is returned to appropriate countries for management and disposal under international control

Global Nuclear Energy Partnership



GNEP NON-PROLIFERATION OBJECTIVES

- Amount of weapons usable material (WUM) reduced, approaching zero, outside the fuel cycle, including “legacy” material
- WUM in most unattractive and unavailable form and place for diversion
- Eliminate rationale for “Countries of concern” to have enrichment/reprocessing
- SNF is returned to appropriate countries under international aegis
- Any moves toward weapon development or nuclear material acquisition are surely, quickly, and clearly apparent

Backup Slides

NUCLEAR TRANSPORTATION

- **Spent fuel transportation safety and security is highly regulated and carefully performed**
- **National Academies' independent, three year study concluded in 2006 that "there are no fundamental technical barriers to the safe transport of spent nuclear fuel in the US…**
- **Transportation packages play a crucial role in transportation safety by providing a robust barrier to the release of radiation and radioactive material**
- **Current transportation regulatory paradigm is effective and works well**
- **Institutional Relationships need constant attention**

NUCLEAR TRANSPORTATION EXPERIENCE

- **Over the last 40 years, 3,000 shipments on spent nuclear fuel have navigated approximately 2 million miles of US roads and railways.**

- **Internationally 70,000 ton of fuel has been shipped over the last 25 years with approximately 600 shipments a year**

- **5000 shipments of transuranic wastes have been safely transported over 5 million miles to New Mexico’s WIPP facility in the past 5 years**

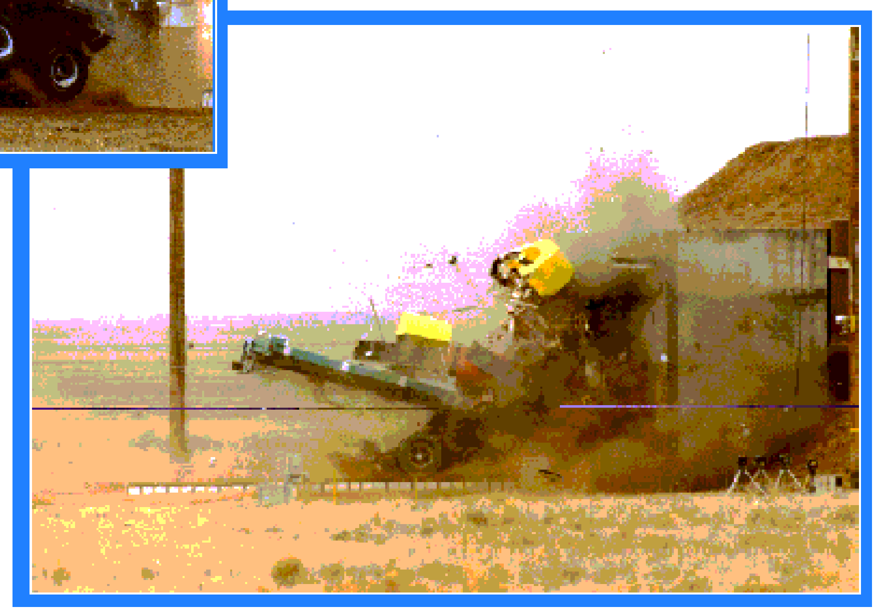
- **Every shipment is carefully tracked and monitored along public routes that must meet strict safety requirements**.

Cask Performance and Testing

- **Cask designers must demonstrate cask designs can meet the regulatory performance standards.**
- **NRC reviews each cask license application and determines if the designer has met the requirements or if more analysis or testing is required.**
- **Compliance with the NRC regulations may be demonstrated by:**
  - **Computer modeling**
  - **Scale-model tests**
  - **Full-scale tests**

Crash Testing at Sandia National Laboratory

At 81.5 MPH, Locomotive Crashes into Tractor-Trailer and Full-Scale Cask at Grade Crossing



At 84 MPH, Tractor-Trailer with Full-Scale Cask Crashes into Stationary Concrete Target

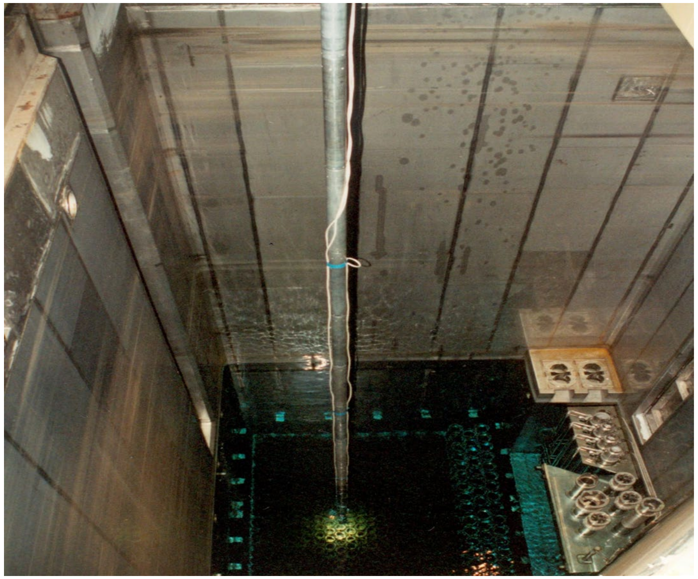
Full-scale impact demonstrations to assess validity of analytical and scale modeling methods and to collect quantitative data on extremes and accident environments

Post Crash Results

Other Crash Testing

- **Central Electricity Generating Board (U.K.): Operation "Smash-Hit"**
  - **British fuel cask placed on track and impacted by 100 mph train**
  - **Cask sustained only superficial damage that would have met regulatory requirements**
  - **Really a Public Confidence Test**

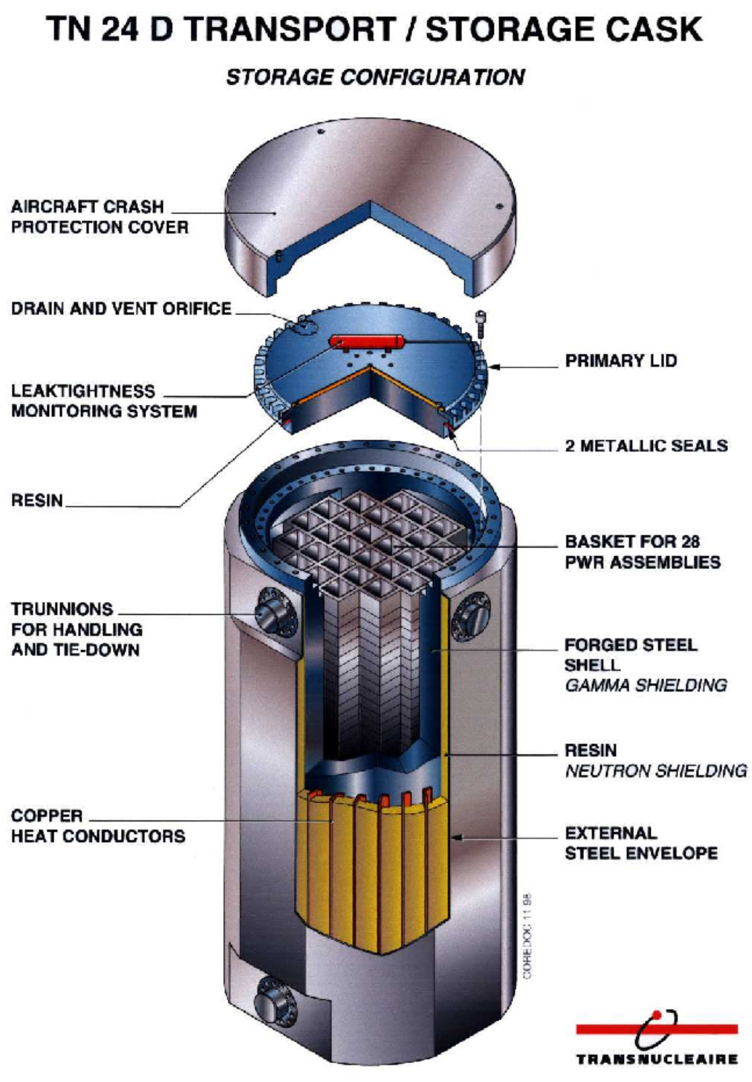
Spent fuel storage types



- At-reactor wet storage in pools (AR) – initially at all plants
- Away-from-reactor storage (AFR)
  - Wet (pools)
  - Dry
    - **Vaults**
    - **Casks**
    - **Silos**

Casks

- A vessel to hold spent fuel to facilitate movement and storage or eventual disposal
- Modular in nature
- Horizontal or vertical
  - Metal casks
  - Concrete casks
- Single-, dual-, multi-purpose



Interim storage facility: ZWILAG, Switzerland

US Nuclear Waste Fund Balance

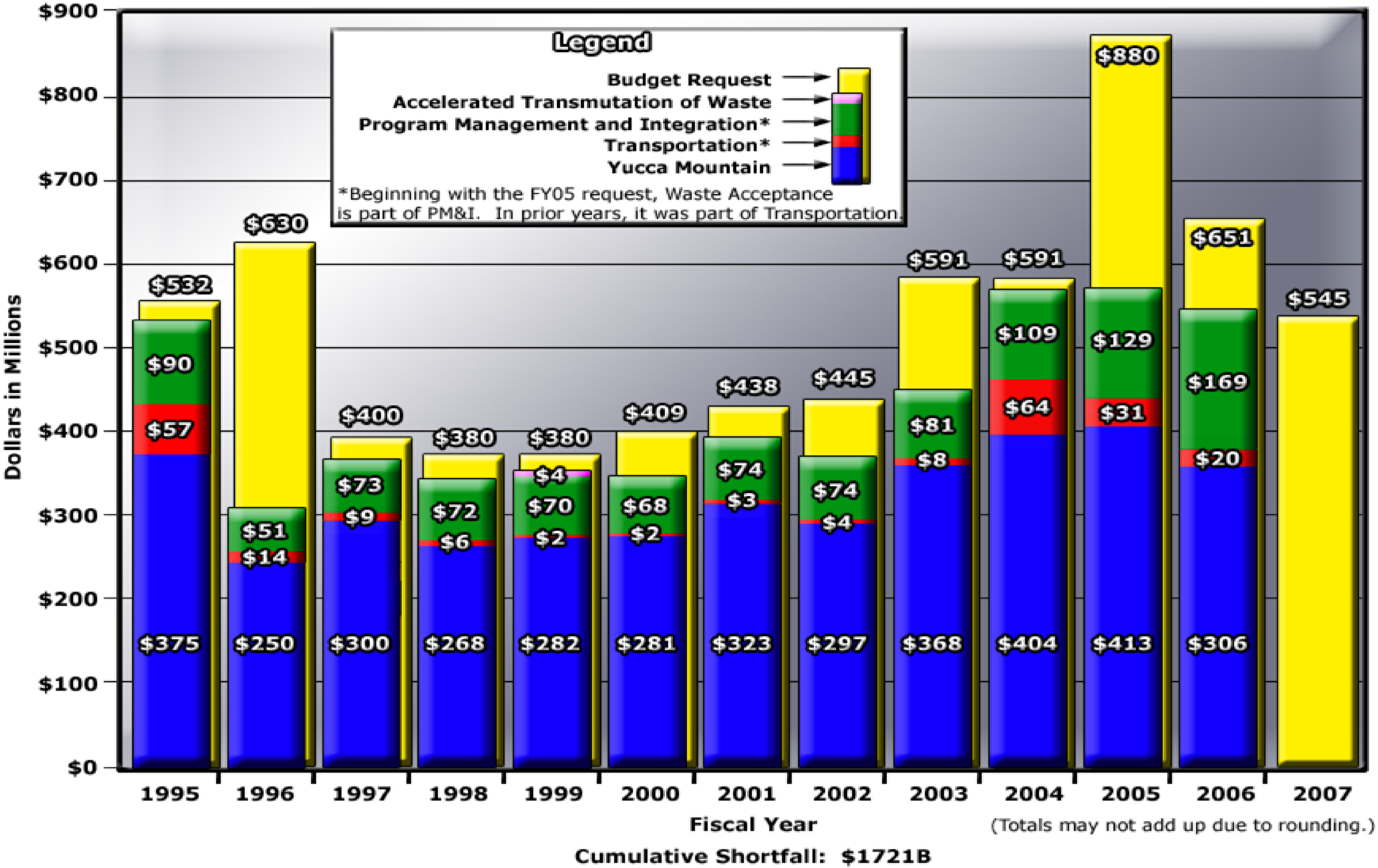
Status of the Nuclear Waste Fund

(in millions of dollars, as of June 30, 2006)

•Ongoing Fees Paid	13.082
•One Time Fees Paid	1.486
•Interest	10.789
•Total NWF Revenue	25.357
•Defense Waste Disposal Appropriations	2.969
•Total Program Revenue	28.326
•Program Costs	-9.051
•NWF Balance	19.275

•Ratepayer Commitments	
•Ongoing Fees Paid	13.082
•One Time Fees Paid	1.486
•Interest	10.789
•Outstanding One Time Fees (+Interest)	2.946
•Total Commitments	28.303

Annual Appropriations and Administration's Budget Request (1995-2007)



No Repository: Economic Analysis

(YM Environmental Impact Statement)

(70,000 MTHM at both repository and existing onsite storage locations)

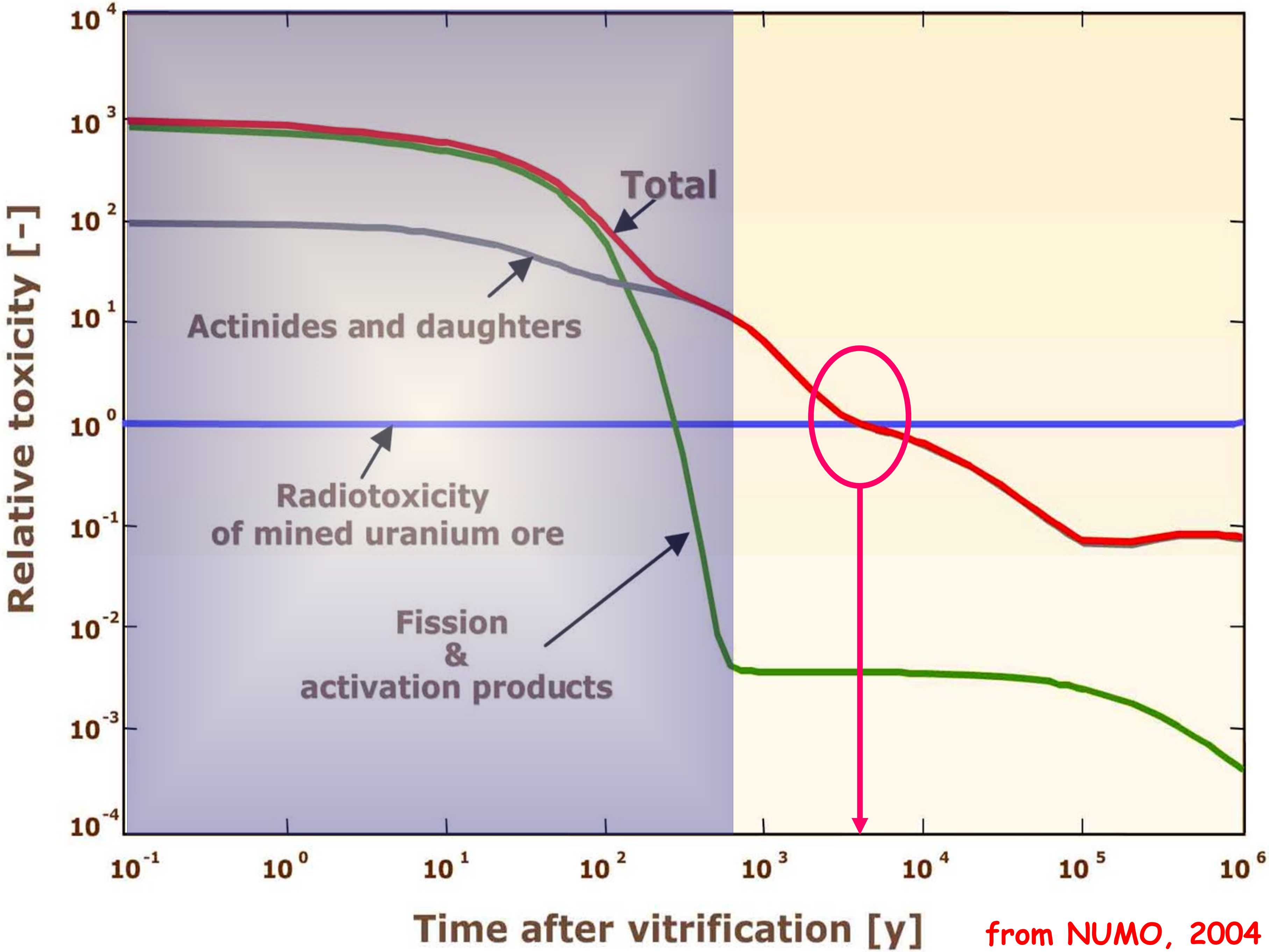
Repository Impacts (0 to 10,000 Years)		**No-Action Impacts (0 to 10,000 Years)**	
Impacts: 0 to closure at 117 to 341 years		**Impacts: 0 to 100 Years**	
Radiological		Radiological	
Loadout and Transport. of SNF & HLW	4 LCFs	Loadout and Transport. of SNF & HLW	0 LCFs
Construction and Operations	4 - 8 LCFs	Construction and Operations	16 LCFs
Subtotal	8 - 12 LCFs	Subtotal	16 LCFs
Nonradiological (Transportation by mostly rail)		Nonradiological	
SNF & HLW transportation to YM	3 - 4 Fatalities	Transportation (Materials and Commuting)	7 Fatalities
Nevada railroad const. & maint.	1- 2 Fatalities	Construction and Operations	2 Fatalities
Repository Constr. Ops. Monitor and closure (Materials Transport and Commuting)	10 - 17 Fatalities		
Construction and Operations at repository (Industrial)	2 - 3 Fatalities		
Total (0 to 100 years)	**24 - 38 Fatalities**	**Total (0 to 100 years)**	**25 Fatalities**
Cost	$43 - 58 Billion	Cost	$ 55 - 61 B

Impacts: 100 to 10,000 Years

		Institutional Control	No Institutional Controls
Radiological	~ 0 LCF	~ 13 LCFs	~ 3,300 LCFs
Transportation	0 Fatalities	~ 760 Fatalities	0 Fatalities
Construction and Operations	0 Fatalities	~ 320 Fatalities	0 Fatalities
Cost	$0	~ $519 - 572 M per Year	$0

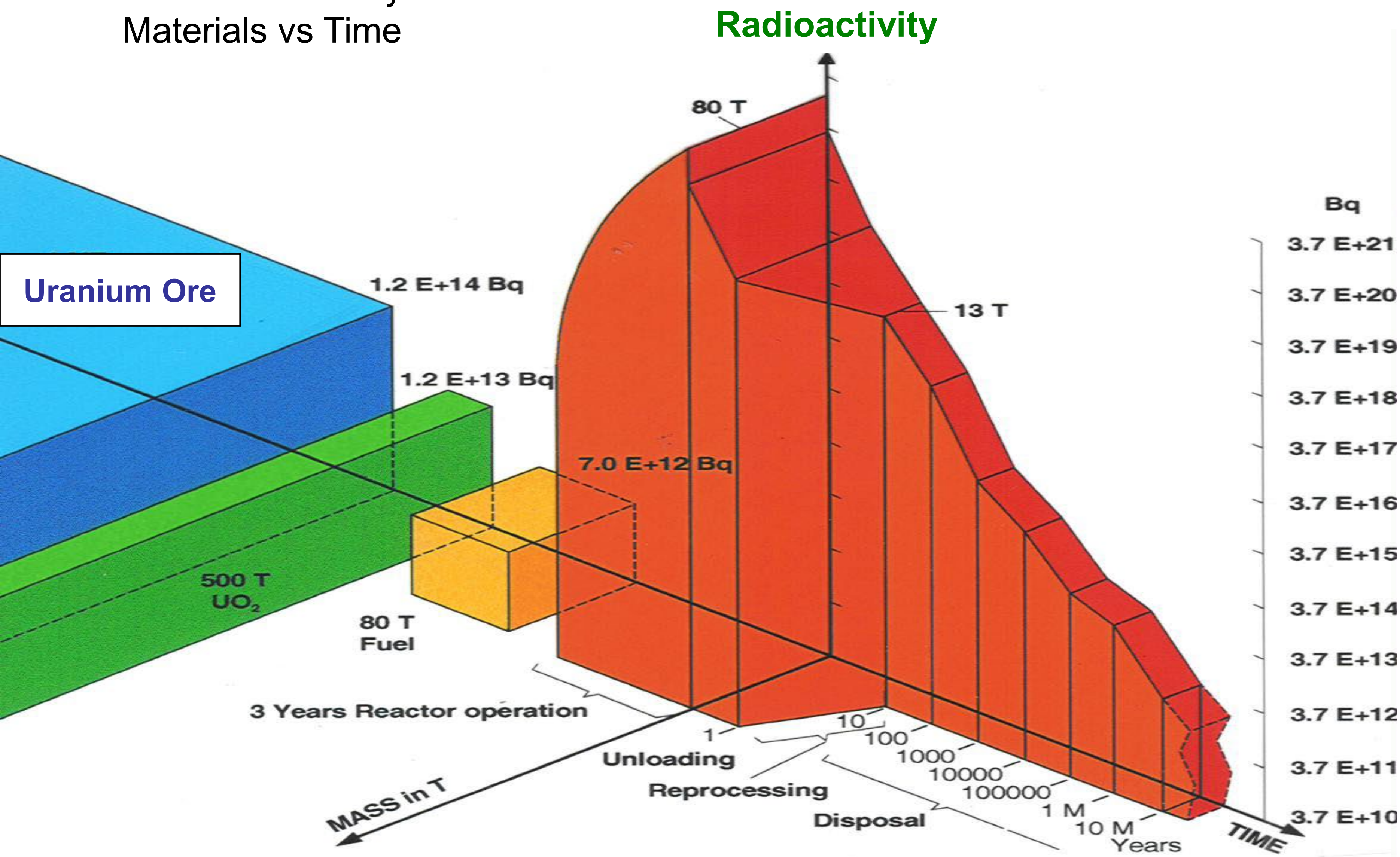
Impacts: 0 to 10,000 Years

Health Impacts, Total	24 - 38 Fatalities or LCFs	~ 1,120 Fatalities or LCFs	~ 3,325 Fatalities or LCFs
Total Cost	$43 - 58 Billion	~ $6 Trillion	$55 - 61 B



from NUMO, 2004

Volume & Toxicity of Nuclear Fuel Materials vs Time

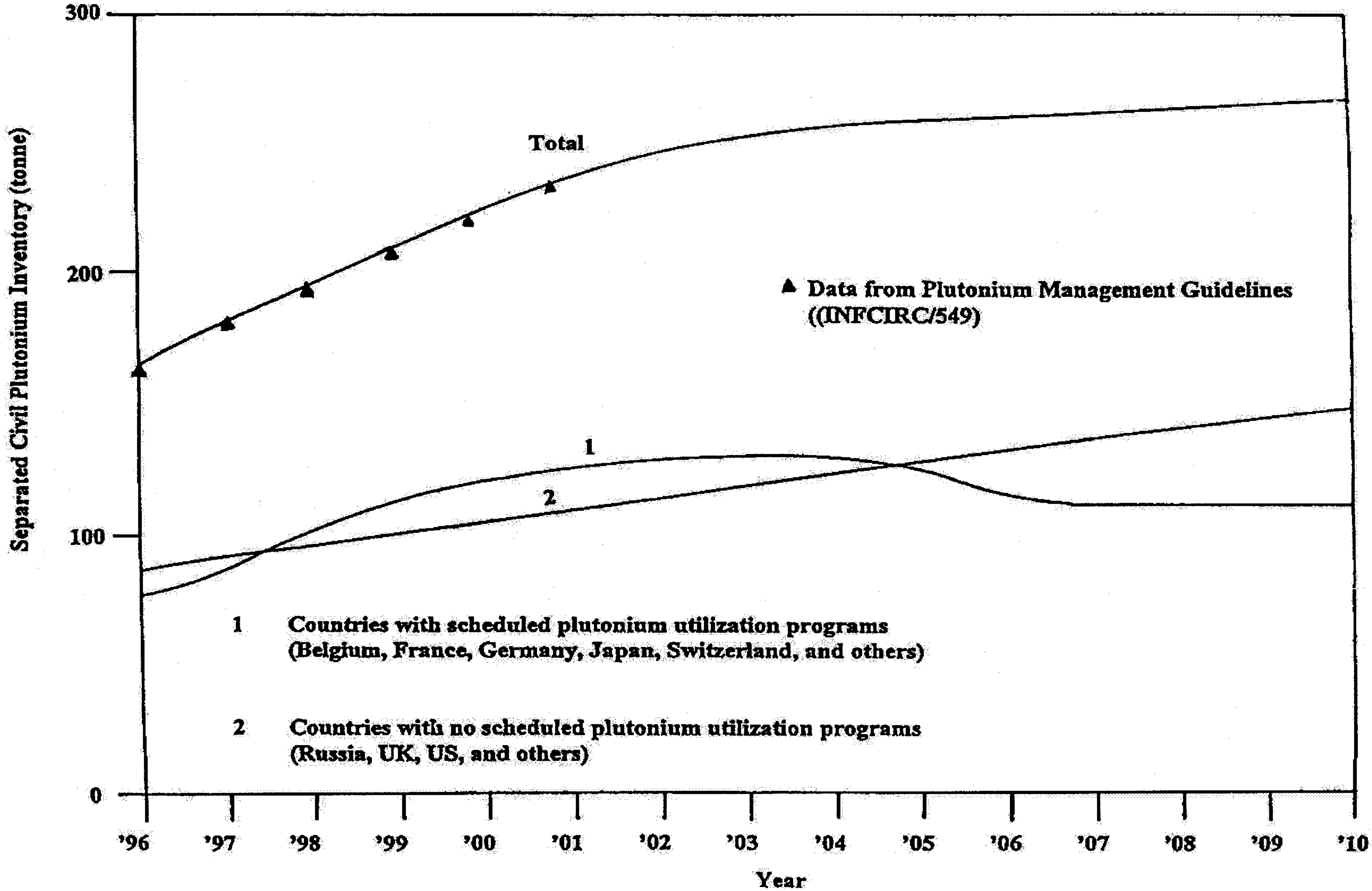


Energy Future?

- Population will grow – 6 billion to at least 7.5 billion in 2020
- World primary energy needs will grow and electricity will grow faster (100 exojoules in 1950 compared to ~400 today to 600-750 in 2020)
- Fossil fuels in energy production and use will account for vast amount of carbon emissions (U.S. 90% of the 1500 MHC/yr; electric 30%)
- U.S. plants (nuclear and fossil) will age, and some will retire 38G nuclear and 71G fossil by 2015 (EIA)

    - 320G of new U.S. capacity by 2015; 1/3 of new domestic electricity plants through 2015 are needed simply as replacements
    - Life extension of nuclear can be advantageous

Global Inventory of Separated Plutonium



Plutonium 2000 Conference, Brussels, Belgium

- Global stock of separated civil plutonium will continue to grow
- U.S. and Russia each declared 50 MT of WG Pu excess, and each agreed to disposition 34 MT in nuclear reactors

Global Inventory of Highly Enriched Uranium

Country	Estimated HEU Inventory, MT	Excess or declared HEU MT
United States	~750	174
Russian Federation	~1050	500
United Kingdom	22	1.3[2]
France	25	5.0[2]
China	20	none
Others (Pakistan, Israel, etc.)	Small, or unknown	none
Total	~1870	~680

1. IAEA TECDOC on Management of HEU, Status and Trends, March 2005
2. INFCIRC549, 2003

Proposal by ElBaradei, Director General of IAEA

Economist, 16 Oct, 2003

- Limit processing and production of weapons-usable materials to facilities under multinational control
- Deploy nuclear-energy systems with built-in features to prevent diversion and misuse of facilities and equipment and facilitate efficient oversight
- Convert existing facilities that use HEU – e.g., to product medical radioisotopes – to LEU
- Consider multinational approaches to the management and disposal of spent fuel and radioactive wastes

Limit enrichment and reprocessing to facilities under multinational control

U.S. President Bush's Speech

National Defense University, on February 11, 2004

"….The world must create a safe, orderly system to field civilian nuclear plants without adding to the danger of weapons proliferation. The world's leading nuclear exporters should refuse to sell enrichment/reprocessing equipment and technologies to any state that does not already possess full-scale, functioning enrichment and reprocessing plants. … should ensure that states have reliable access at reasonable cost to fuel for civilian reactors, so long as those states renounce enrichment and reprocessing. Enrichment and reprocessing are not necessary for nations seeking to harness nuclear energy for peaceful purposes."

Limit enrichment and reprocessing to states that have already full-scale, functioning plants

IAEA Nuclear Waste Management Principles

1. **Protection of Human Health**
   Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.
2. **Protection of the environment**
   Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.
3. **Protection beyond national borders**
   Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.
4. **Protection of future generations**
   Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.
5. **Burdens on future generations**
   Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.
6. **National legal framework**
   Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.
7. **Control of radioactive waste generation**
   Generation of radioactive waste shall be kept to the minimum practicable.
8. **Radioactive waste generation and management interdependencies**
   Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.
9. **Safety of facilities**
   The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.