UT-BATTELLE

Effect of Scale on Capital Costs of Nuclear Fuel Reprocessing

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Incentive for Processing Civilian Spent Nuclear Fuel (SNF)

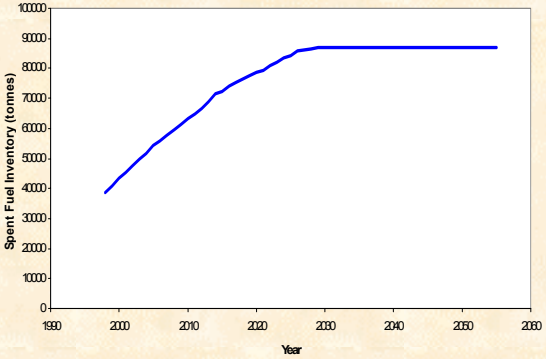
- **Yucca Mountain repository**
  - **Statutory limit of 63,000 MTIHM CSNF**
  - **Life cycle costs of $42.7B—$57.2B**
- **YM Repository Costs — Breakdown**

Element of Cost	Cost ($B)
Repository construction and operation	31.5—43.1
Waste acceptance, storage and transportation	4.3
Transportation infrastructure (in Nevada)	0.8
Program integration and institutional programs	6.1—9.1
TOTAL	**42.7—57.3**

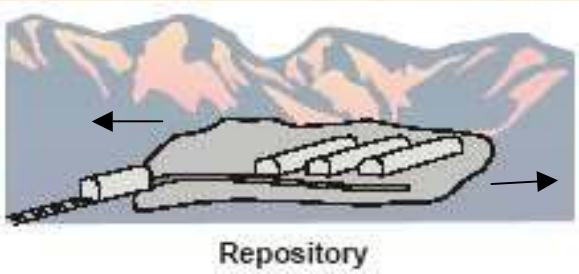
Most elements of cost roughly linear with amount of material emplaced.

Incentive for Processing Civilian Spent Nuclear Fuel (SNF) — continued

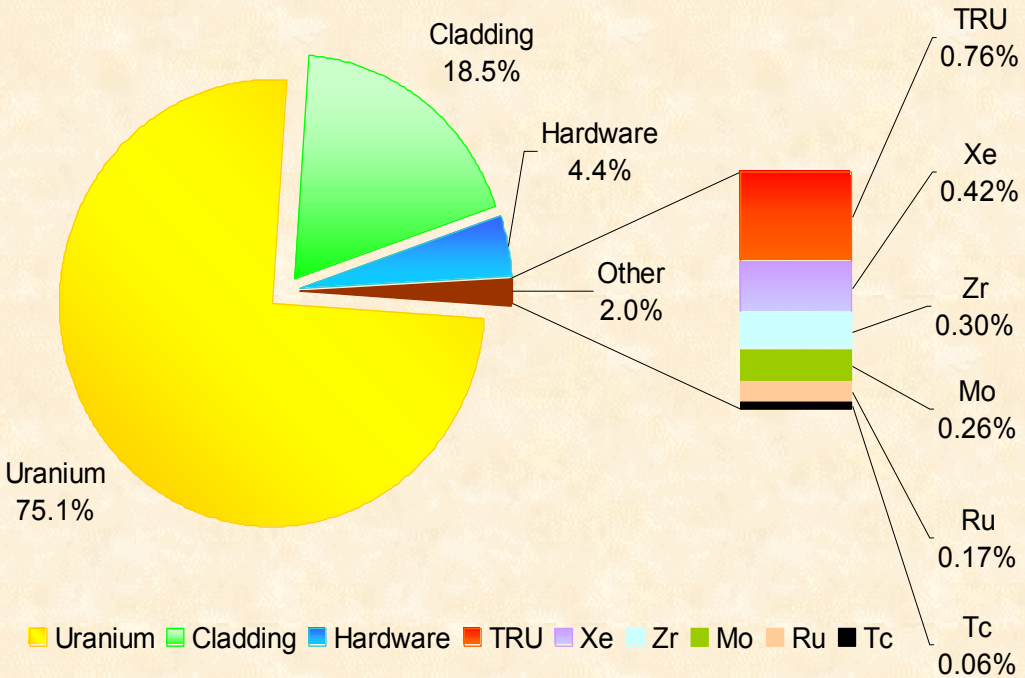
- Current reactor fleet will
  - Discharge YM statutory limit by the year 2010, i.e. 63,000 MTIHM
  - Discharge 86,881 MTIHM of SNF by 2030
    - Lifetime of current fleet
    - No new reactor additions, phase out of nuclear

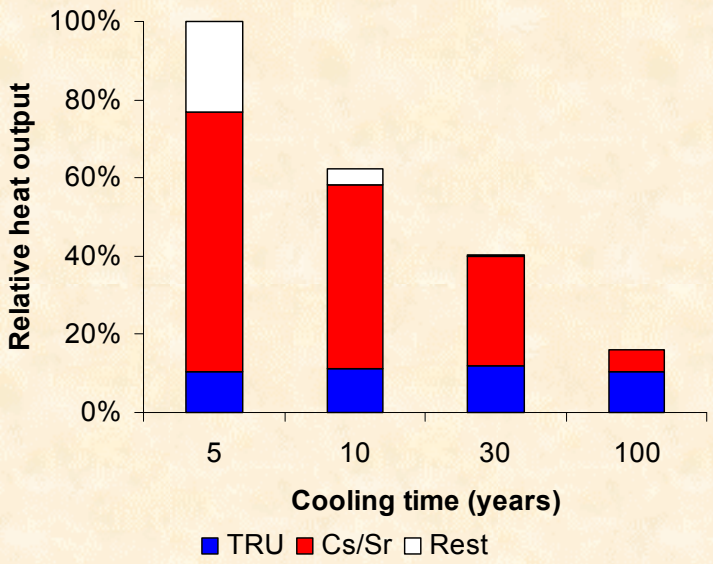


- Without methods to reduce the quantity and heat generation of the emplaced waste
  - Expansion of existing repository or second repository will be needed
  - Growth of nuclear power could require a new repository every 4 to 10 years



Contributors of Heat & Mass in SNF

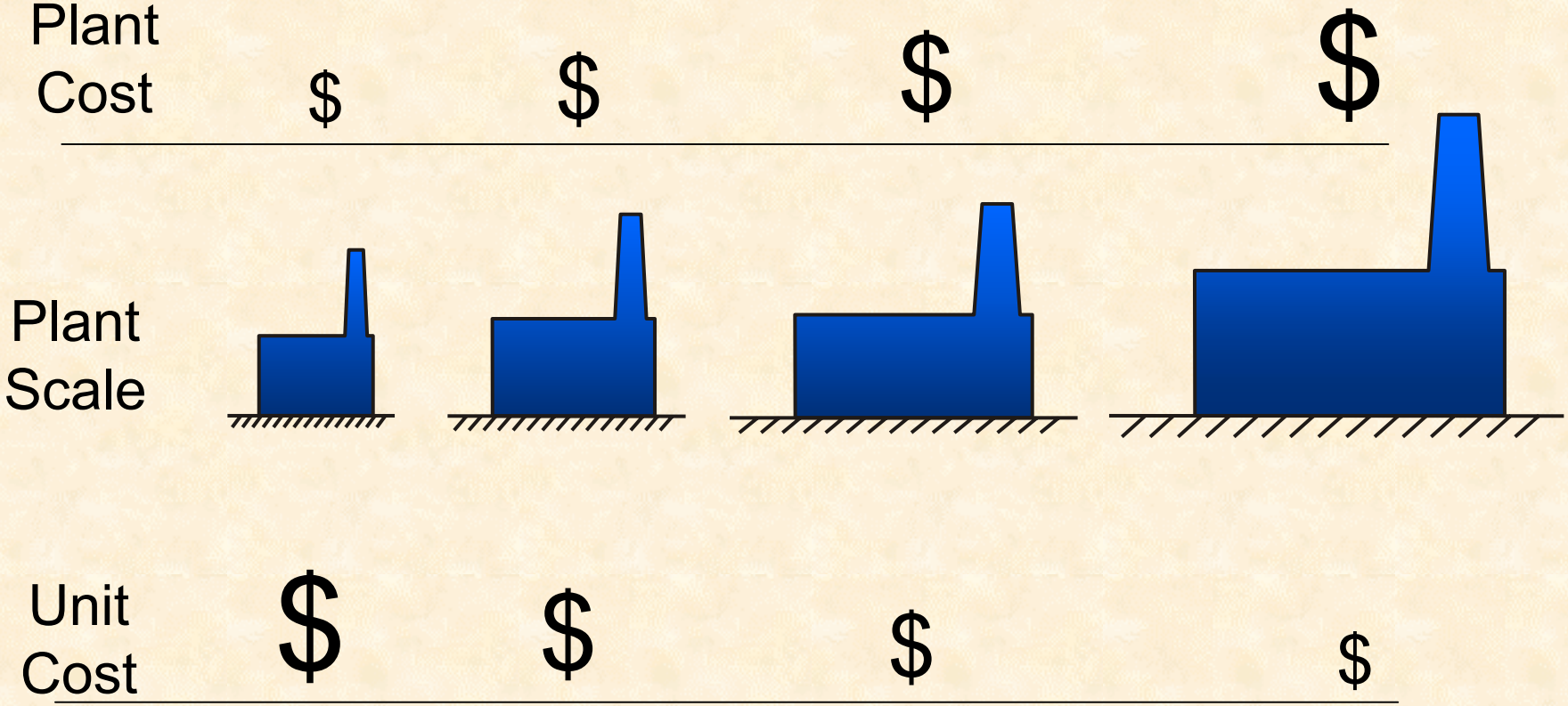




SNF Processing Needs to be Cost Effective

- Many factors affect deployment costs
  - Waste & product criteria
  - Discharge limits
  - Separations technology
  - Location
  - Facility throughput
  - Number of process lines for given throughput
  - Etc

Here We Focus on Capital Costs



Approach

- Identify existing sources of cost data
  - Reprocessing plants, including
    - Fuel receipt and storage
  - Waste processing plant, including
    - HLW vitrification
    - HLW interim storage
    - ILW encapsulation
    - ILW interim storage
- Escalate data from various times to present
  - Data from the 1970s, 1980s, and early 1990s
  - All data on aqueous processing technology
- Fit data to simple model
- Evaluate
  - Overall capital cost vs. plant capacity
  - Unit installed cost vs. plant capacity

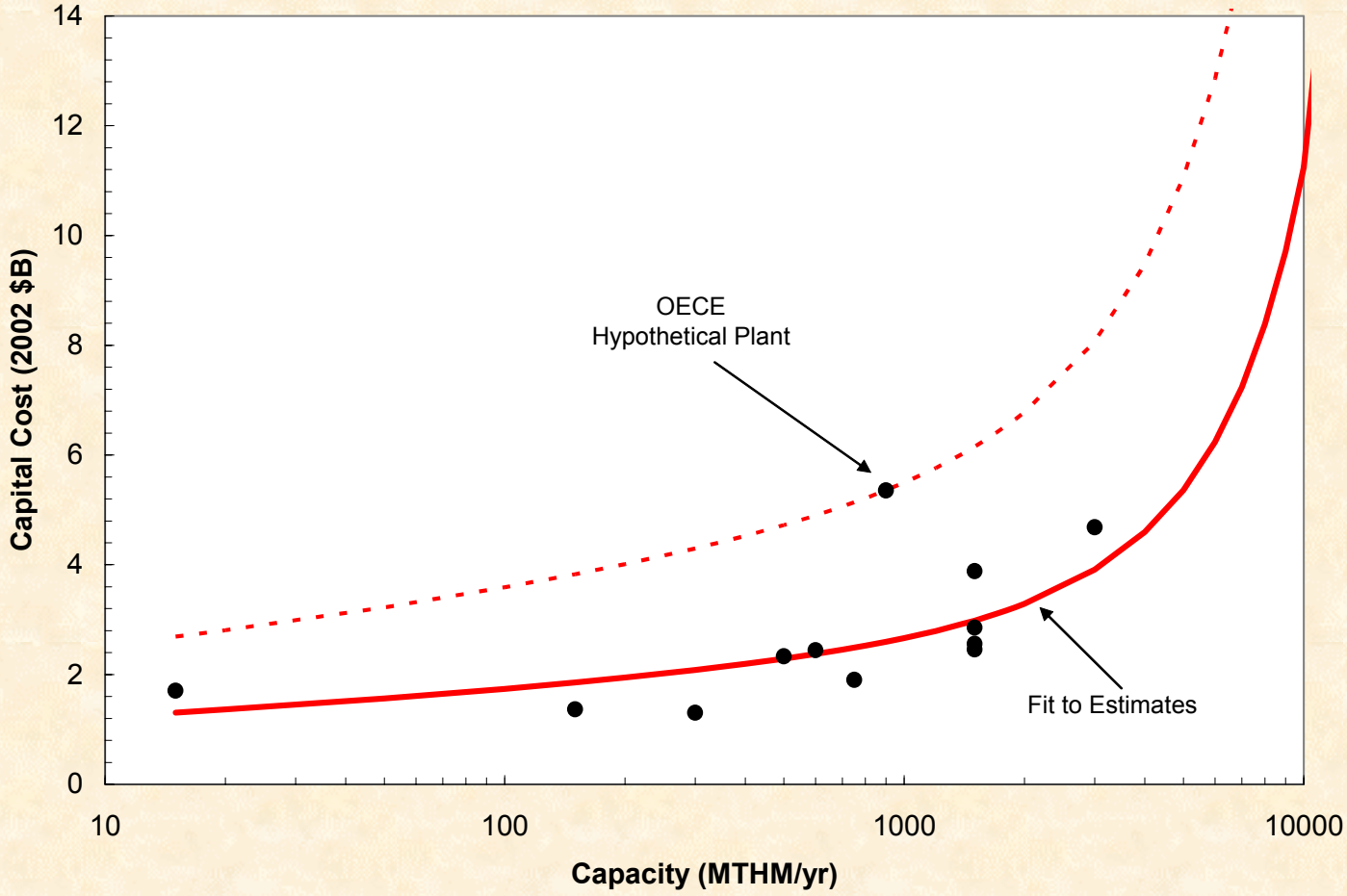
Plants with Costs Adjusted to 2002 Dollars — Aqueous Processing

Plant ID	(MTIHM/yr)	Basis Yr	Cost ($B)
ORNL Demo	15	1982	1.709
HEF	1500	1982	1.367
AGNS	1500	1982	2.564
Exxon	500	1978	2.332
Exxon	1500	1978	2.461
DuPont	1500	1978	3.886
IAEA	300	1976	1.307
IAEA	750	1976	1.906
IAEA	1500	1976	2.859
IAEA	3000	1976	4.684
THORP	600	1984	2.447
OECD hypothetical	900	1991	5.355

Simple Cost Scaling Rule and Extension

- Usual cost scaling rule
  - $C = aS^n$
- Previous workers indicate
  - Exponent, n, is not constant
  - n varies with plant scale
- Try $n = \beta S + \varepsilon$
  - Simple linear relationship
- Unit installed cost
  - $U = C/S$
  - C is calculated from extended scaling rule

Results — Capital Cost vs. Capacity



Results — Observations on Capital Cost

- Capital costs vs. plant capacity
  - Shape of curve similar to that reported by Haire*
  - Cost estimates adequately fit by equation
  - Scaling exponent ranges from ~0.15 for small plants to unity for very large plants
  - Cost relatively flat with capacity below 1000 MTIHM/yr
  - Cost increases rapidly with capacity above 10000 MTIHM/yr
- Compared to OECD hypothetical plant
  - Estimates seem to be generally low
  - OECD value appears based more on experience
  - Multiplying estimates by 2.06 adjusts line upward to meet OECD

*ANS Topical Meeting, October 2003

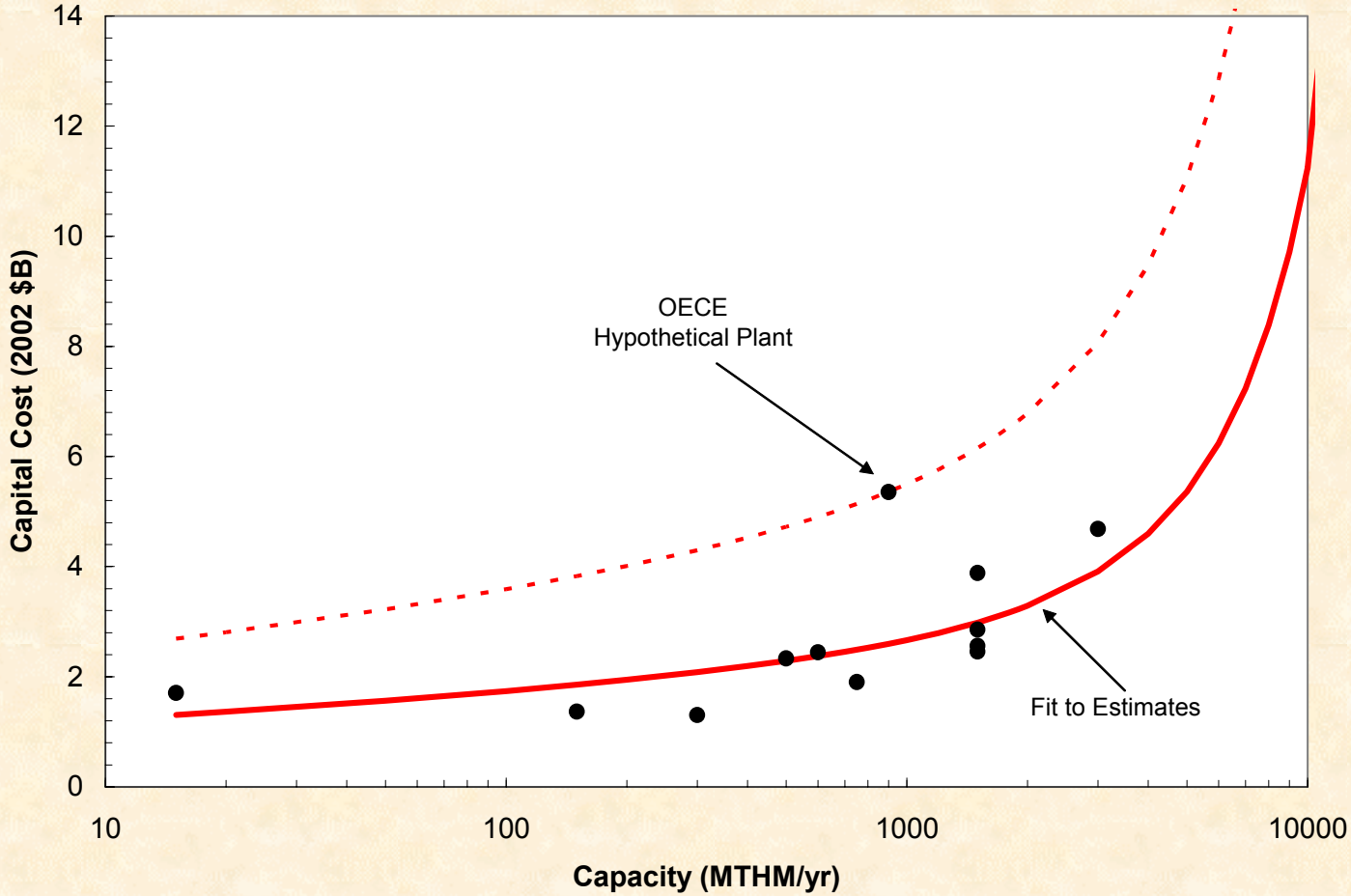
Capital Costs for a Selected Case

Basis: 2000 MTIHM/yr Plant

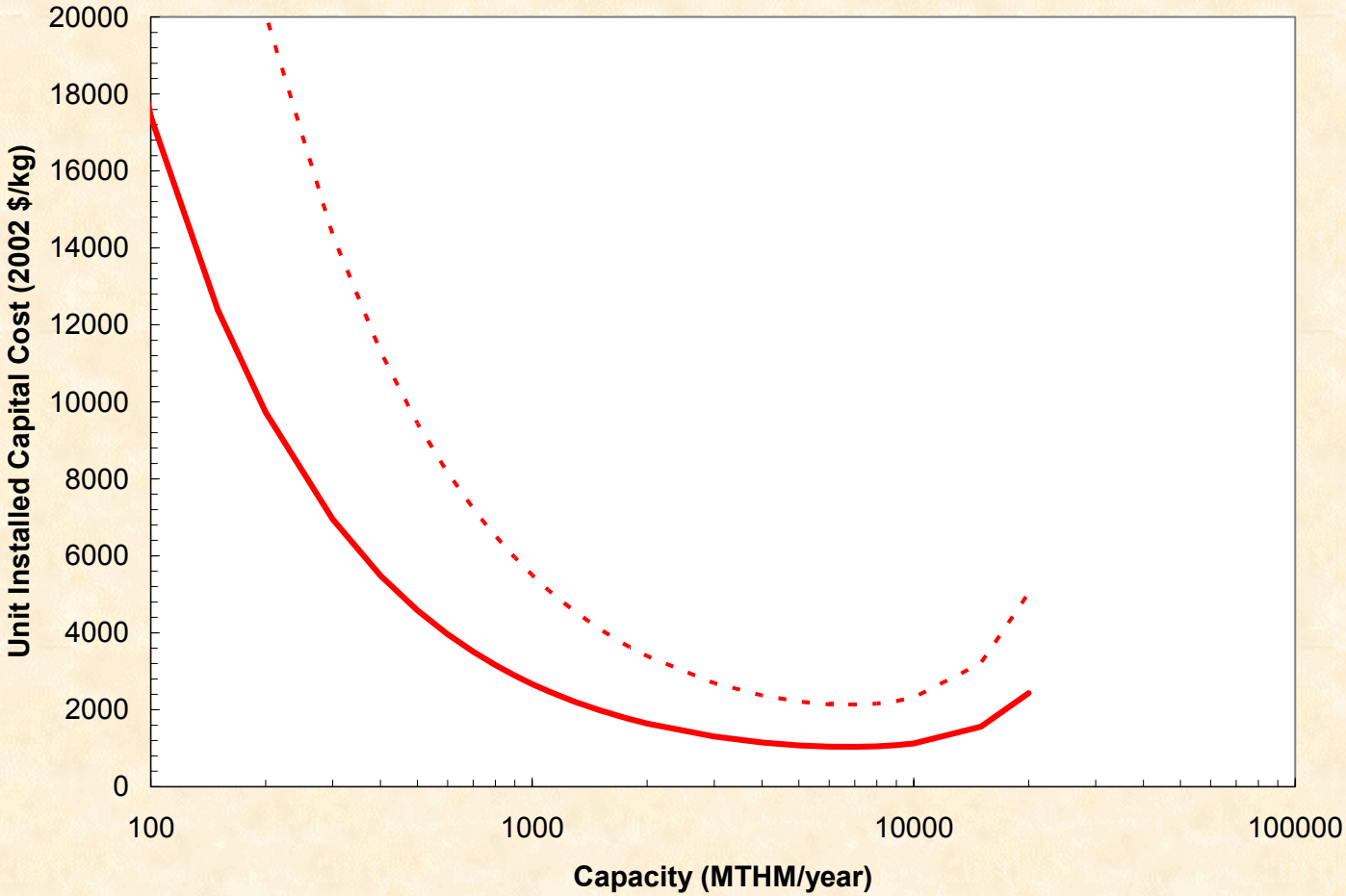
Additional Literature: Dual-line plants are ~50% more than single line plants. Waste processing facility cost is ~30% of the single line reprocessing plant.

	Lower ($B)	Upper ($B)
Single-line Plant	3.3	6.8
Addition for Dual-line (50%)	1.6	3.4
Addition for Waste Processing (30%)	1.0	2.0
TOTAL	**5.9**	**12.2**

Results — Capital Cost vs. Capacity



Results — Unit-installed Cost vs. Capacity



Results — Observations on Unit-installed Cost

- Broad near minimum between 2000—8000 MTIHM/yr
- True minimum at ~7000 MTIHM/yr
- Example unit-installed costs, single-line design, reprocessing only

MTIHM/yr	Lower ($/kg)	Upper ($/kg)	Relative $
500	4680	9660	4.5
2000	1650	3390	1.6
7000	1040	2130	1.0
10000	1130	2320	1.1

Unit-installed Capital Cost

Assumptions: 30-yr amortization
Model cost limits

	upper–lower $/kg)		
MTIHM/yr	0%	5%	10%
500	156–322	301–622	493–1017
2000	55–113	106–218	174–357
7000	35–71	67–137	110–224
10000	38–77	73–149	119–224

Summary

- Simple models of variation in plant cost with plant throughput indicate
  - Capital cost varies little with plant sizes below ~1000 MTIHM/yr
  - Costs increase sharply with plant sizes above ~10000 MTIHM/yr
- Unit installed costs derived from the model indicate
  - Minimum installed cost occurs at plant scales much greater than any currently deployed
  - A relatively broad minimum for plant sizes between 2000 to 10000 MTIHM/yr
- For a 2000 MTIHM/yr plant
  - Scale not much beyond industrial practice
  - Capital component of processing cost expected to be ~$110/kg —$220/kg at present interest rates
  - Smaller plants significantly increase unit processing cost