New Generation Nuclear Fission?

William C Sailor

Los Alamos National Laboratory

Presentation for the Aspen Global Change Institute meeting "Long-Term Technology Pathways to Stabilization of Greenhouse Gas Concentrations"

Aspen, CO

July 8, 2003

Acknowlegements

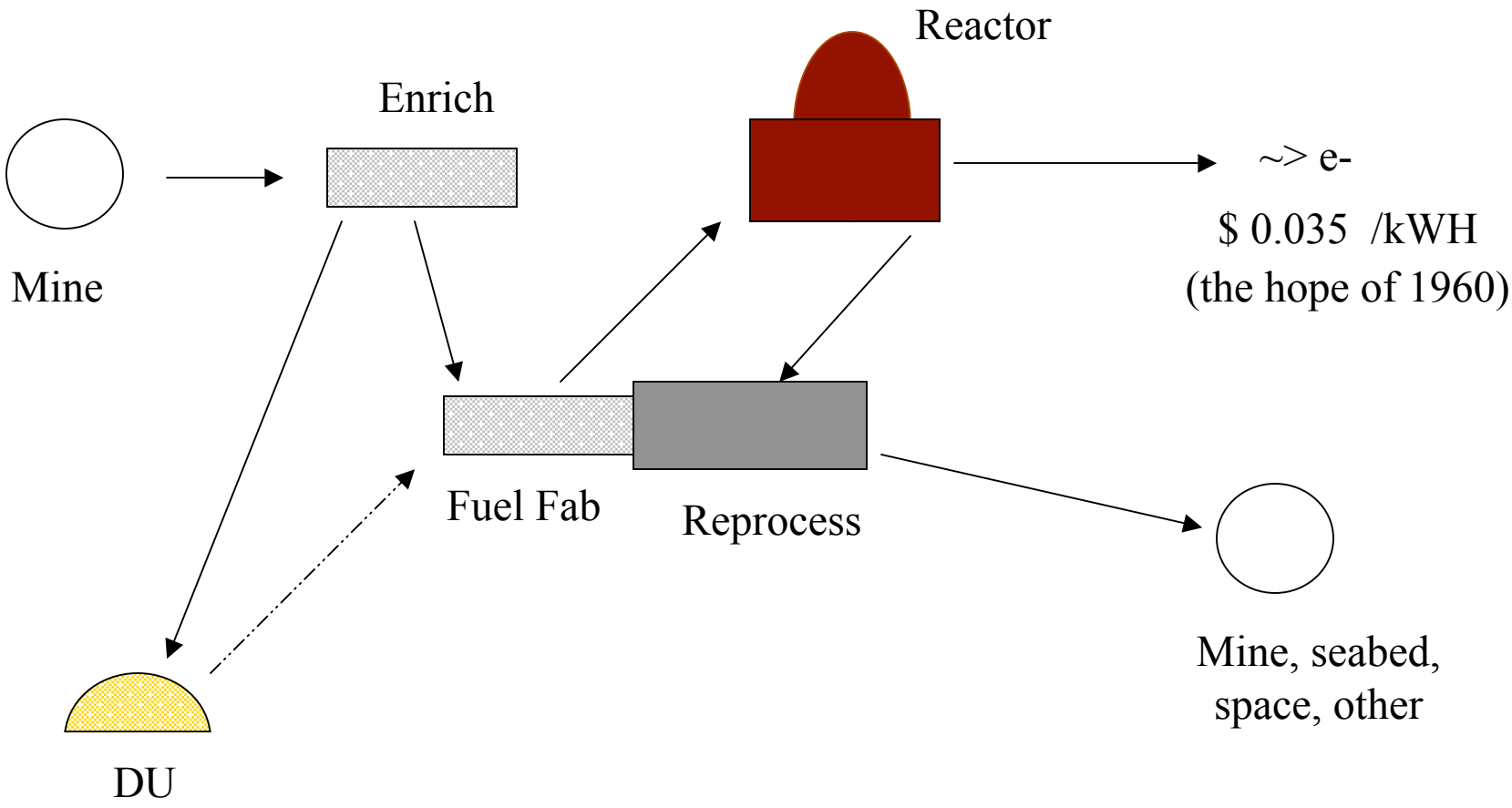
- Matt Bunn, Belfer Center, Harvard University
- David Wade, Argonne National Lab
- Jim Tape, Los Alamos National Lab
- Steve Fetter, Dept Public Policy, U Maryland
- David Bodansky, Dept Physics, U Washington
- Chaim Braun, Stanford University

Outline

- Fuel Cycle Introduction
- Reprocessing and Fast Reactors
- Nuclear Power and Proliferation
- Recommendation Summary

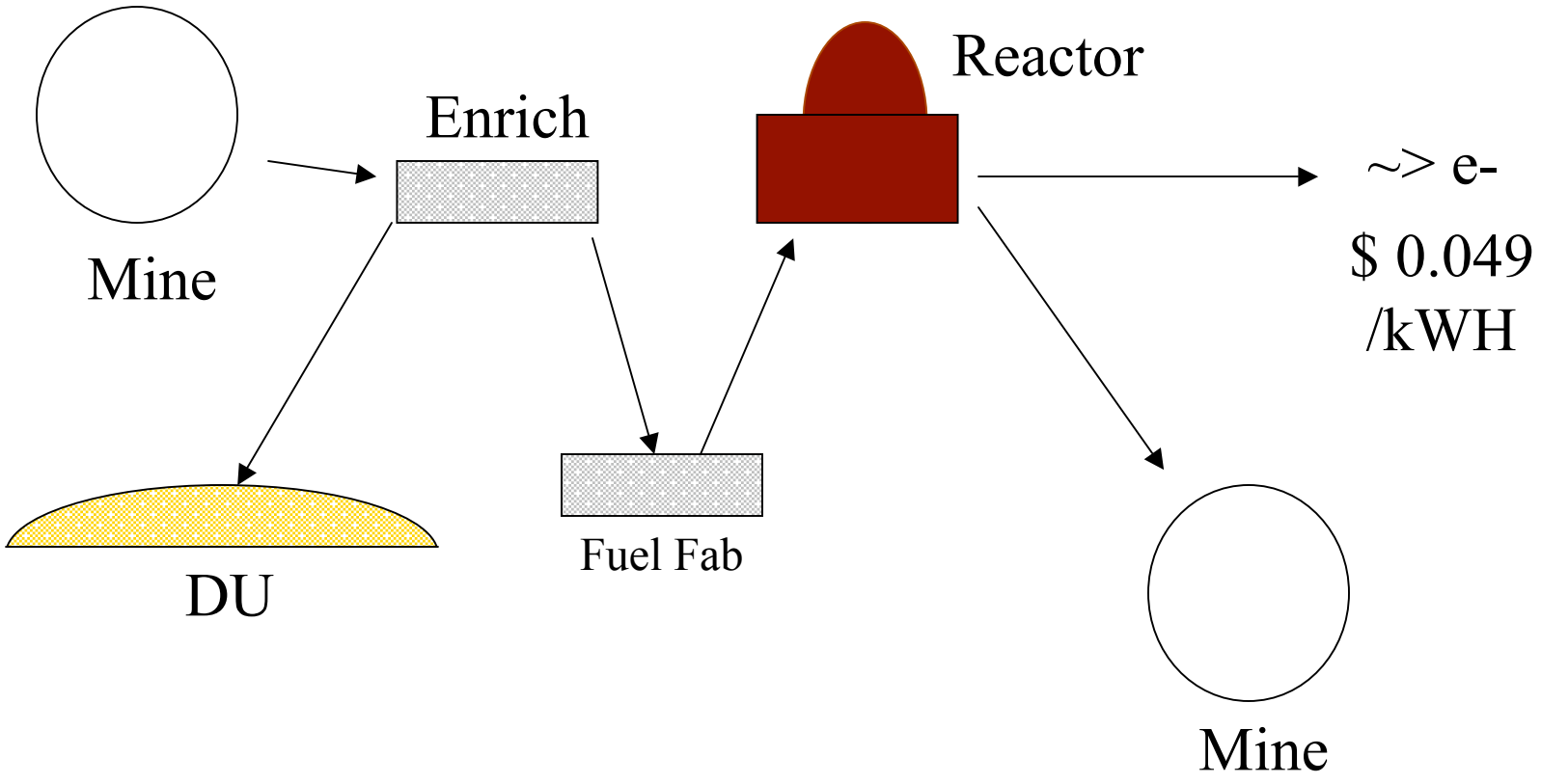
Fuel Cycle I:

The “Complete” Fast Breeder or Light Water Reactor Fuel Cycle of 1960

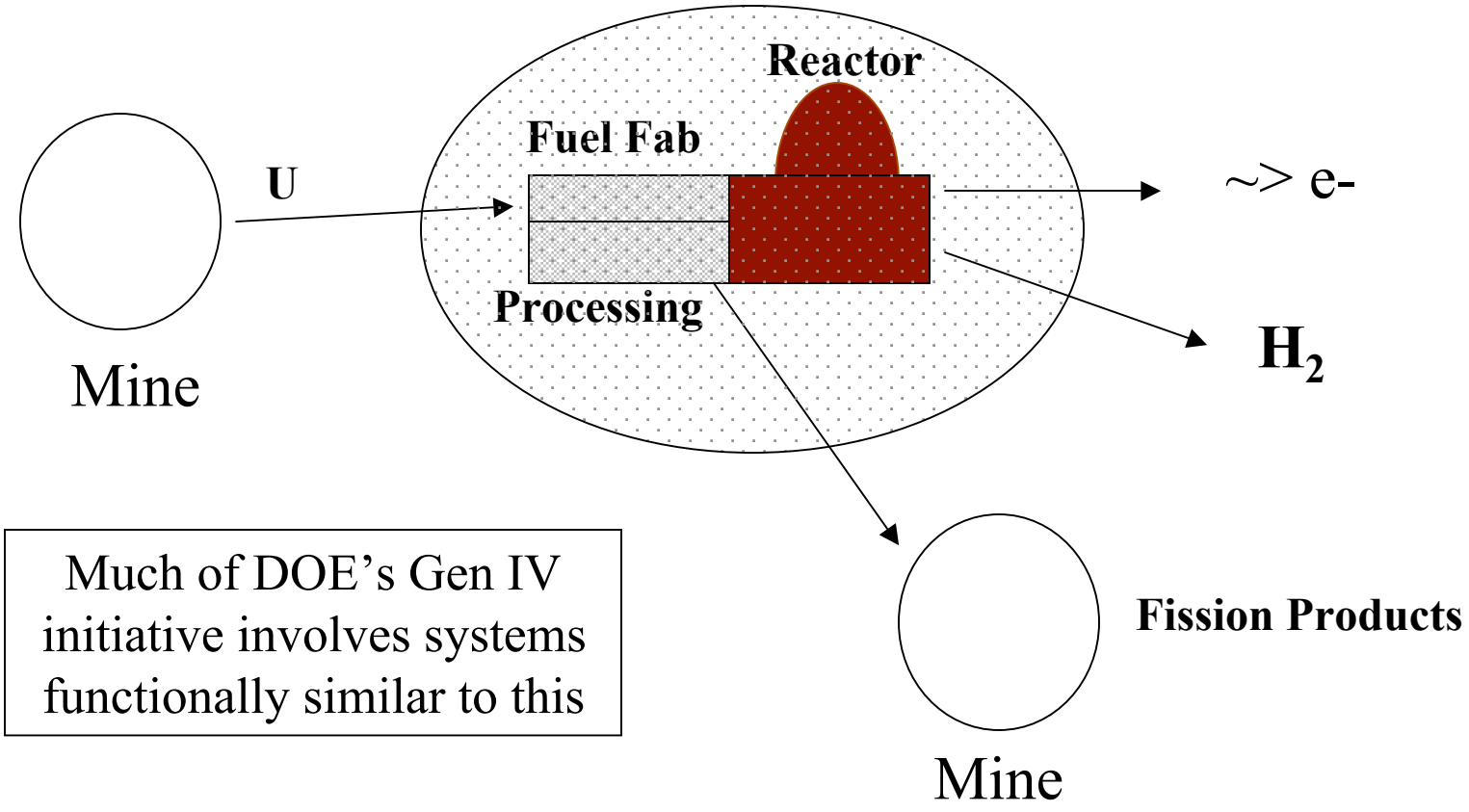


Fuel Cycle II:
Most Economical Expansion of Nuclear Power

("Once-thru" fuel cycle; cost number for a PWR, 36 month construction)



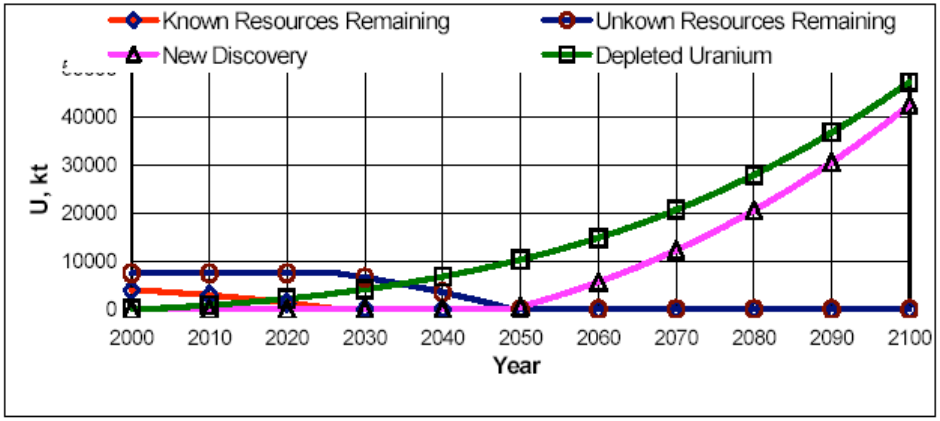
Fuel Cycle III:
The Ultimate Fast Reactor Fuel Cycle
(fun to work on; not economical now)



Much of DOE's Gen IV initiative involves systems functionally similar to this

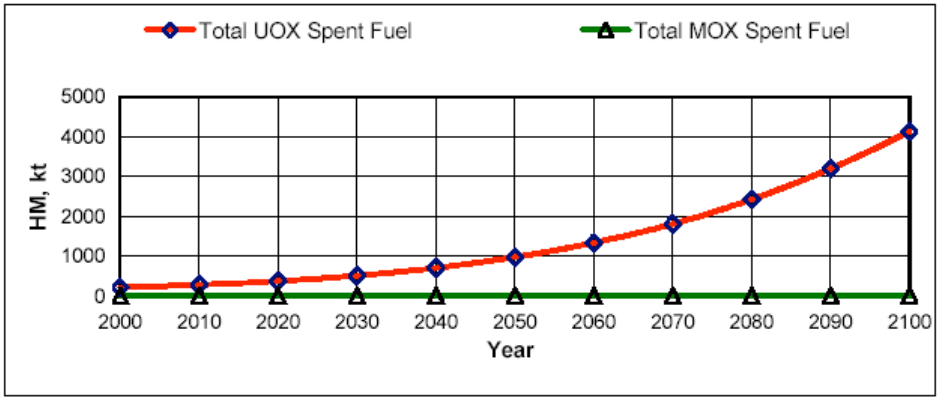
Reprocessing I: Negative Consequences of Greatly Expanding the Once-Through Fuel Cycle (Wade)

Not enough U



Redbook Known plus Speculative Reserves Recoverable at <130 $/kg is ~15 million tonnes

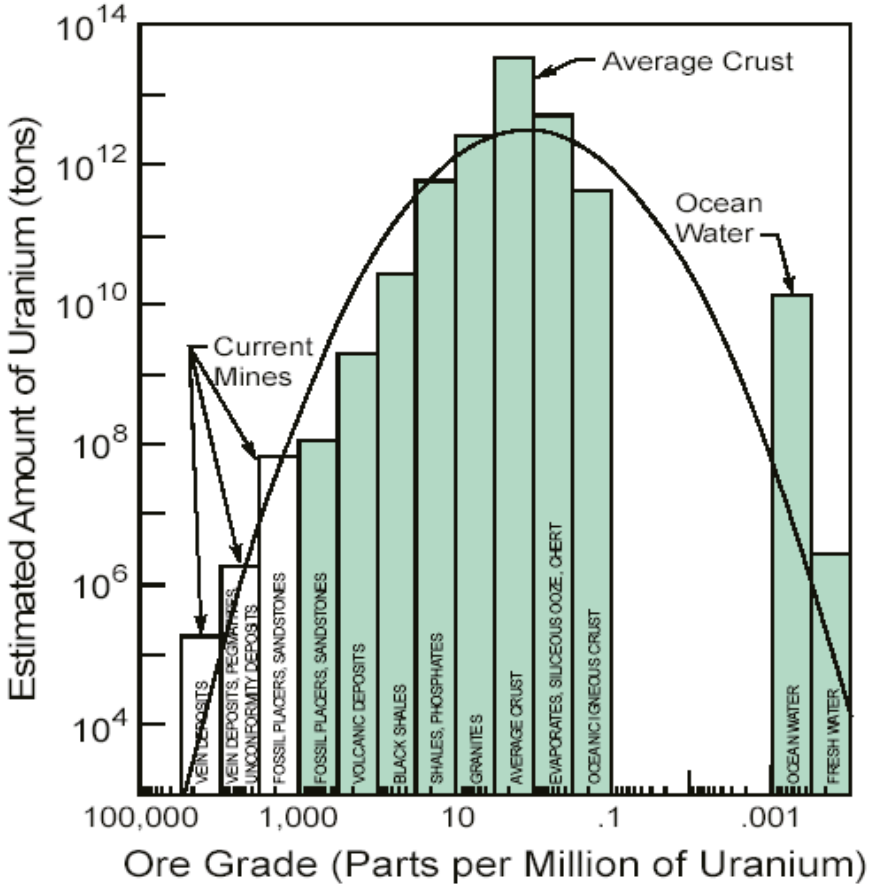
Not enough Repository Space



Yucca Mt. legislated capacity is ~70 kilotonnes

Finnish Repository at Eurajoki is 4 kilotonnes

Reprocessing II: How much Uranium is there?
Theoretical Uranium Ore Crustal Abundance vs Assay



Kenneth S. Deffeyes and Ian D. MacGregor, "World Uranium Resources," Scientific American Vol. 242, No. 1, January 1980, pp. 66-76.

Reprocessing III: Resources Expand* as a Power Law: $R/R_o = (p/p_0)^x$

where
R_o is "reserves' at p_0 = \$40/kgU (2.1 M tU, from Red Book)
R is "resources available" at a higher price
p = price in dollars/kgU
x is an exponent $2.35 < x < 3.32$

Organization	Exponent	R @ \$130	R @ \$260
Gen IV FCCG	2.35	30 M	200 M
Princeton, 1978	2.74	50 M	400 M
U Info Center	3.32	100 M	1000 M

*Drawn from personal communications with M. Bunn, Harvard and S. Fetter, U. Maryland
x is sometimes call the "long-term elasticity of supply"

Reprocessing IV: Will U price go up or down?
Copper price has gone down over the last 200 years

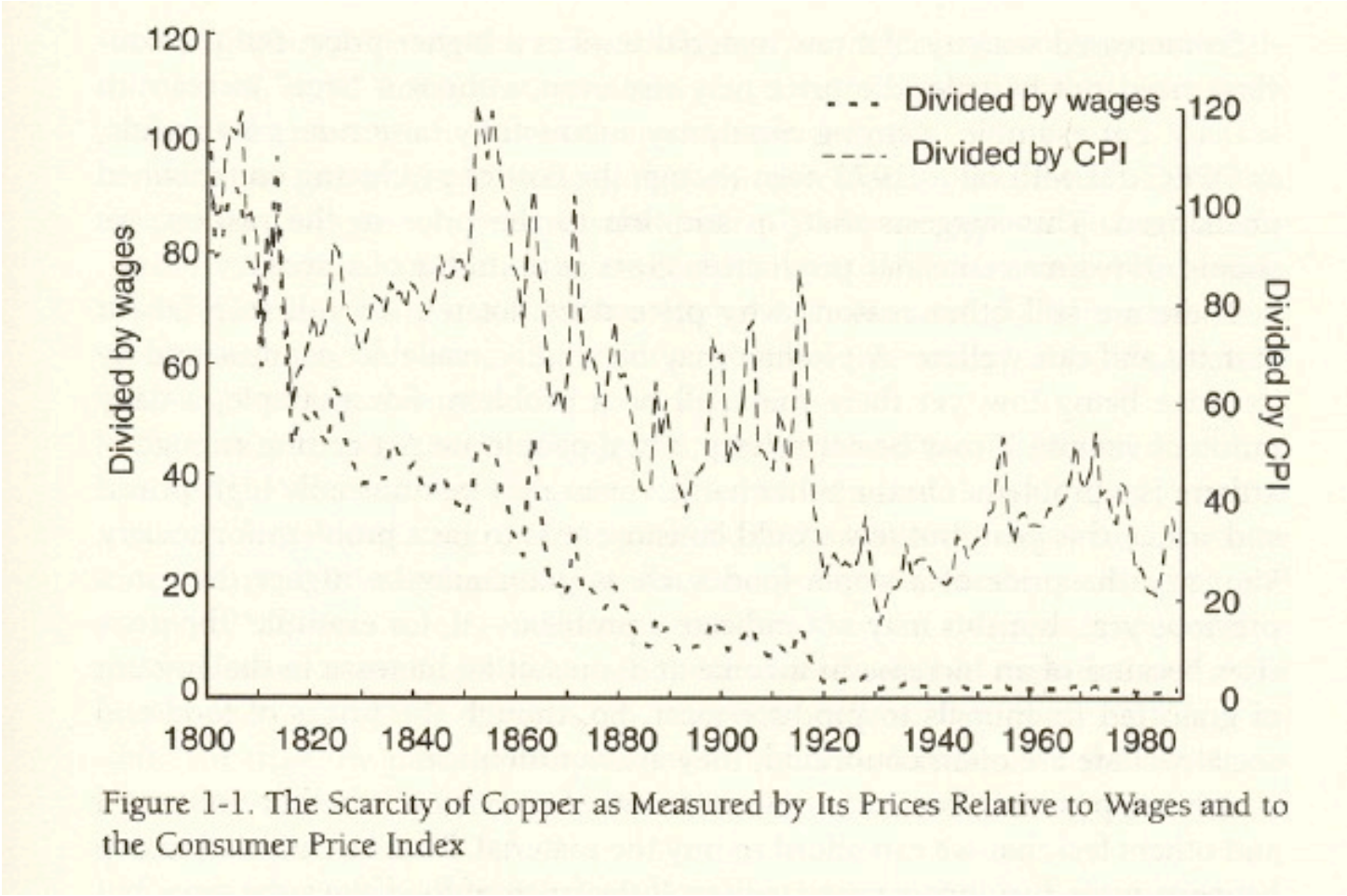
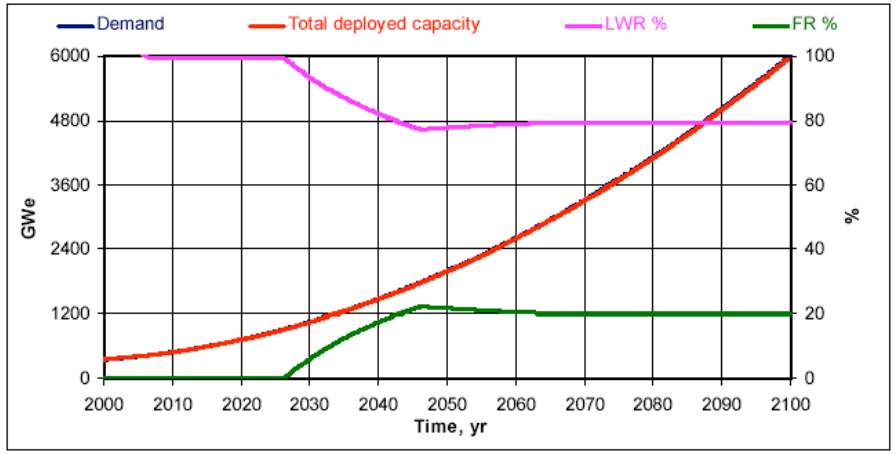


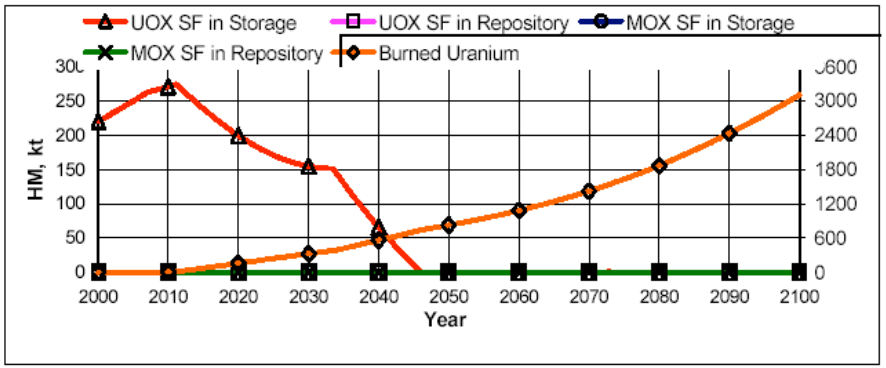
Figure 1-1. The Scarcity of Copper as Measured by Its Prices Relative to Wages and to the Consumer Price Index

Reprocessing V: Not enough* repository space?

In this scenario, FR's ultimately become 20% of nuclear capacity



Virtually no uranium, plutonium, etc go to a repository



*D. C. Wade, member of Gen IV FCCCG, Argonne

Reprocessing VI: Increased Waste Disposal Options with Gen IV, but other troubles arise

Yucca Mt

"no" Np, Pu, Am, Cm, etc.

^{129}I as AgI_2 ^{14}C as Ca_2C

^{99}Tc as metal alloy

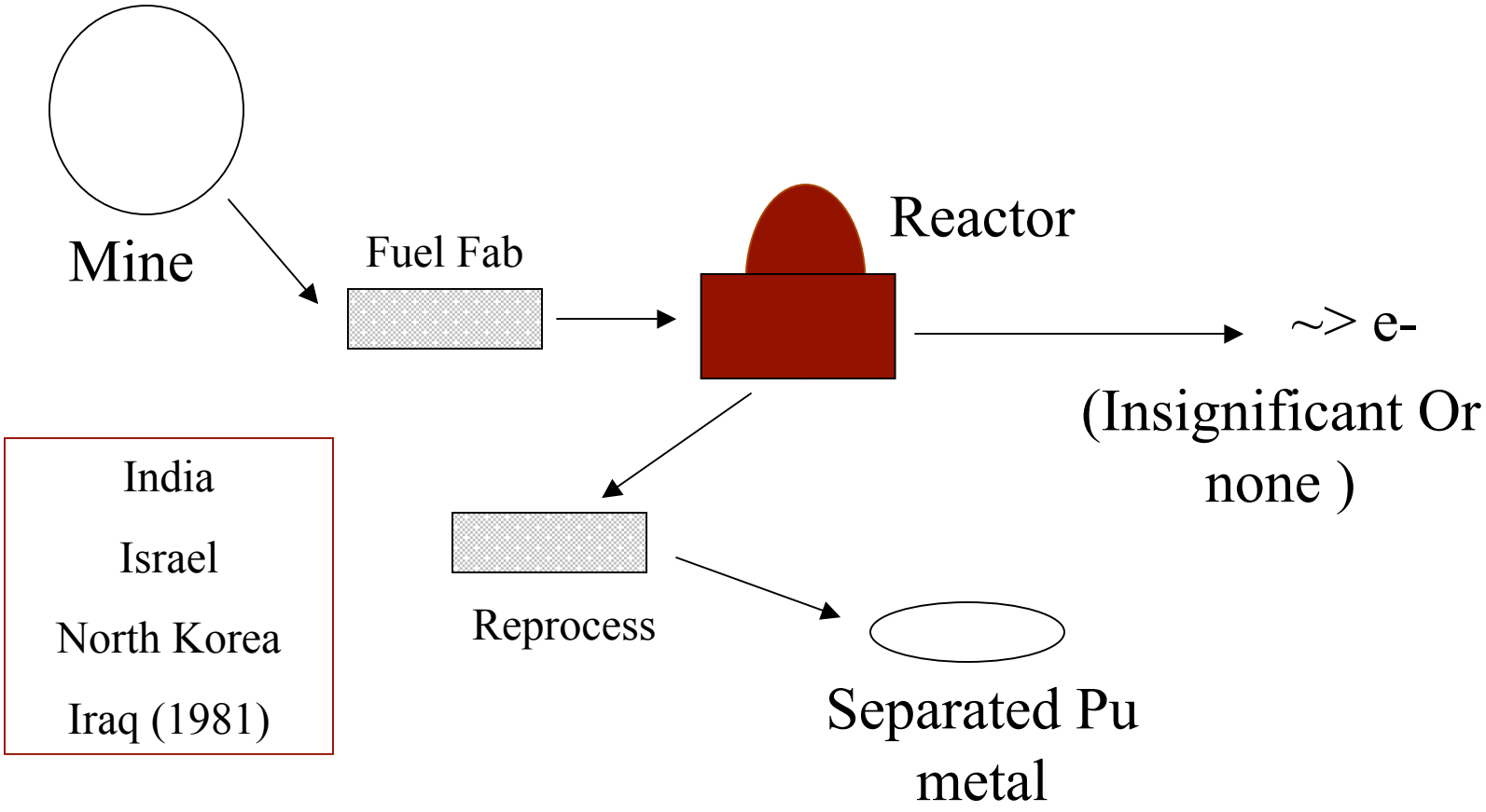
59Ni, 93Zr, . . .

Another Site

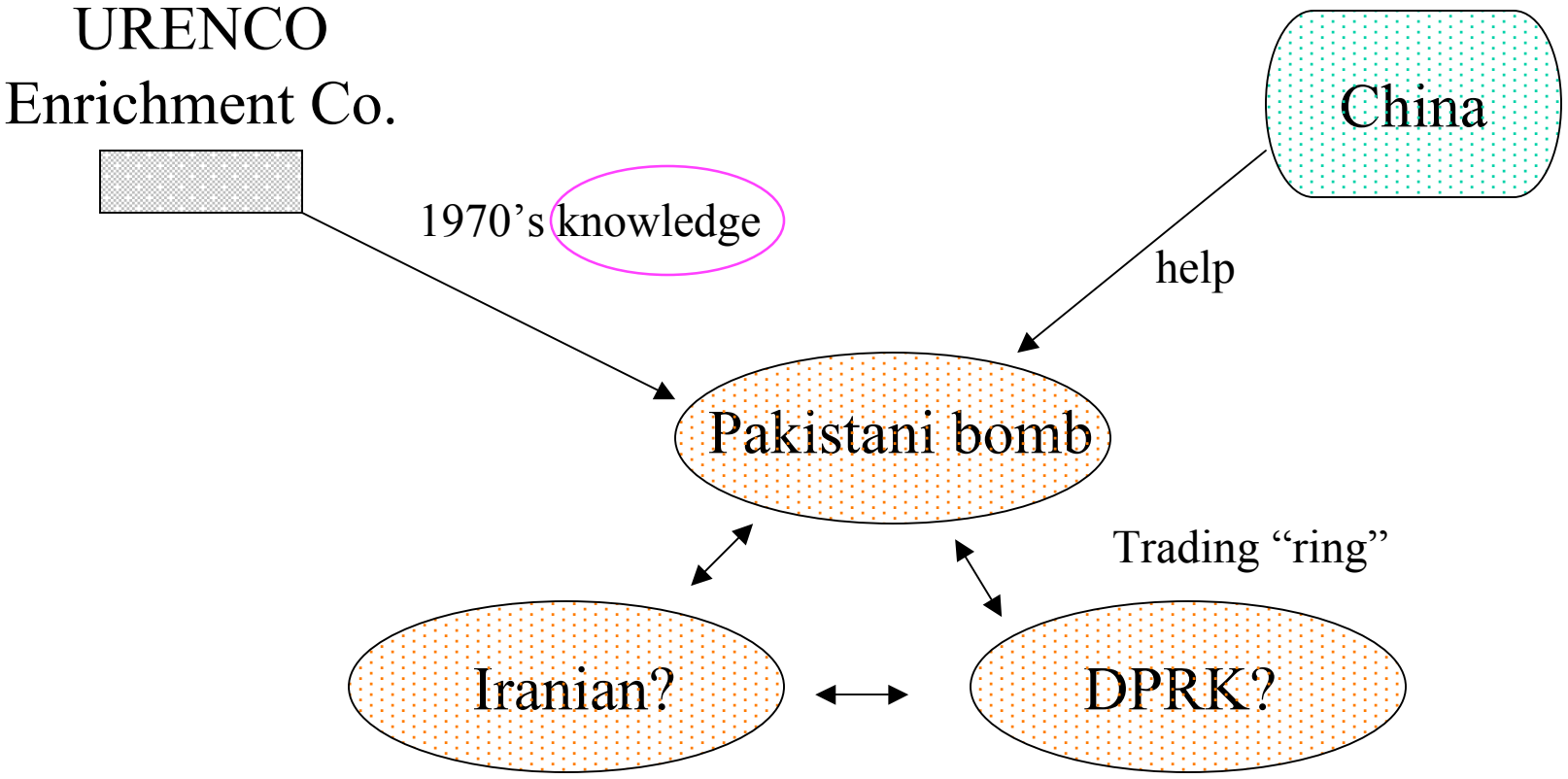
^{137}Cs and ^{90}Sr

Very hot for ~300 years

Proliferation I: Another Use for An Uneconomical Fuel Cycle: Reprocessing Fuel Cycle as a Weapons Cover Story



Proliferation II: The latest trend: Enrichment "Breakout" of States*



*Prepared with the assistance from Chaim Braun, Stanford University

Proliferation III: Iran (and our reaction to it) May Set the Stage for the Future of Nonproliferation

- One PWR under construction
- Gas Centrifuge Pilot plant was undeclared
- Large Gas Centrifuge plant (shown ->) under construction
- IAEA safeguards status in question

NATANZ, IRAN -- CLOSE-UP

INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

IMAGE CREDIT: DIGITALGLOBE
DATE OF IMAGE: 16 SEPTEMBER 2002

THE GAS CENTRIFUGE URANIUM ENRICHMENT PLANT AT NATANZ, IRAN.

Summary I

- Nuclear power can be expanded with a once-through fuel cycle or with a more advanced, fuel-efficient fuel cycle.
- Public opinion is central to the expansion.
- If uranium costs stay low (likely) a once-through fuel cycle will be cheapest.

Summary II

- Advanced fuel cycles would provide more waste disposal options than the once-through fuel cycle.
- There is hope for increased nuclear proliferation prevention regardless of fuel cycle choice.
- Expansion must occur fully within the control of the international safeguards regime.

Summary III

- **More Relative Advantages Must be Given to states to stay within the Non-Proliferation Regime**
- **Assistance should be provided to non-weapon states with their entire energy infrastructure, i.e., fossil, nuclear, and reduced-carbon energy sources**
- **CDM recipients should be required to be in good standing in the NPT**
- **CDM should include nuclear energy for those countries agreeing to IAEA INFCIRC/540 (comprehensive inspections)**