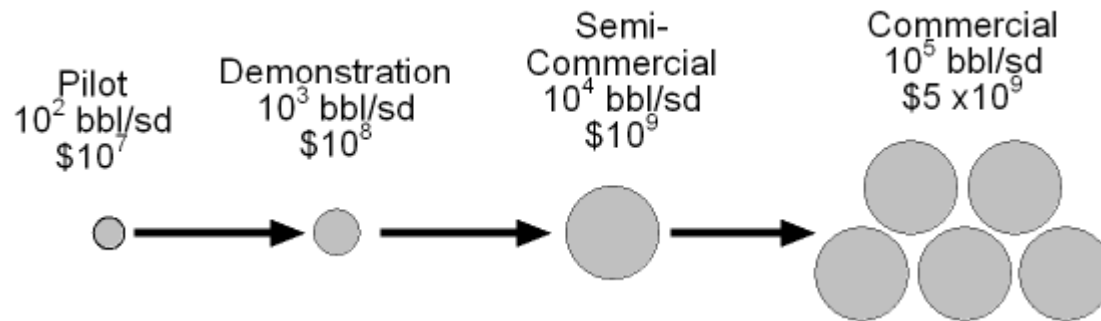




Time and Cost to Commercialize
an Oil Shale Retorting Technology

Richard Sherritt
27th Oil Shale Symposium
Golden Colorado
16 Oct 2007

Staged Development



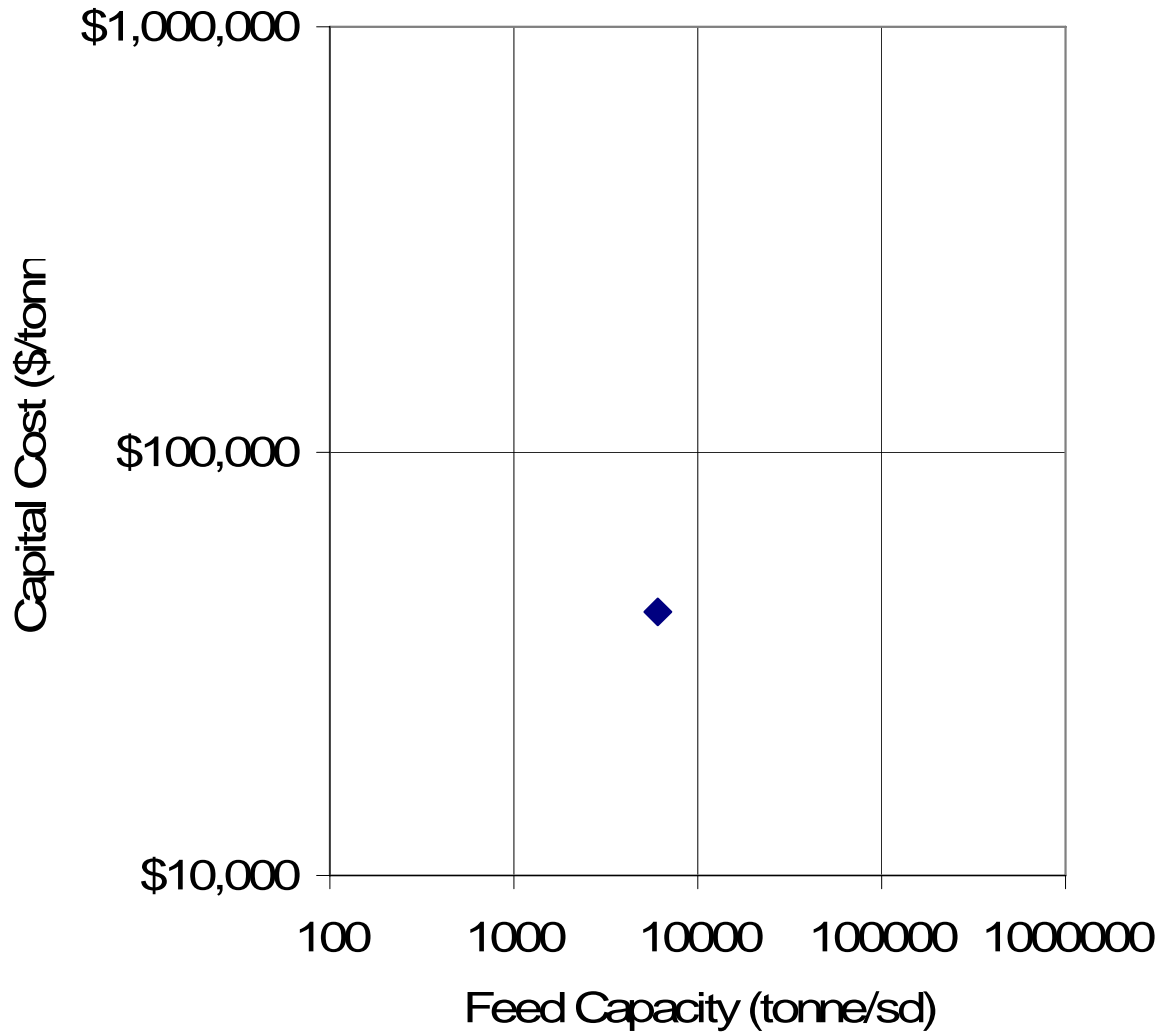
More small scale-up steps increase time and cost of development.

Fewer large scale-up steps increase risk of not achieving design capacity.

What is the optimum number of stages to balance cost and risk?

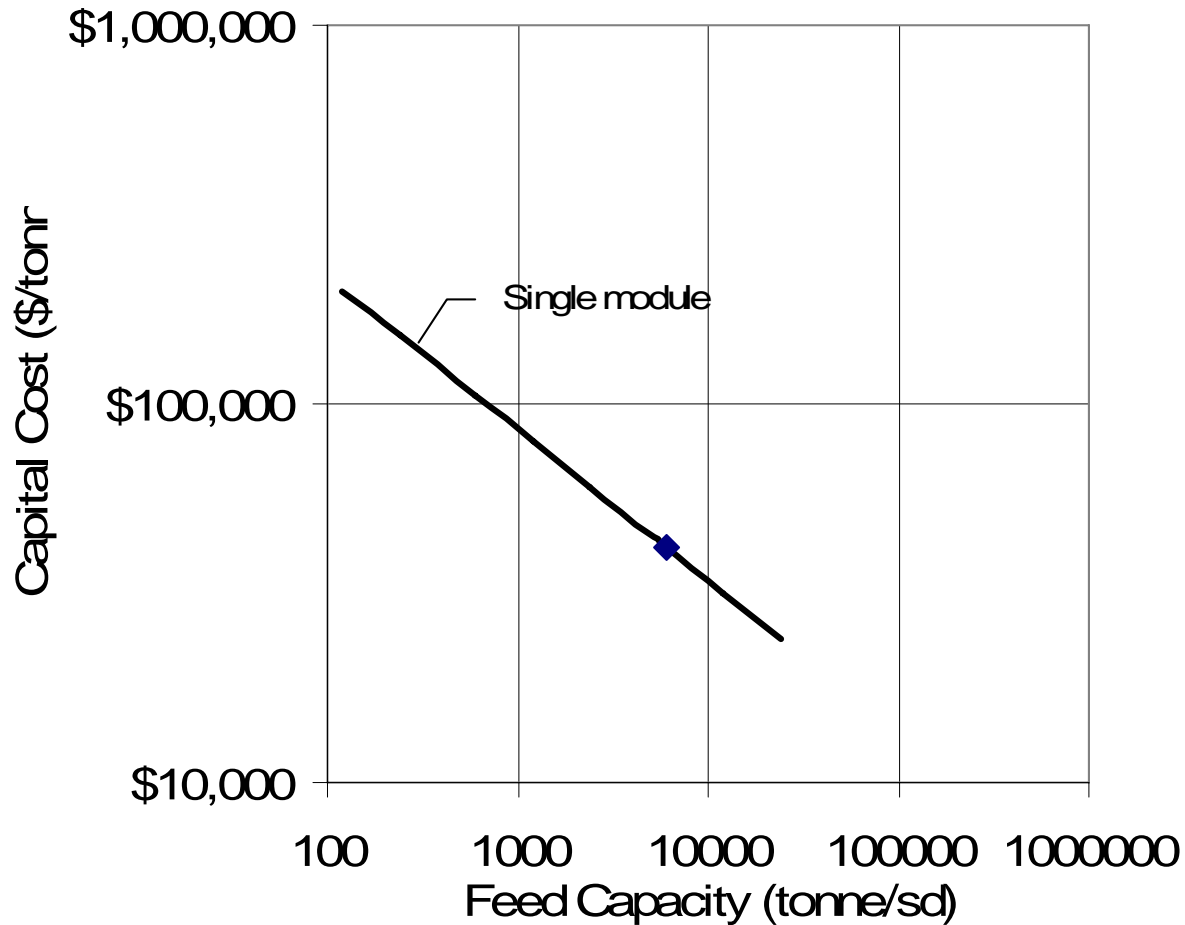
How to compare technologies that are at different stages of development?

Capital Cost



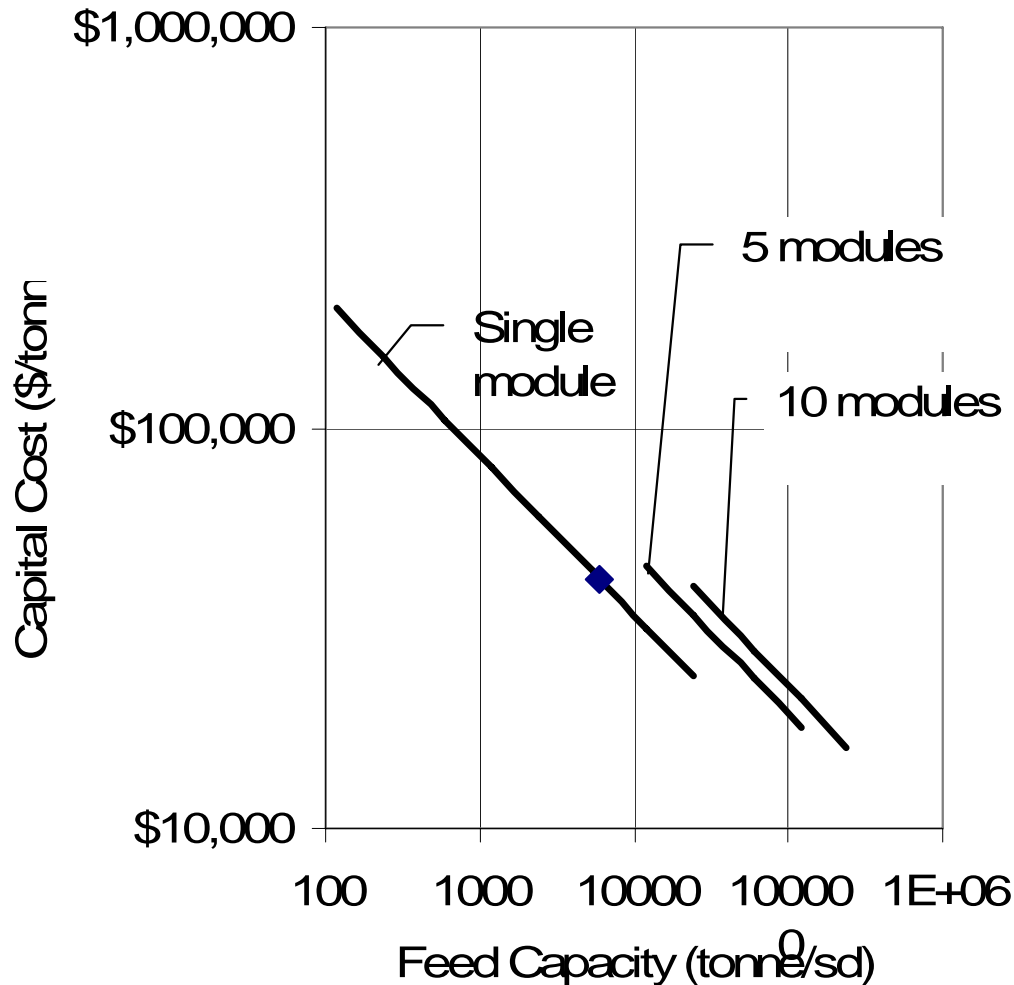
- \$250M for 6000 bbl/sd single module

Capital Cost



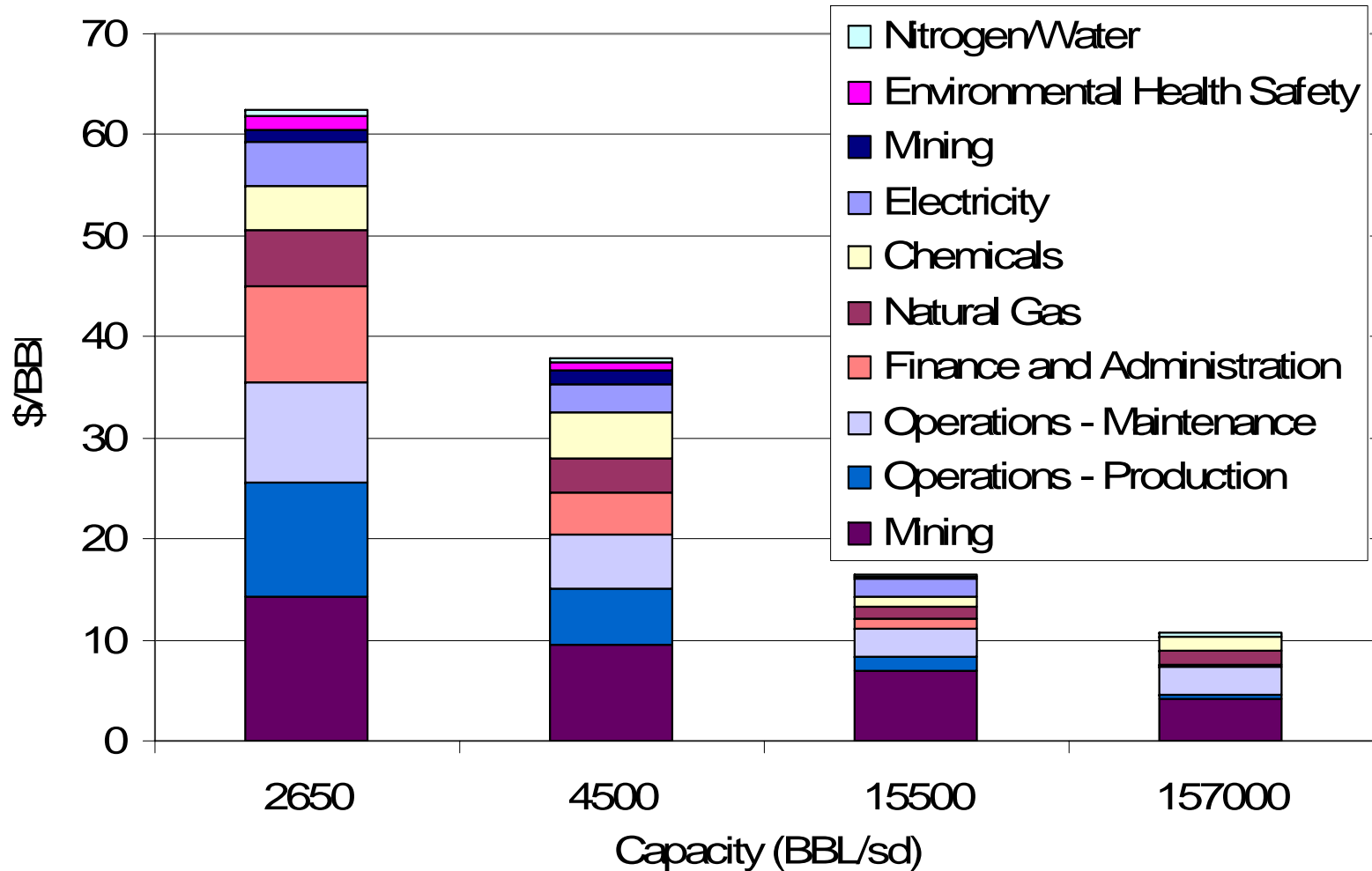
- \$250M for 6000 bbl/sd single module
- 0.6 cost exponent for single module

Capital Cost

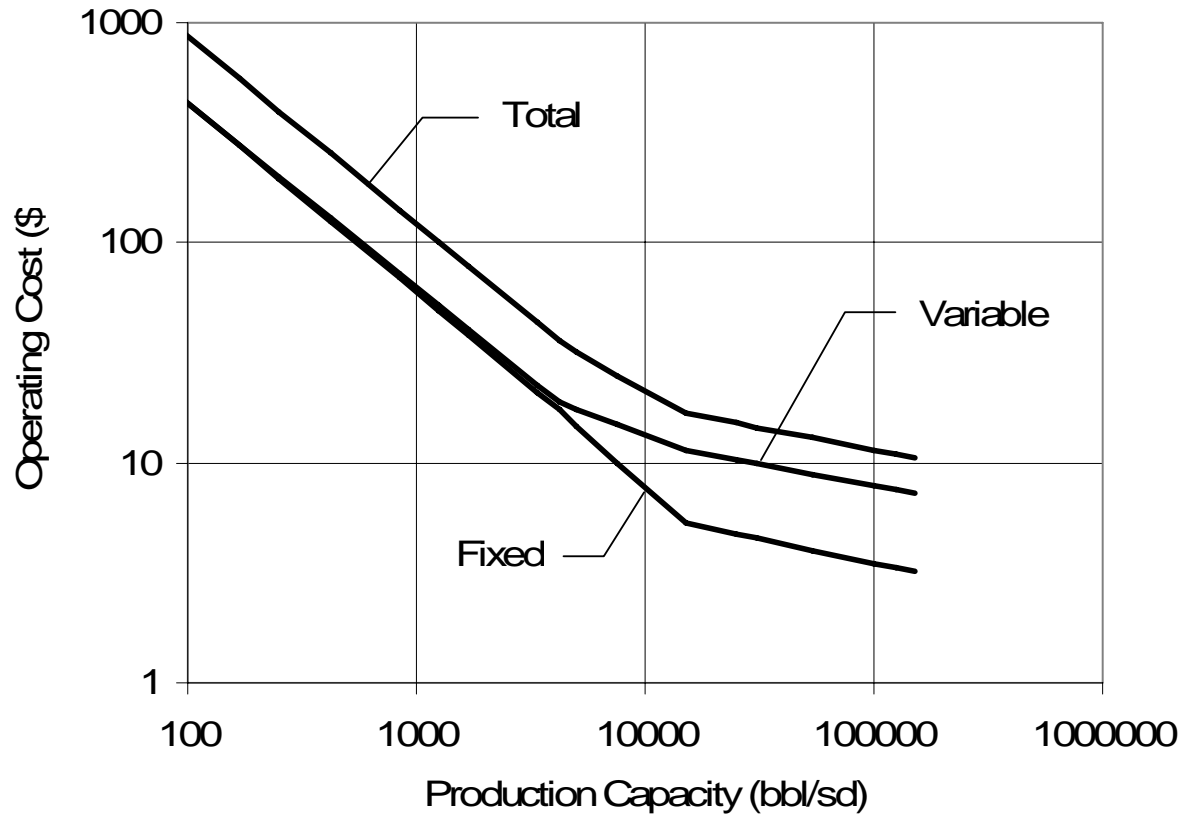


- \$250M for 6000 bbl/sd single module
- 0.6 cost exponent for single module
- 25% reduction per module for 5 modules
- 33% reduction per module for 10 modules (Buchmann et al 1993)

Operating Costs

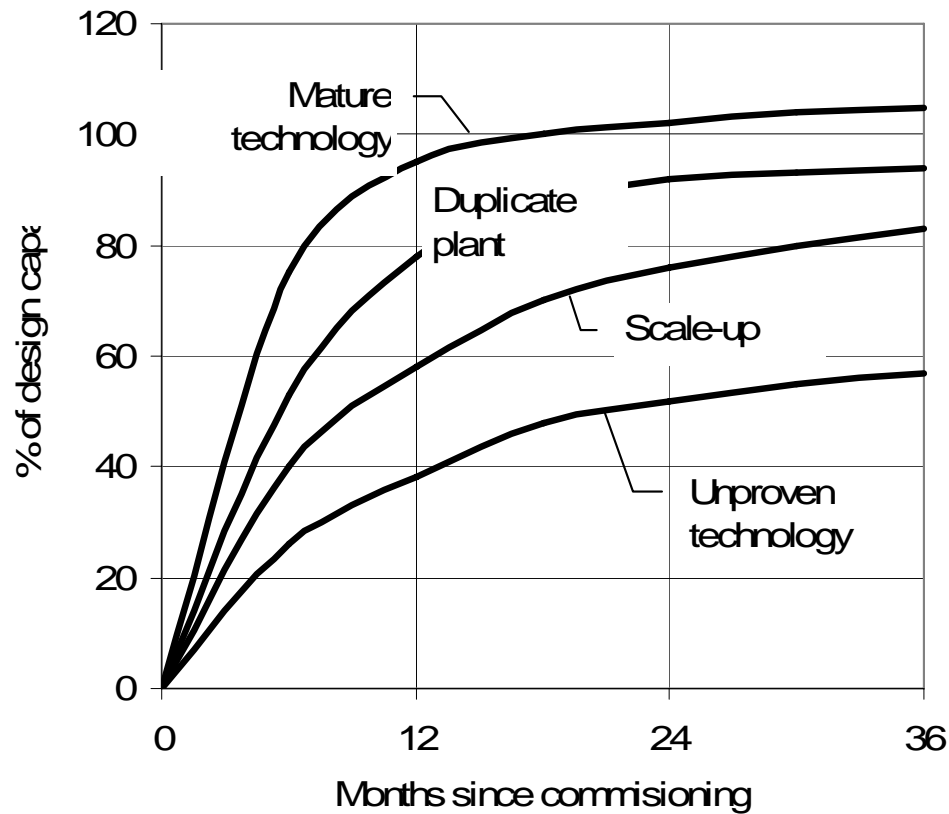


Operating Costs



- Includes grade reduction with increase in capacity

Rate of Achieving Design Capacity for Mineral Processing Plants



- Study by McNulty (1998)
- Rate is affected by design readiness and departure from prior plants.
- Plants with 'unproven technology' result were often abandoned after 4 years of operation.

Rate of Achieving Design Capacity for Shale Oil Plants

Shale Oil Examples

Project	Year	Scale-up Factor	Capacity curve achieved
Unocal-Parachute Crk	1987	100:1	Unproven technology
PetroSIX	1992	5:1	Scale-up
ATP-Stuart	2000	50:1	Unproven technology

Example 1: Best Number of Scale-up Stages?

- Scenario

Successful completion of 10 bbl/sd pilot plant

Resource = 125 000 bbl/sd for 30 yrs = 1B bbl

Example 1: Options

1 intermediate plant

10 → 1250 → 125 000 bbl/sd

2 intermediate plants

10 → 250 → 5 000 → 125 000 bbl/sd

5 intermediate plants

10 → 50 → 250 → 1250 → 5000 → 25 000 → 125 000 bbl/sd

Example 1: Assumptions

Discount Factor	8%
Plant life	30 years
Oil price	\$50/bbl
Design availability	90%
Salvage value	0

If unsuccessful scale-up, then abandon current plant after 4 years of operation and no follow-on plants.

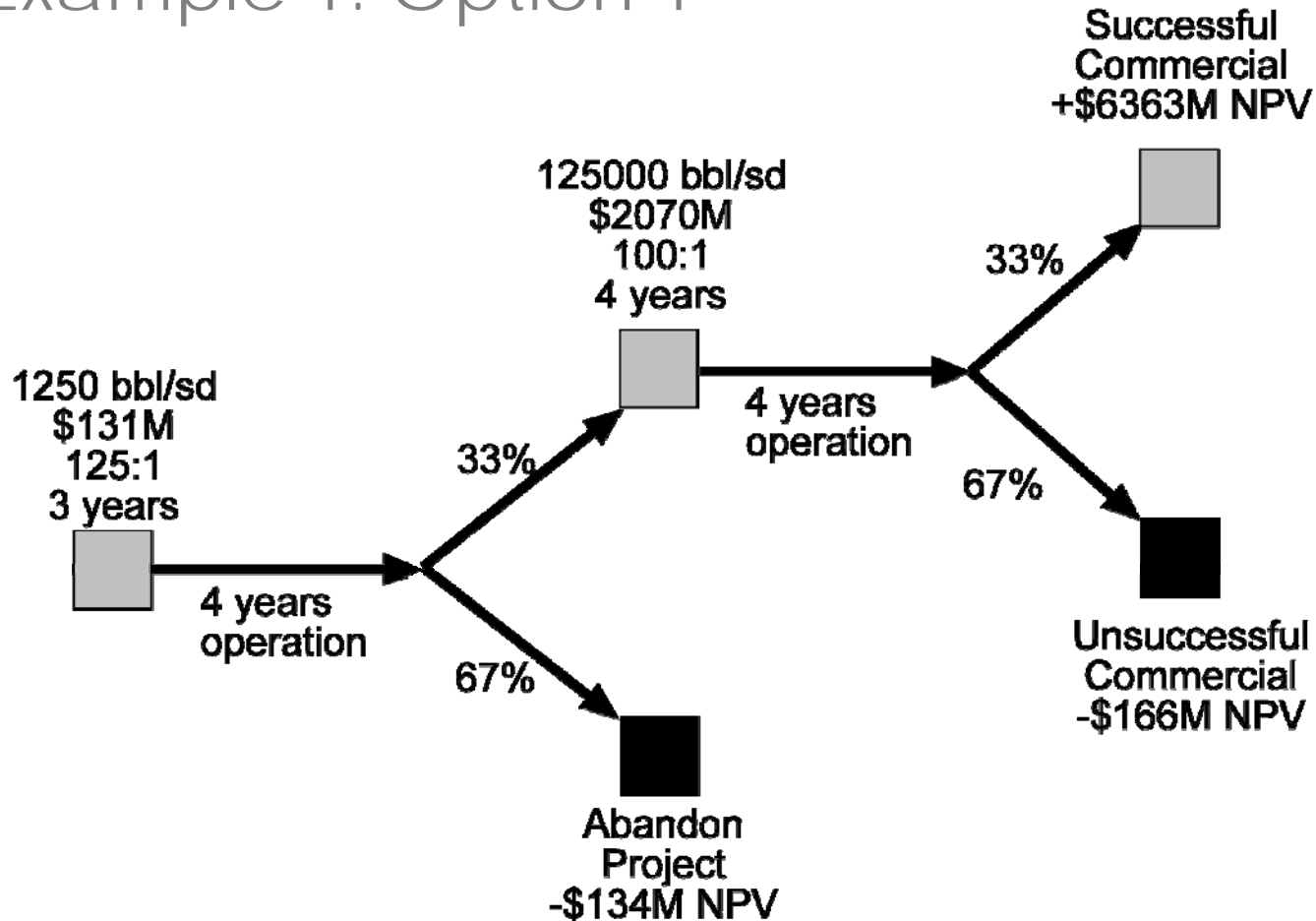
Example 1: Assumption

- Probability of success depends on scale-up factor

Rate of achieving design capacity

Scale-up Factor	Rate of achieving design capacity	
	'Scale-up' curve	'Unproven technology' curve
5:1	90%	10%
25:1	67%	33%
100:1	33%	67%

Example 1: Option 1



Weighted NPV = $(0.67)(-134) + (0.22)(-166) + (0.11)(6363) = \$552M$

Example 1: Results

No. of intermediate plants	Number of possible outcomes	Best outcome		Weighted NPV \$M
		NPV \$M	Probability %	
1	3	6363	11	552
2	4	3861	22	978
5	7	530	53	188

Example 2: New or Demonstrated Technology?

Scenario:

Old technology

80% availability

successfully demonstrated @ 5000 bbl/sd

New technology

95% availability

successfully piloted @ 250 bbl/sd

Example 2: Options

Old technology

1 intermediate plants

5 000 → 25 000 → 125 000 bbl/sd

New technology

2 intermediate plants

250 → 5 000 → 25 000 → 125 000 bbl/sd

Example 2: Results

Demonstrated capacity Bbl/sd	Availability %	Number of intermediate plants	Best outcome		Weighted NPV \$M
			NPV \$M	Probability %	
5000	80	1	4991	81	3977
250	95	2	3369	53	1671

Conclusions

- Development time and costs need to be considered when evaluating shale oil projects
- Scale-up risk also needs to be considered.
- A new technology must promise a significant advantage to justify additional development time and cost.



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