# Resources for the Long Term

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# Uranium is Cheap!

- The average price of uranium paid by U.S. reactor operators in 2005 was $37/kg. In once-through LWRs, this contributes:

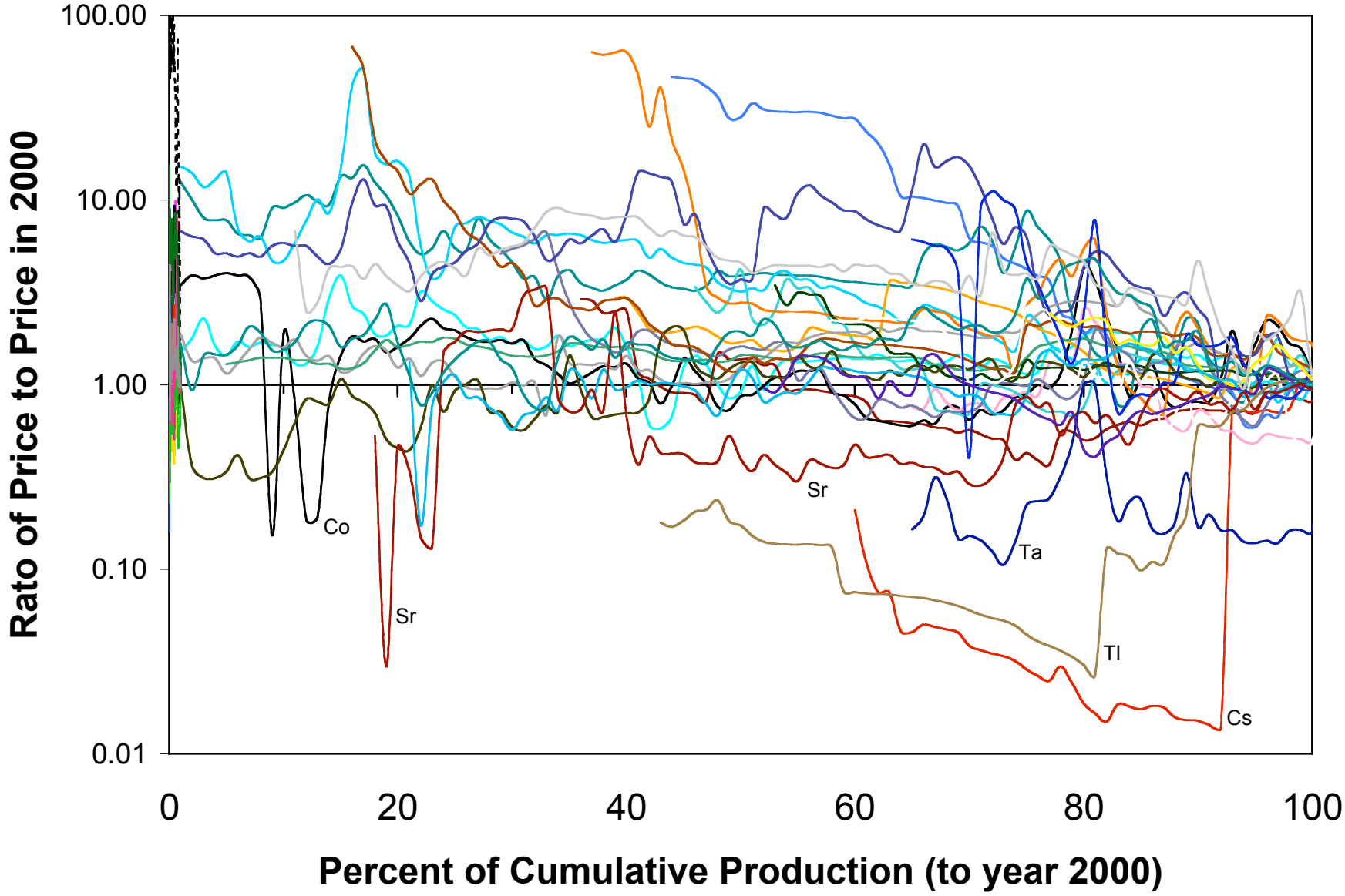
$$\left[\frac{\$37}{kg_U}\right]\left[\frac{8\ kg_U}{kg_{LEU}}\right]\left[\frac{kg_{LEU}}{50\ MW_{th}d}\right]\left[\frac{MW_{th}}{0.32\ MW_e}\right]\left[\frac{d}{24\ h}\right] = 0.8\frac{\$}{MWh}$$

- About 1% of the price of nuclear-generated electricity
- The price of uranium could increase by 5x without significantly affecting LWR COE
- If price increases 5x, supply will increase >100x

# Uranium Resources

- Once-through LWRs least expensive if U price < $130/kg, even in best case for recycle.
- How much U is available? Red Book gives 16 Mt available at $130/kg, but…
  - high-cost resources in many countries (e.g., Australia) not estimated;
  - unconventional resources (e.g., phosphates) not included;
  - little investment in exploration in last 25 y
  - most minerals have steadily decreased in price with increasing consumption

# 43 of 47 Elements Have Decreased in Price



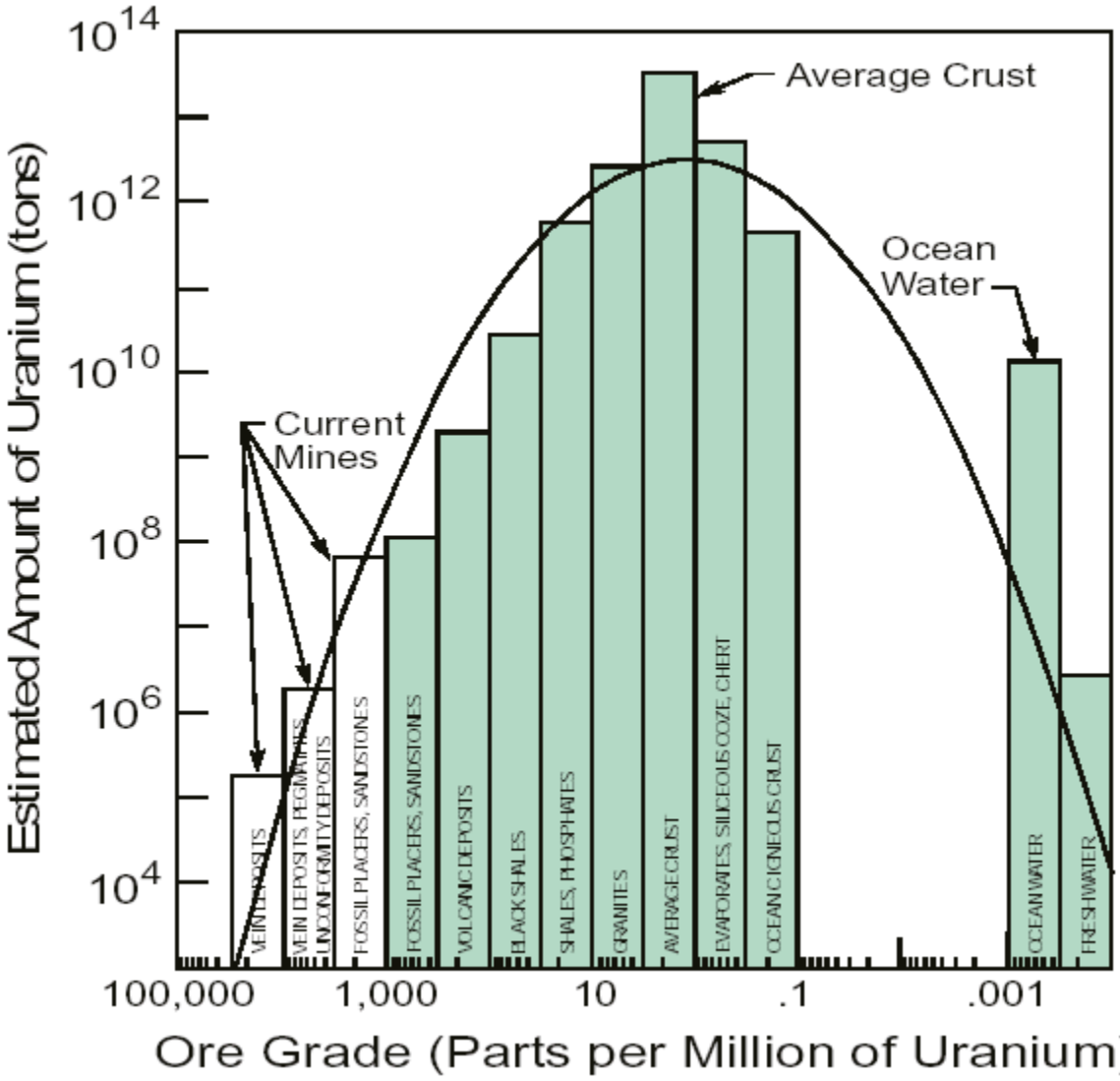
# A Very Rough Estimate of Ultimately Recoverable Uranium Resources

- Red Book give 2.1 Mt at $40/kg
- Hore-Lacy: “a doubling of price from present levels could be expected to create a tenfold increase in measured resources.”
- So there should be 21 Mt available at $80/kg and 210 Mt at $160/kg
- In general:

$$R \sim 2.1(P/40)^{\varepsilon}$$

where $\varepsilon$ = long-term price elasticity of supply

# Deffeyes and MacGregor (1980)

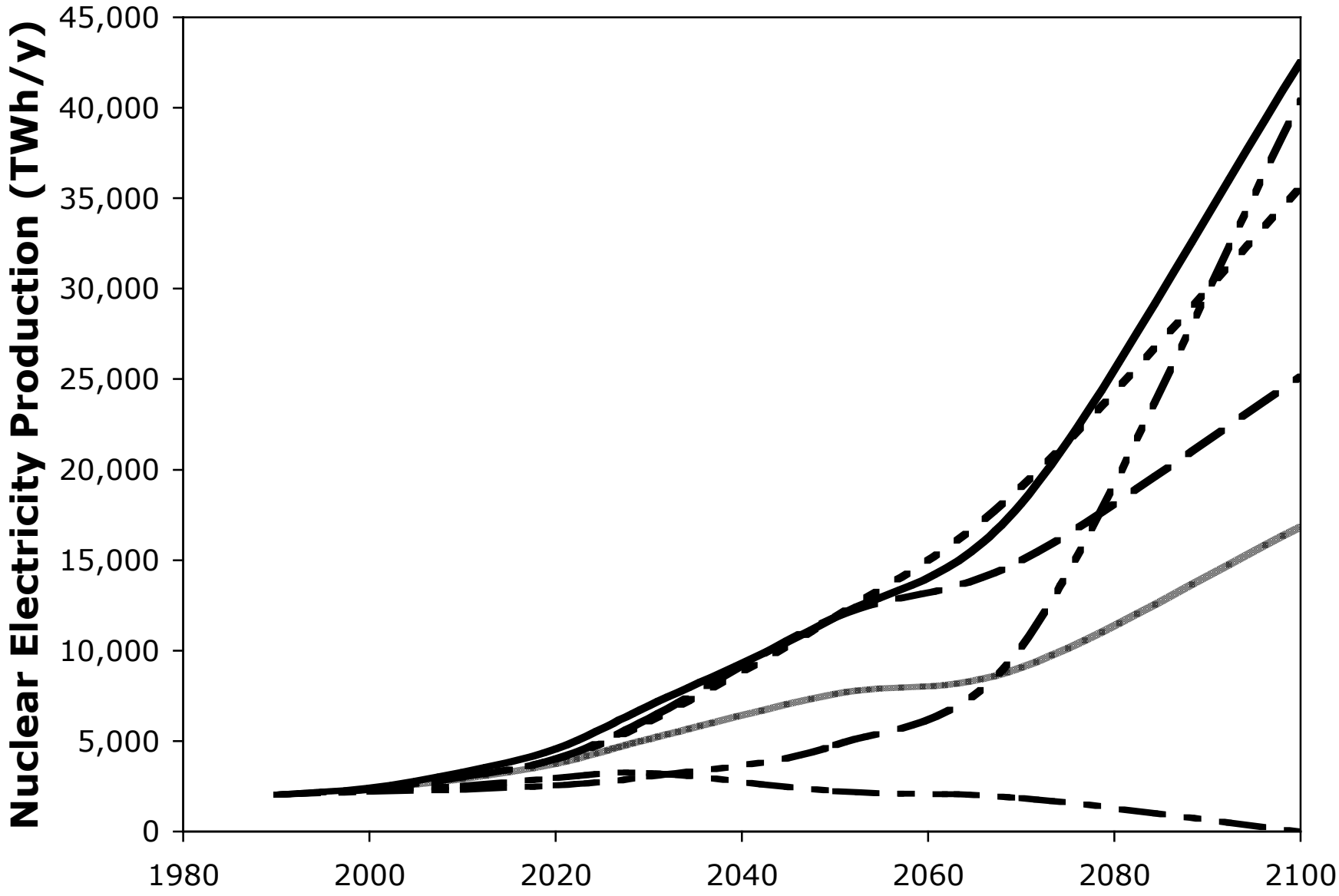



On average, a 10-fold decrease in ore grade is associated with a 300-fold increase in available resource

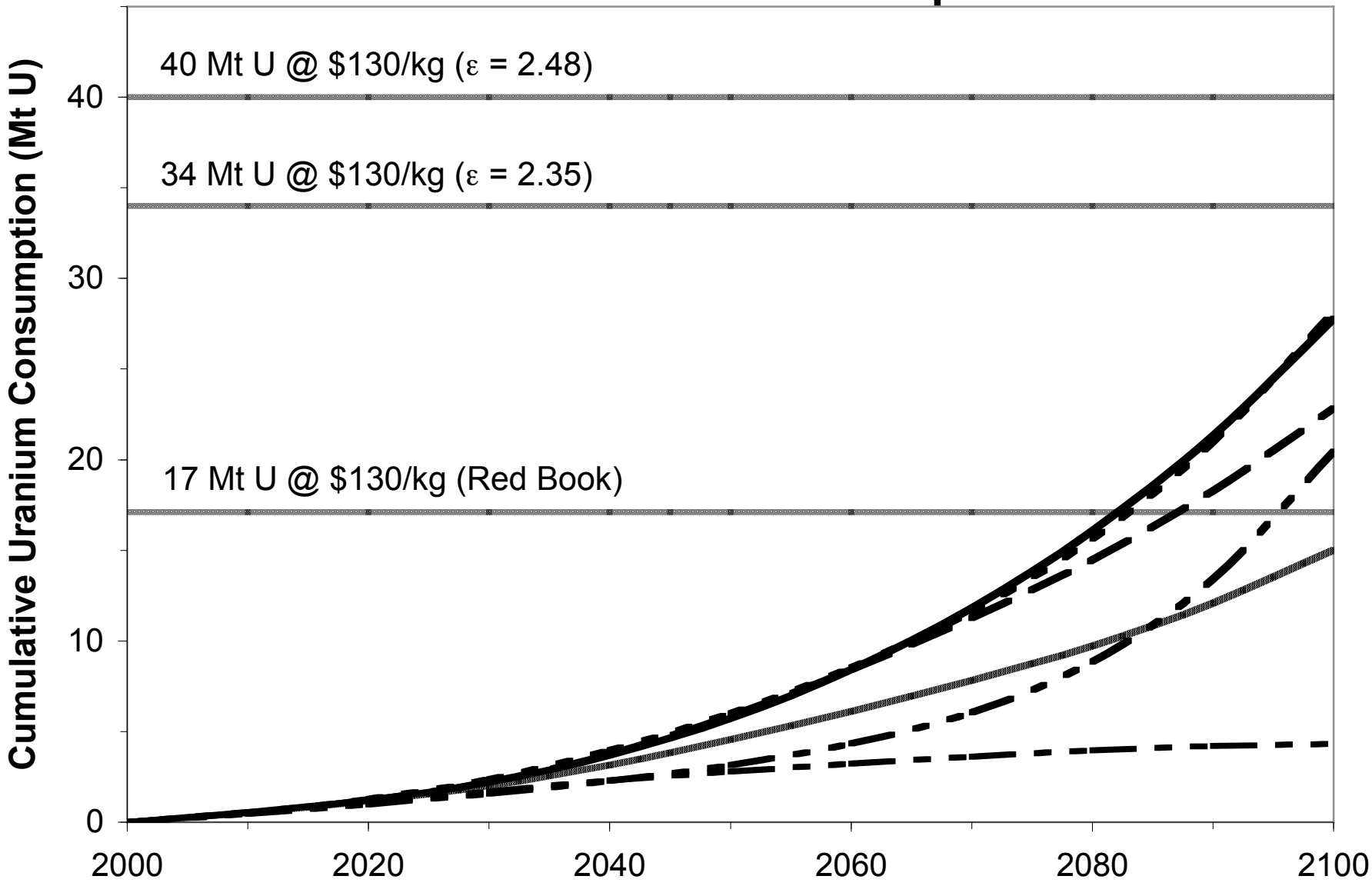
# Recoverable Resources

| Source | Long-term elasticity of supply ε | MtU recoverable at price less than | | |
|---|---|---|---|---|
| | | $40 | $80 | $130 |
| UIC (doubling price creates ten-fold increase in measured resources) | 3.32 | 2.1 | 21 | 105 |
| Deffeyes and MacGregor (ten-fold decrease in concentration = 300-fold increase in resource, p ~ c) | 2.48 | 2.1 | 12 | 39 |
| Gen-IV (based on U.S. reserves for various mining methods) | 2.35 | 2.1 | 11 | 34 |
| Red Book | | 2.1 | 11 | 16 |

# IIASA/WEC Global Energy Perspectives



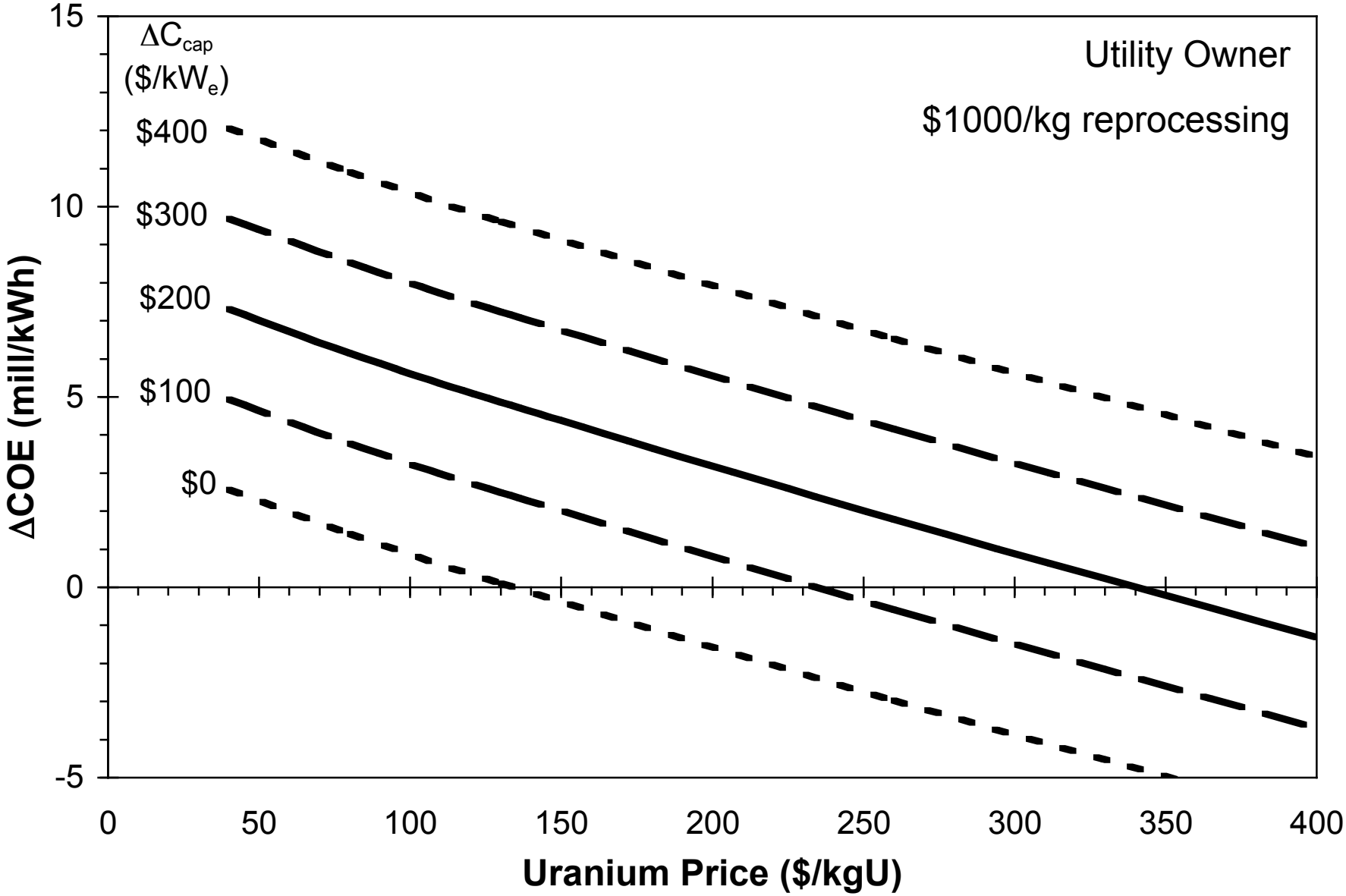
# Cumulative U consumption: LWRs with direct disposal



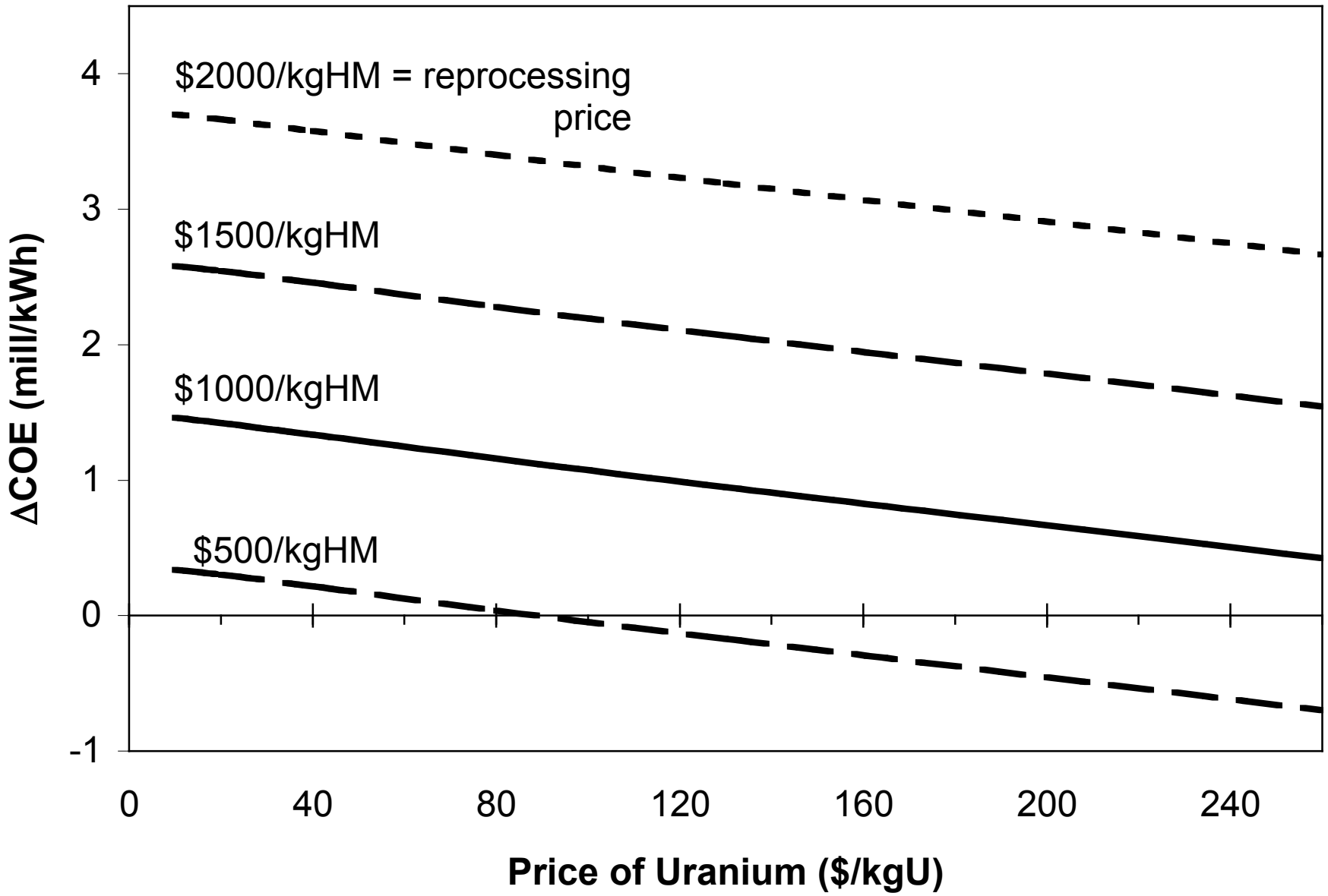
# Uranium from Seawater

- Huge (4500 MtU) but very dilute (3 ppb) resource
- Gen-IV study estimated recovery cost at $240 to $450/kgU
- Automatic co-recovery of other valuable metals would reduce effective costs
- Even if at these high prices, U from seawater could fuel once-through cycle for centuries at 10% increased cost, possibly at lower cost than fast breeder reactors
- Need for additional R&D

# Premium for R&R in FBRs



# Premium for R&R in LWRs



# These estimates are favorable to R&R

- $200/kg interim-storage charge included for direct disposal (but not R&R)
- $200/kg cost savings for waste disposal
- $1000/kg for reprocessing--well below credible estimates for a new plant
- MOX fuel fabrication well below recent prices
- No charges for Pu storage, Am removal, or extra security for fuel storage, transport, use