Closing the Nuclear Fuel Cycle in the US: *How Experience Should Guide Us*

Savannah River Section
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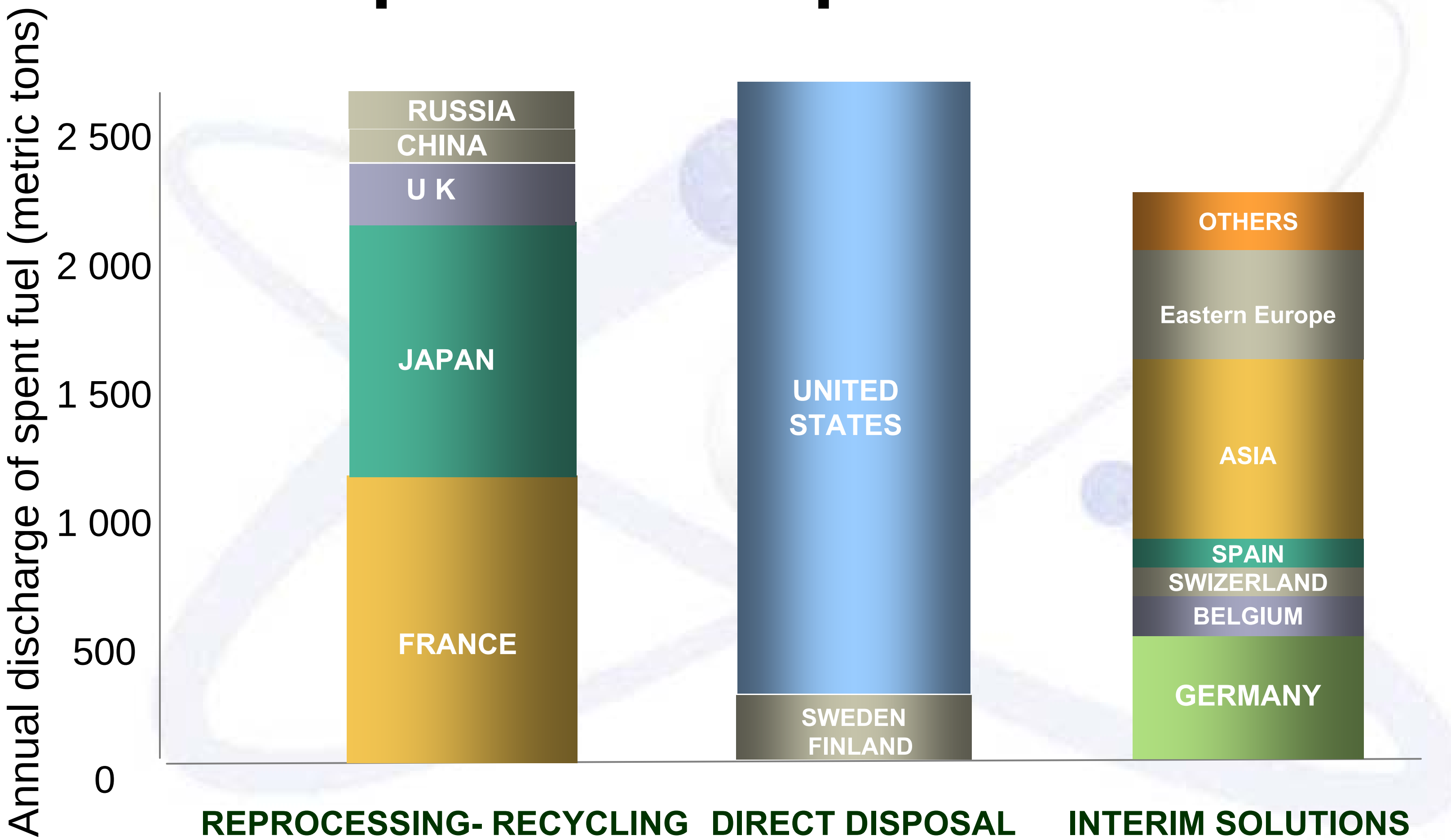
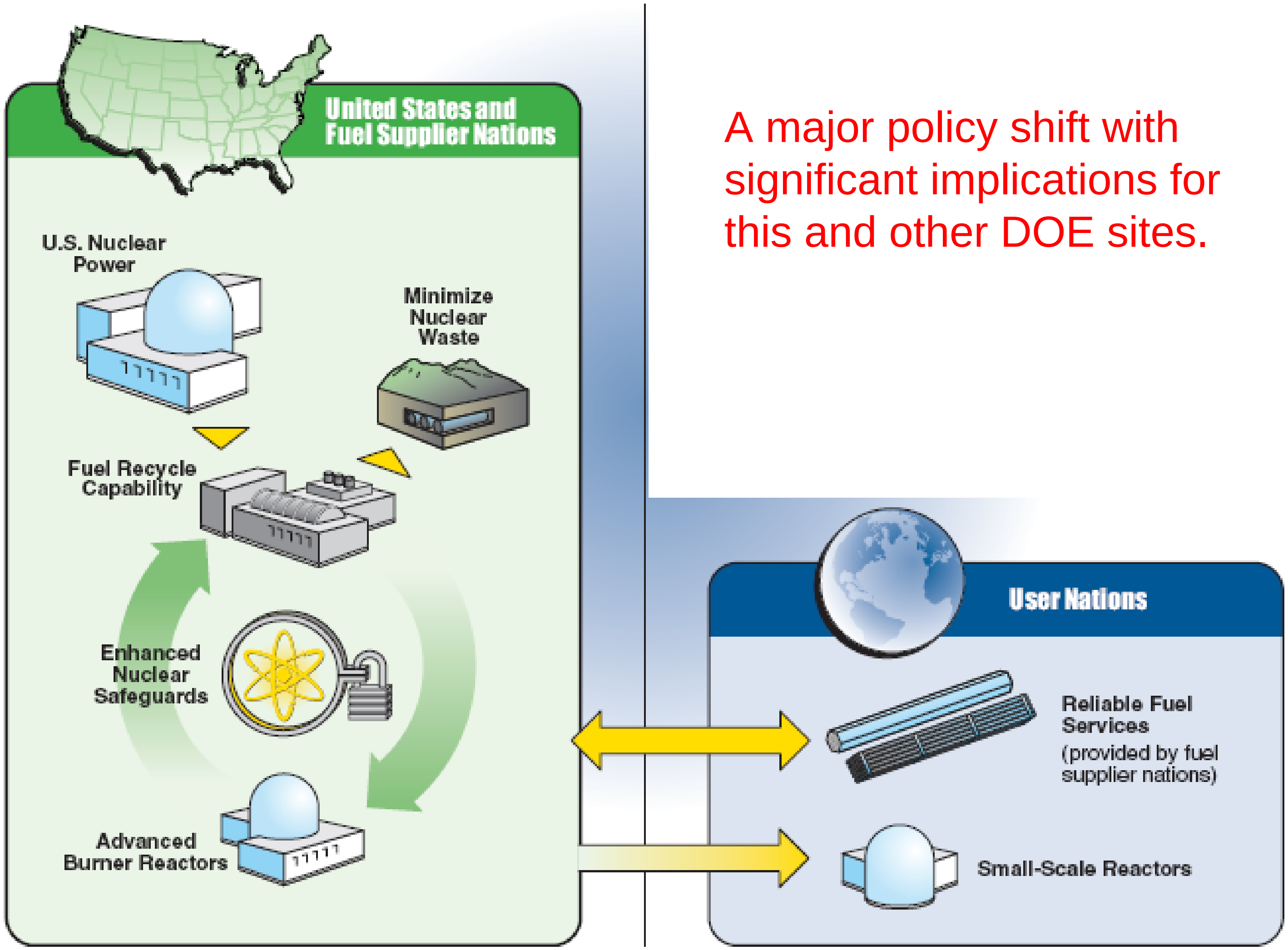
Why this talk? Why Now? Why Me?

- Blame Carl
- *Global Nuclear Energy Partnership announced at noon today—a change in policy*
- The ANS role may help shape the debate
  - And may affect the future of the Society
  - And I have the microphone
    - And I need your input

National policies re spent fuel



Global Nuclear Energy Partnership (GNEP)

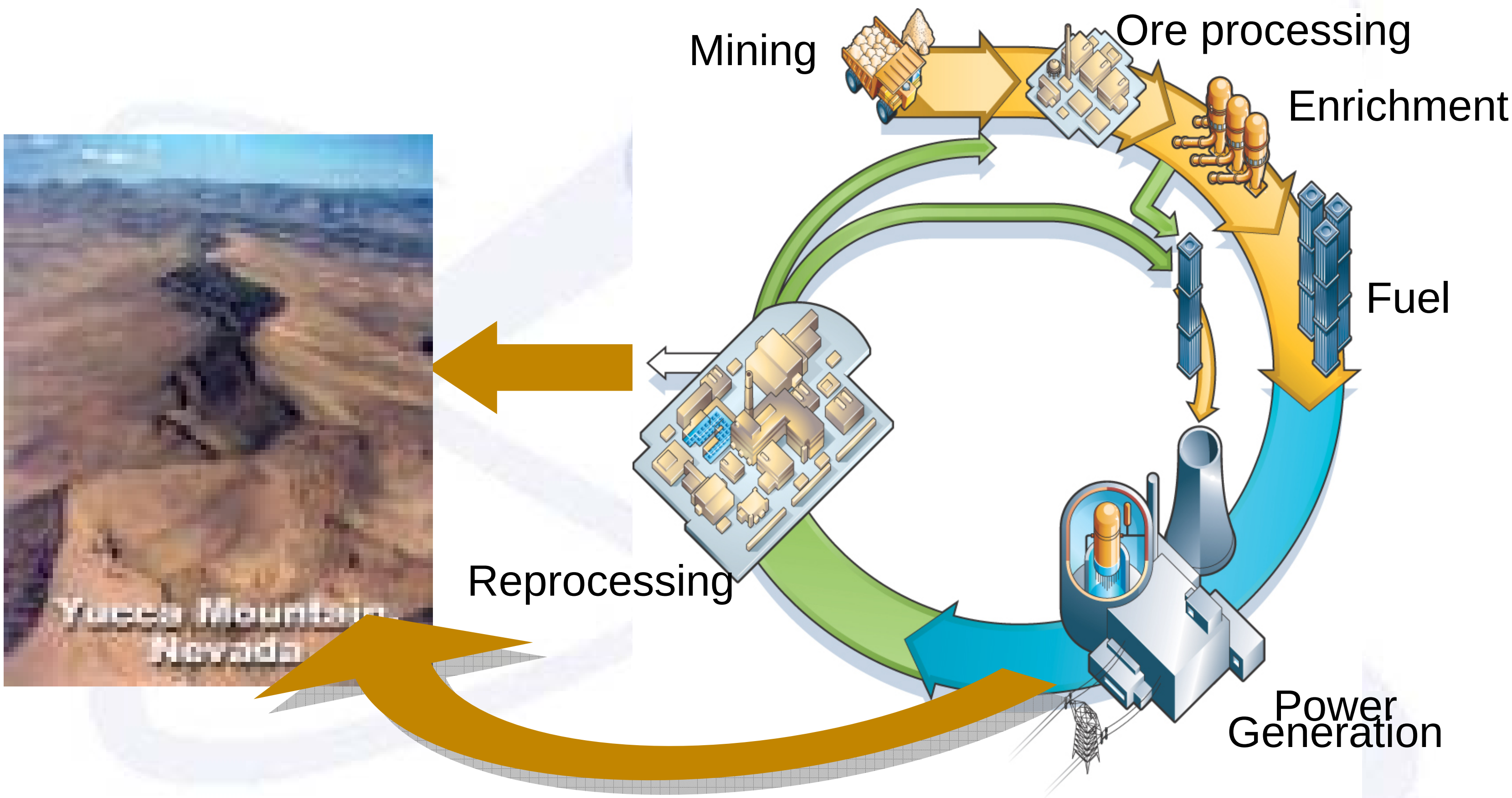


A major policy shift with significant implications for this and other DOE sites.

Key Elements of GNEP

- Expand domestic use of nuclear power
- Demonstrate more proliferation-resistant recycling
- Minimize nuclear waste
- Develop advanced burner reactors
- Establish reliable fuel services
- Demonstrate small-scale reactors
- Develop enhanced nuclear safeguards

Fuel Cycle: Present and Future (?)



Courtesy Cogema

US reprocessing experience: defense complex

- Hanford, Washington
  - T Plant
  - B Plant
  - REDOX
  - PUREX
- Savannah River, South Carolina
  - F Canyon
  - H Canyon
- National Reactor Testing Station, Idaho Idaho Chemical Processing Plant

T plant

- Bismuth phosphate precipitation process
- 26m X 31m X 245m “canyon”
- Started operations in December, 1944

REDOX plant

- 19,000 tons of fuel processed in 16 years of operation
- Started up in 1951

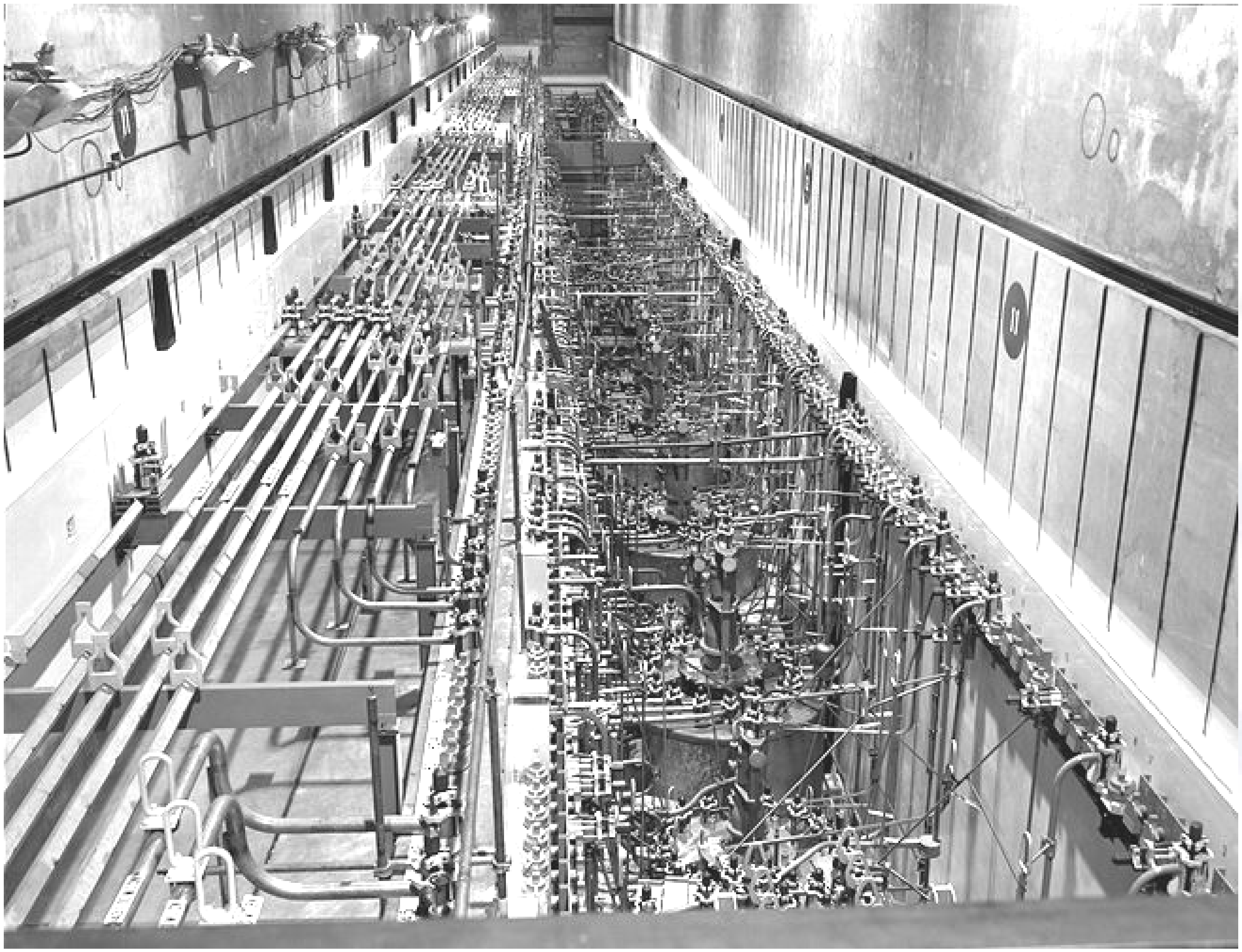
PUREX plant

- 1956
- 3000 t/year capacity

F Canyon at Savannah River

Idaho Chemical Processing Plant

H-Canyon interior



- Used for highly enriched uranium
- Built at Savannah River

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

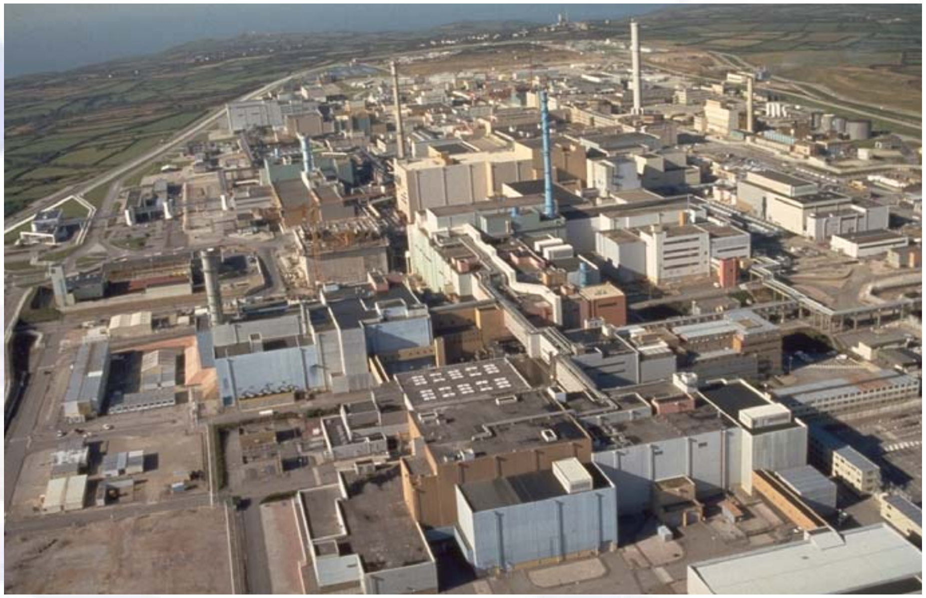
US reprocessing experience: commercialization attempts

- West Valley, New York
  - Successfully operated
  - Decided against investment in mandatory upgrades
- Morris, Illinois
  - Design flaws, never went to hot operations
  - Operates as a spent fuel storage facility
- Barnwell, South Carolina
  - $500,000,000 private investment stranded
  - Thank you, Mr. Carter

Current commercial reprocessing

Sellafield, UK

Courtesy of BNFL



La Hague, France

Courtesy of COGEMA

Rokkasho—the Japanese venture

- 800 t/y
- Under construction
- 2007 revised startup date
- $20 B cost

Courtesy of JNFL


VETEMENT
COGEMA
T7 FONCTIONS PRINCIPALES
MAIN FUNCTIONS

Rokkasho—the scale of facilities

Building	Approximate floor area (m^2)	Height (stories)	
		Above ground	Below ground
Spent Fuel Receiving and Storage	9,400	3	3
Head End	6,000	5	4
Separations	5,700	4	3
Purification	6,500	6	3
Uranium Denitration	1,500	5	1
Uranium- Plutonium Co-denitration	2,700	2	2
Uranium Oxide Storage	2,700	2	2
Uranium-Plutonium Mixed Oxide Storage	2,700	1	4
High Active Liquid Waste Vitrification	5,100	2	4
Vitrified Package Storage	5,700	1	2
Low Active Liquid Waste Treatment	2,600	3	2
Low Active Waste Treatment	9,500	4	2
Control	2,900	3	2
Analytical Laboratory	4,900	3	3

Footprint:

~70,000 m^2

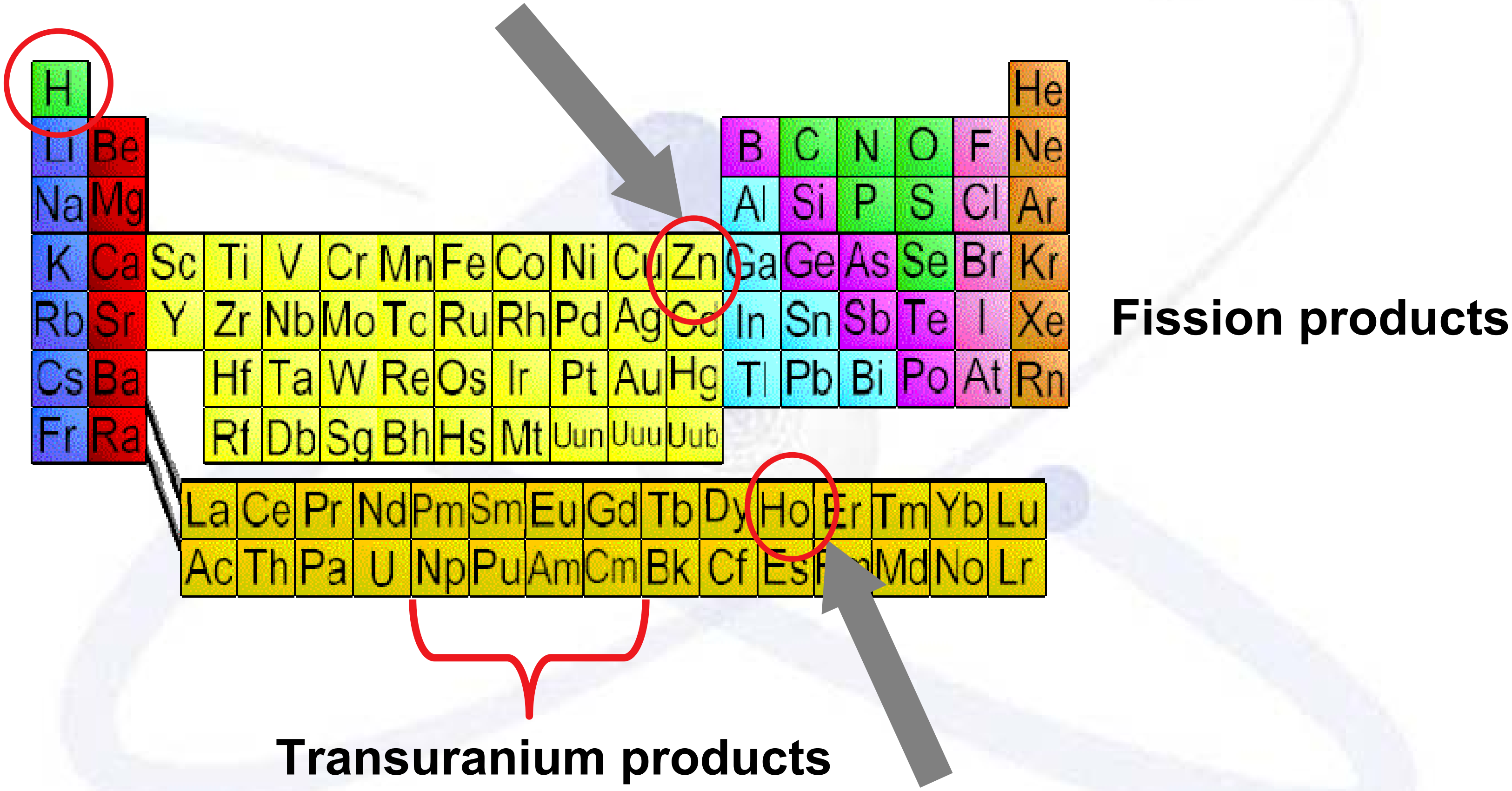
~6 stories

Courtesy of JNFL

Challenges for reprocessing US commercial spent nuclear fuel

- Technically difficult
- Cold war legacy
- Organized opposition
  - Environmental activists
  - Arms control advocates
- Large investment required
- Yucca Mountain Project
- Role of the federal government
- Policy stability
- Siting

A small chemistry problem



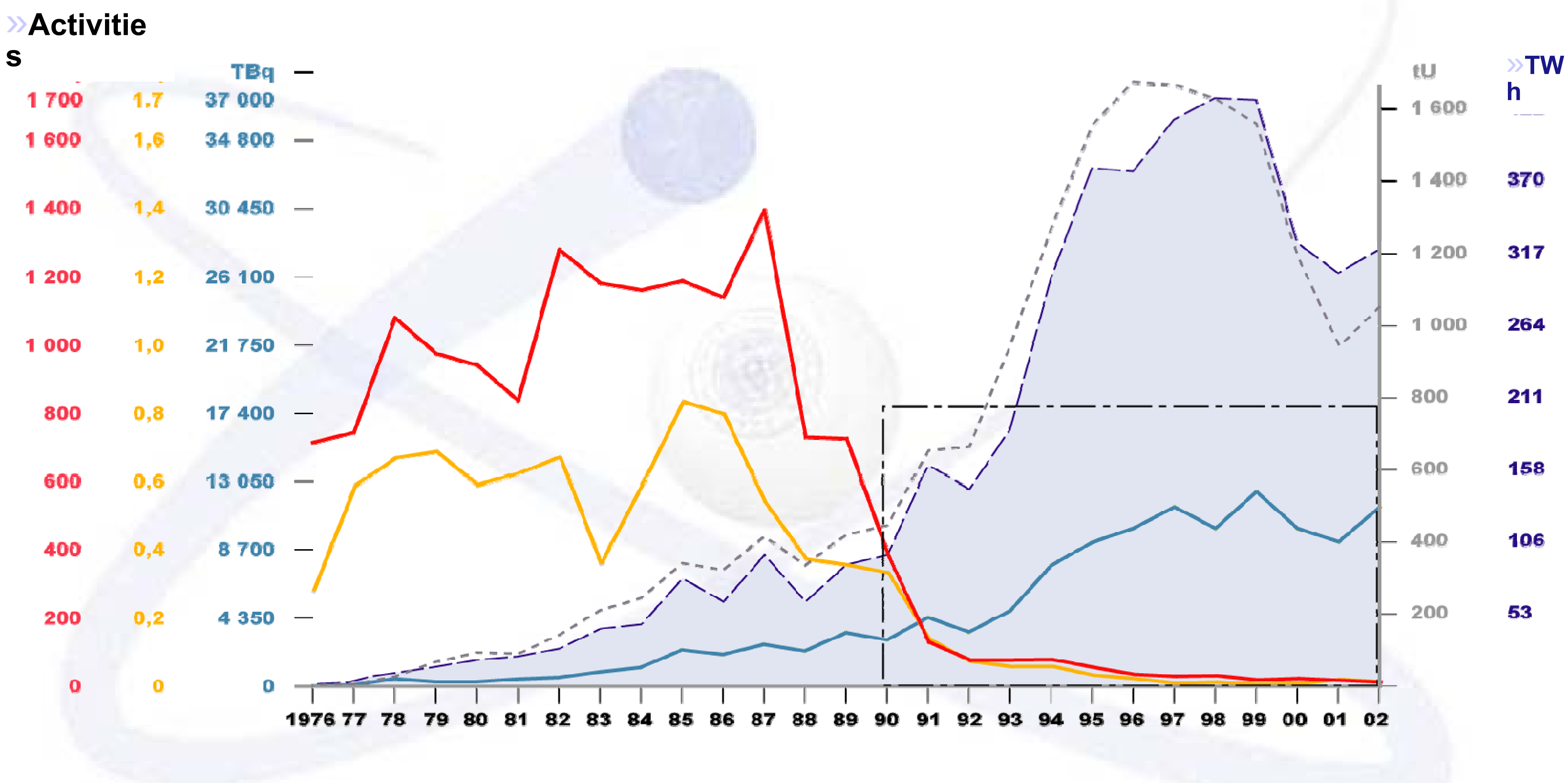
Environmental effects of reprocessing

- Concerns
  - Radioactive material that escapes intentionally or accidentally during processing
  - Dose to the public
  - Radioactive contamination of land and water
- Legacy of military reprocessing in US and former Soviet Union
  - High waste volumes
  - “Downwind” dose to public
  - Contamination of sizable land areas, lakes and rivers
- Vast improvements with modern reprocessing

Modern plants control discharges

- UK experience at Sellafield
  - In 1976, peak dose to critical group was ~2 millisieverts/year
  - Today the peak dose is ~0.1 millisieverts/year
    - Primarily from legacy seabed contamination
- French experience at La Hague
  - Liquid radioactive discharges have decreased by more than 2 orders of magnitude since 1976
  - Worker exposure has decreased by a factor of 20
  - Current average dose to the public is <0.01 millisieverts/year
    - Background dose in the region is 2.4 millisieverts/year

Discharges at La Hague 1976-2002



Courtesy of COGEMA

Liquid discharges : β, γ activities (other than tritium)

Liquid discharges : α radiation

Liquid discharges : tritium

tU : Tons of reprocessed spent fuel per year

TWh : energy produced by the reprocessed fuel

Seacoast siting a problem in US

Nonproliferation and recycle

- Pros
  - Active management: materials in process—making money while being safeguarded
  - Better in long term—less plutonium distributed around the world
  - Eliminate plutonium stores over time
  - Can be made less attractive than alternative routes to proliferation?
- Cons
  - Diplomatic problems from change in policy
  - Spread know-how around the world
  - Too much separated plutonium already
  - Inadequate tools to assess risk

IAEA wins Nobel Peace Prize 2005

1 of every 10 US light bulbs is powered by uranium from a former Soviet warhead.

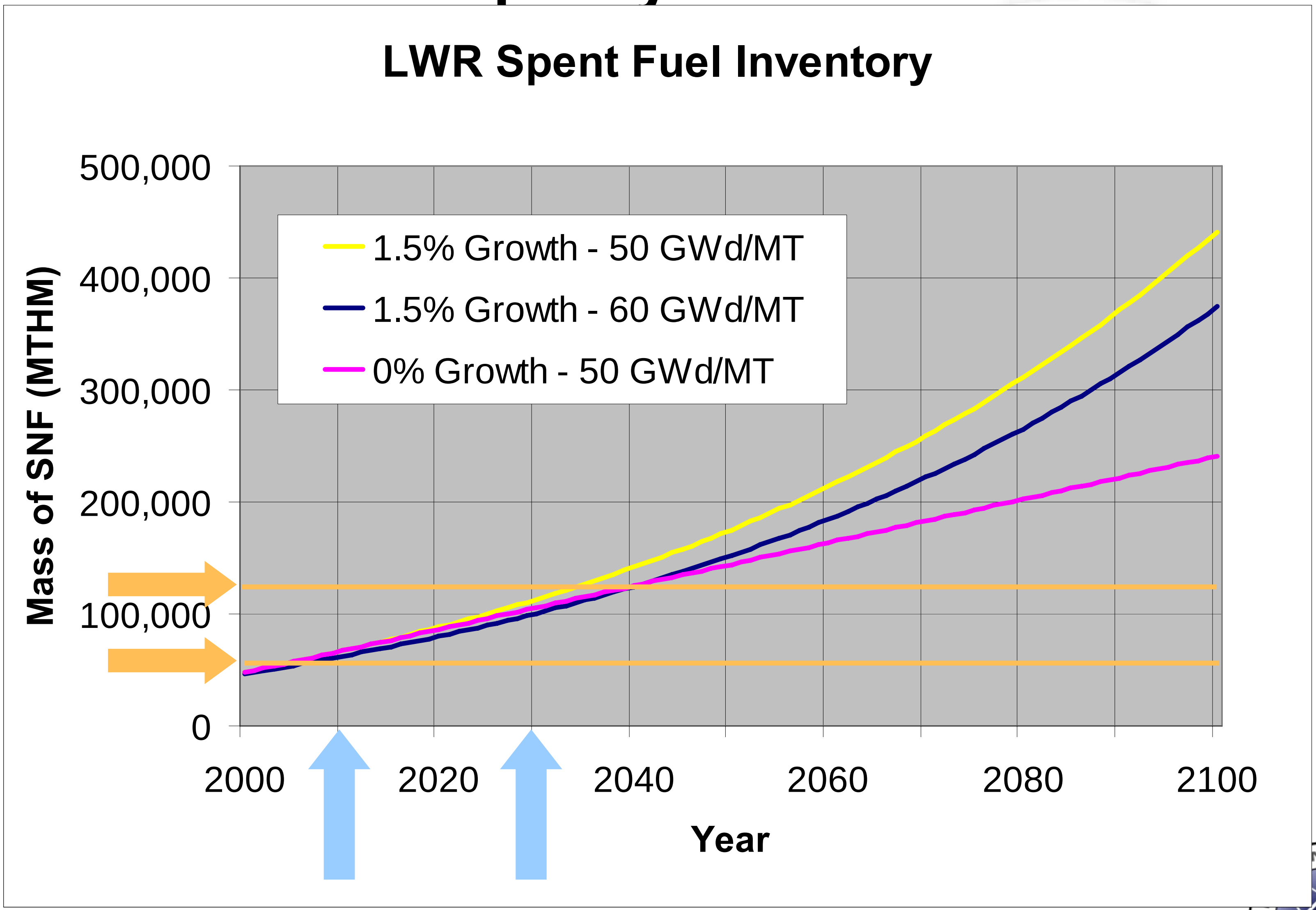
Fuel cycle cost elements

Cost Component	Units	OECD-NEA	MIT/Harvard
Ore	$/kg	20-30-40	30
Conversion	$/kg	3-5-7	8
Enrichment	$/kg SWU	50-80-110	100
UOX fabrication	$/kgIHM	200-250-300	275
SF storage/disposal	$/kgIHM	410-530-650	400
Reprocessing	$/kgIHM	700-800-900	1000
HLW storage/disposal	$/kgIHM	63-72-81	300

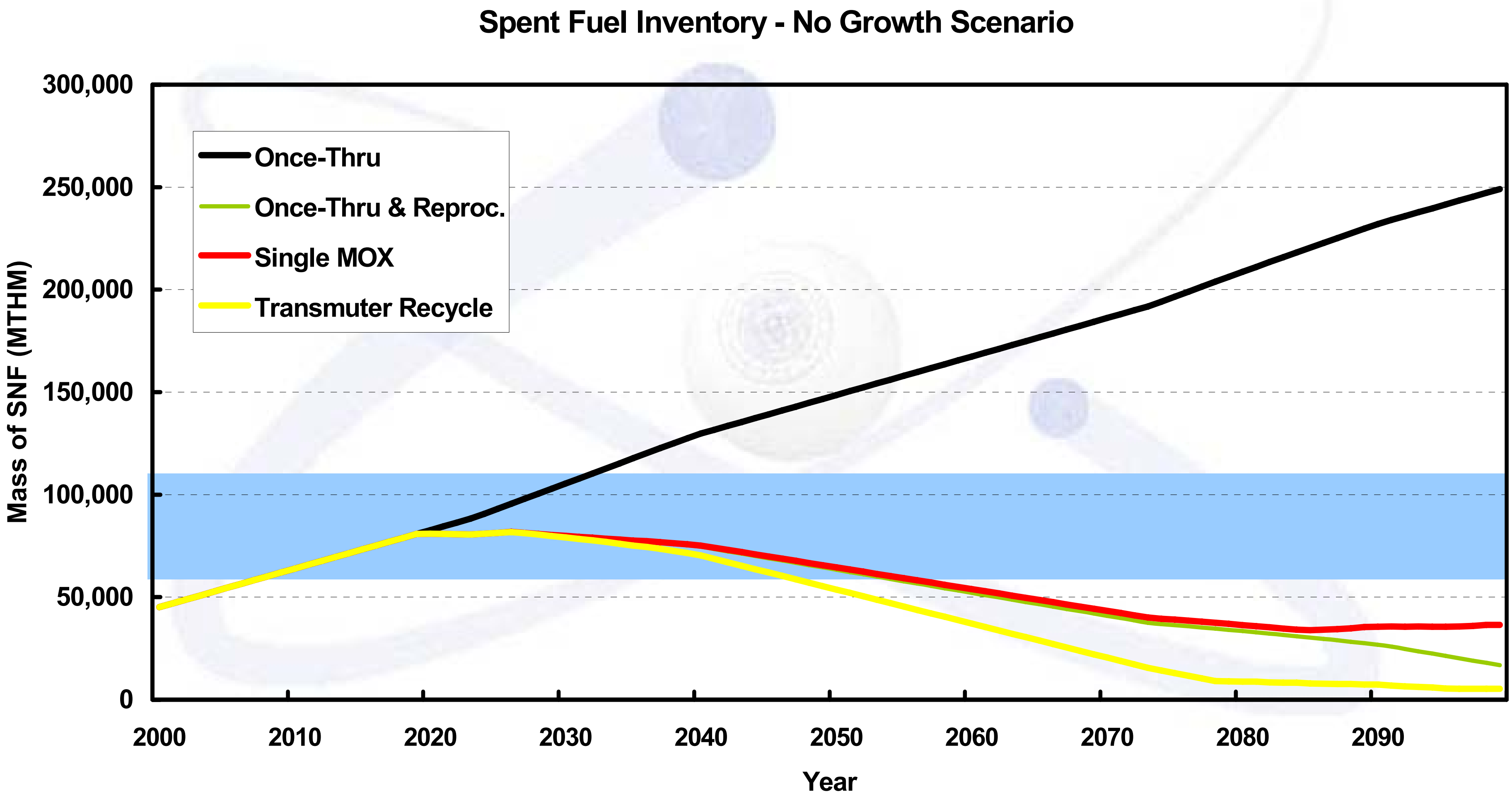
IHM: initial heavy metal
Cogema 2005 Estimate: ~$600/kg for 25-year cooled fuel

Repository design criteria set R&D goals

Yucca Mountain capacity is committed



Spent fuel accumulation—No Growth



Number of US repositories required

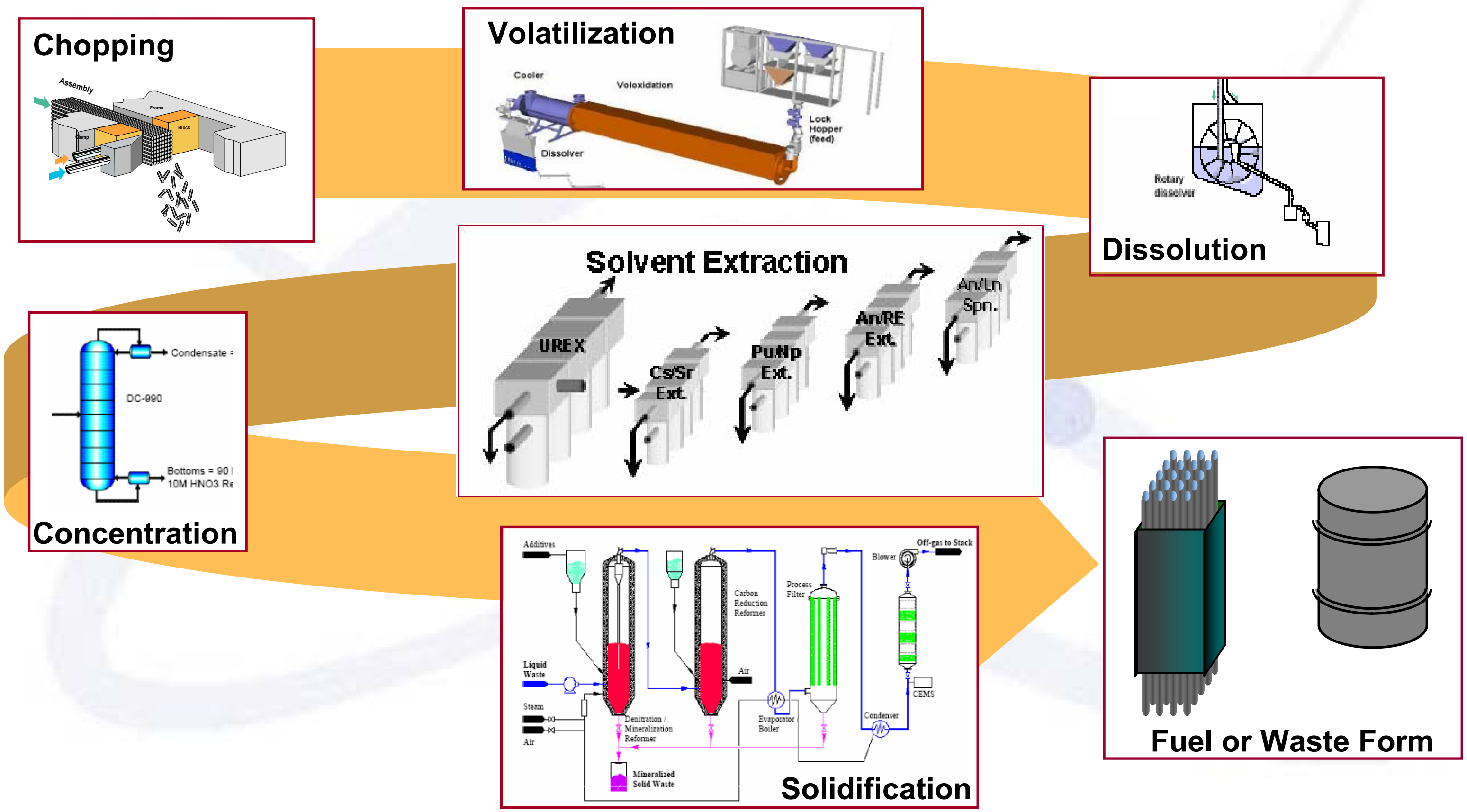
Nuclear Futures		Existing License Completion	Extended License Completion	Continuing Level Energy Generation	Continuing Market Share Generation	Growing Market Share Generation
Cumulative spent fuel in 2100 (MTiHM)		90,000	120,000	250,000	600,000	1,500,000
		Existing Reactors Only <-----		-----> Existing and New Reactors		
Fuel Management Approach		**Number of Repositories Needed (at 70,000 MT each)**				
-----> No Recycle	Direct Disposal (current policy)	2	2	4	9	22
	Direct Disposal with Expanded Repository Capacity	1	1	2	5	13
Recycle <-----	Limited Thermal Recycle with Expanded Repository Capacity	1	1	1	3	7
	Repeated Combined Thermal and Fast Recycle	(requires new reactors)		1	1	1

Courtesy of K. McCarthy

Getting green: closing the fuel cycle

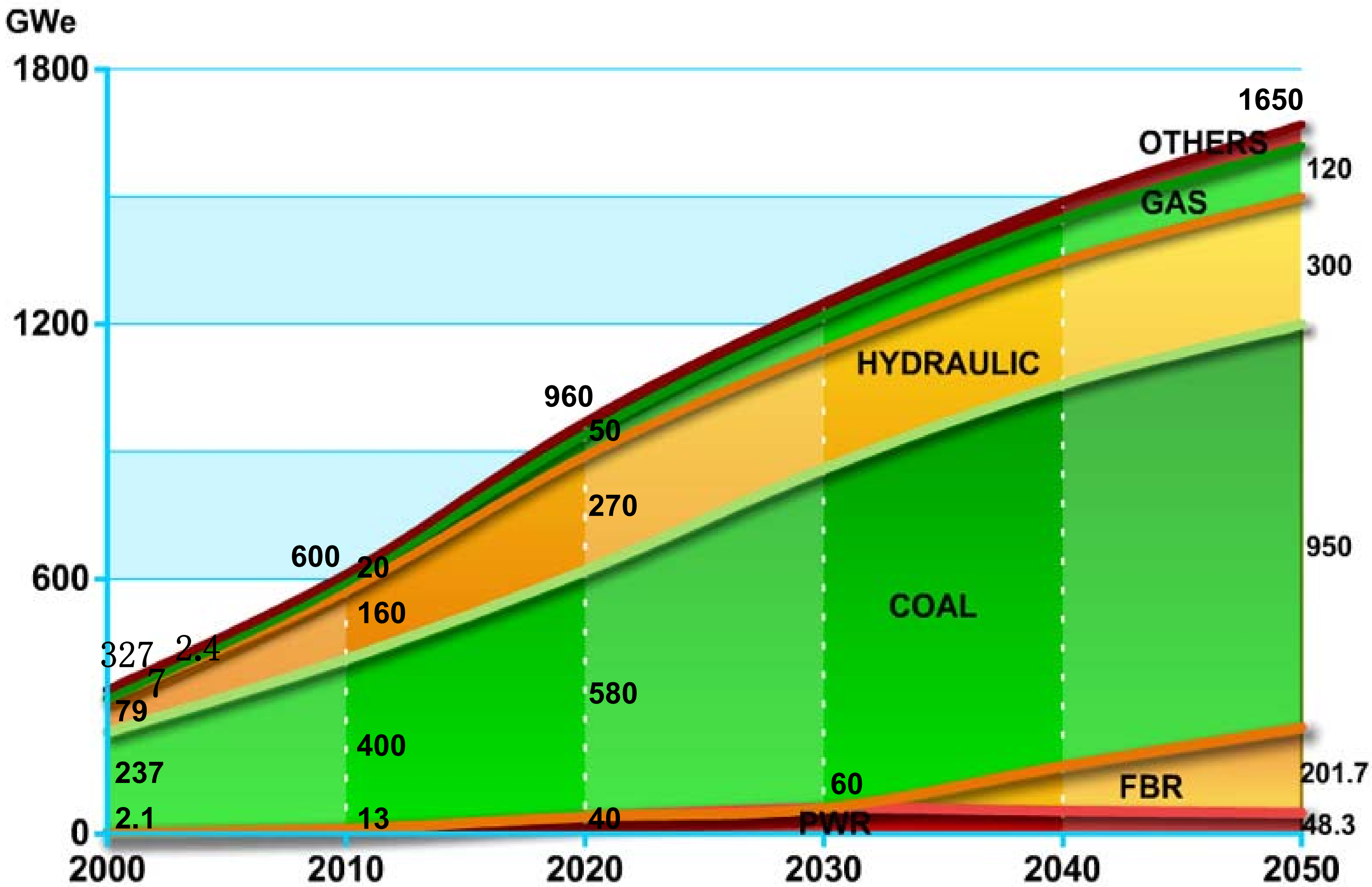
- Nuclear is currently an extractive industry
- “Closing the fuel cycle is inevitable.” GLOBAL 2005
- It takes 50 years to fully implement a new energy technology
- No huge rush for US to implement, but…
  - Spent fuel assurance needed by utilities
  - Maybe last chance to influence international development
  - Serious R&D is needed now

Advanced reprocessing technology—UREX+



Courtesy of P. Finck

Global competition for uranium is next?



Courtesy of Mi XU, GLOBAL 2005

Electric Capacity Development Envisaged In China

One last chance to get it right

- Trust
- Waste
- Nonproliferation
- Improvements made by steps
- Air and water emissions
- Federal/Private issues
- Investment magnitude and profile
- Yucca Mountain
- Sustainability through administration changes
- One voice (more or less)

A role for the ANS

- Provide trusted, objective technical information
- Engage the local sections in the debate across the country
- Engage Washington connections
- Help build a consensus in the technical community
- Provide the key technical forums

Nuclear is taking off!