Factors Affecting Catalyst Management Strategy: An Independent Perspective

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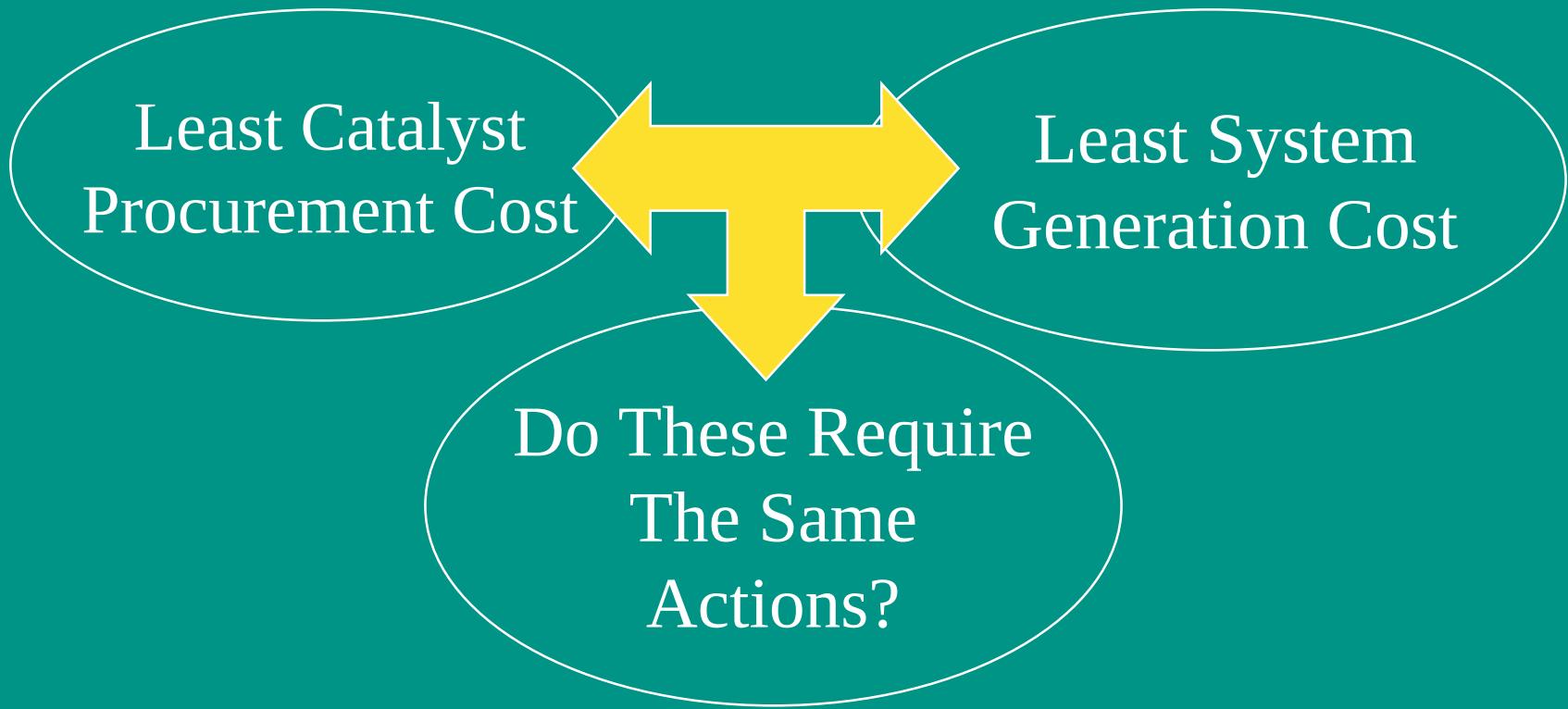
What Do Operators Want From A Catalyst Management Strategy?



Design, Operating Decisions Dictate Catalyst Management Strategy

- Target Performance
  - NOx removal/residual NH3
  - SO3 production
- Initial Guarantee Period (e.g. 16K vs 20K hours)
- Reactor Arrangement
  (2+1, 3+1, 3+2)
- Coal Composition (As, S, CaO, alkalinity, etc.)
- Operating Factors: Unit, System

When To Add, Replace Catalyst?
Unit Factors

- Unit Tolerance for Catalyst Deactivation
  - Increase in NH3 @ constant NOx removal
  - Compromise in NOx removal @ constant NH3
- Air Heater Pressure Drop
- Ash Resale and Impact of NH3-contamination
- Additional NOx Removal From Combustion Controls

  (80% from 0.40 lbs/MBtu = 77.5% from 0.36 lbs/MBtu)

When To Add, Replace Catalyst? *System Factors*

- Frequency of Outages
  - Boiler, turbine ~ 12 week durations @ 24-36 months
  - Frequency of multi-day, multi-week “minor” outages
- Outage Cost: Incremental Production, Replacement Power
- Additional, Temporary NOx “Allowances”
  - markets
  - in-system

Example Case: Regeneration, Outage Timing

- Reference Unit
  - 500 MW, 80% c.f., 10 and 40 ppm As coal
  - 0.40 lbs/MBtu boiler exit; 85% NOx removal
  - 3200 1/h SV, 3+1 reactor, 16K hrs initial guarantee
- Two Catalyst Regeneration Options
- System Features:
  - 28 months between boiler, turbine outages
  - one “unplanned” 5 day outage annually

Unit Basis: New vs. Regenerated Catalyst

- New Catalyst: $200 c.f. (k/ko ~1)
- Two Regeneration Options
  - 95% activity for 70% new price
  - 90% activity for 60% new price
- Catalyst Addition/Replacement Options
  - #1: (new/regen)
    - supplement with new, replace with regen
  - #2: (regen/regen)
    - supplement with regen, replace with regen

New vs Regenerated Catalyst
(10 ppm case, 115K hrs)

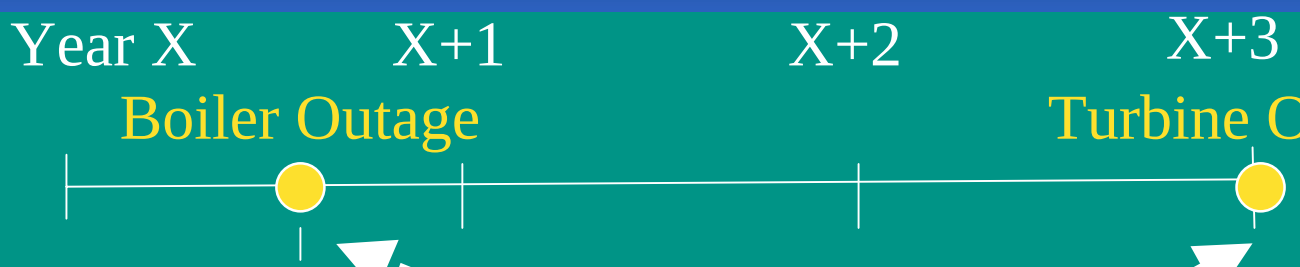
NPV ($M) Of New, Regen Catalyst: 115K Hrs, Annual Operation

Arsenic Regen Option	*10 ppm* 60/90	*10 ppm* 70/95	*40 ppm* 60/90	*40 ppm* 70/95
New	7	7	13.2	13.2
New/regen	5.3	5.3	9.6	9.4
Regen/regen	4.8	5.4	10.2	9.9
Savings	1.7-2.2		3.0-3.6	

Outage Timing Considerations

- Seasonal Operation: Limited Time Offer?
- NSR Settlement, “3P” Legislation
  - Annual NOx caps
  - Some proposals < 0.10 lbs/MBtu
- Deregulation: Key Units (SCR) Run Harder, Longer
  - Boiler, turbine outages: 30+ month intervals
  - 2 week annual outage: history?

One Outage Timing Scenario



Accelerate Outage
15 months
Consequence:
higher catalyst cost

Unit A

Estimated EOL

Defer Unit Outage
12 months
Consequences:
- Higher residual NH3
- Lower NOx removal
- Load limit

17 day Outage
Consequence: Lost generation

4-5 day "Mini-Outage" for cleaning
Consequences: possible lost generation

Assumptions: Selected Catalyst Replacement Options

- Replace Catalyst Per EOL Schedule
  - 17 day outage
  - Higher generation cost
    - low: 100% via coal 2,500 Btu/kWh
    - moderate: 50% coal/20% CT/30% market @$20/MWh
- Accelerate Change by 15 months

  4th layer: 70 vs. 79K hrs, new catalyst
- Aggressive Cleaning/In-Situ Regeneration
  - 4th layer relative activity: 0.42 ---> 0.65
  - 30% new catalyst cost
  - 4-5 days outage

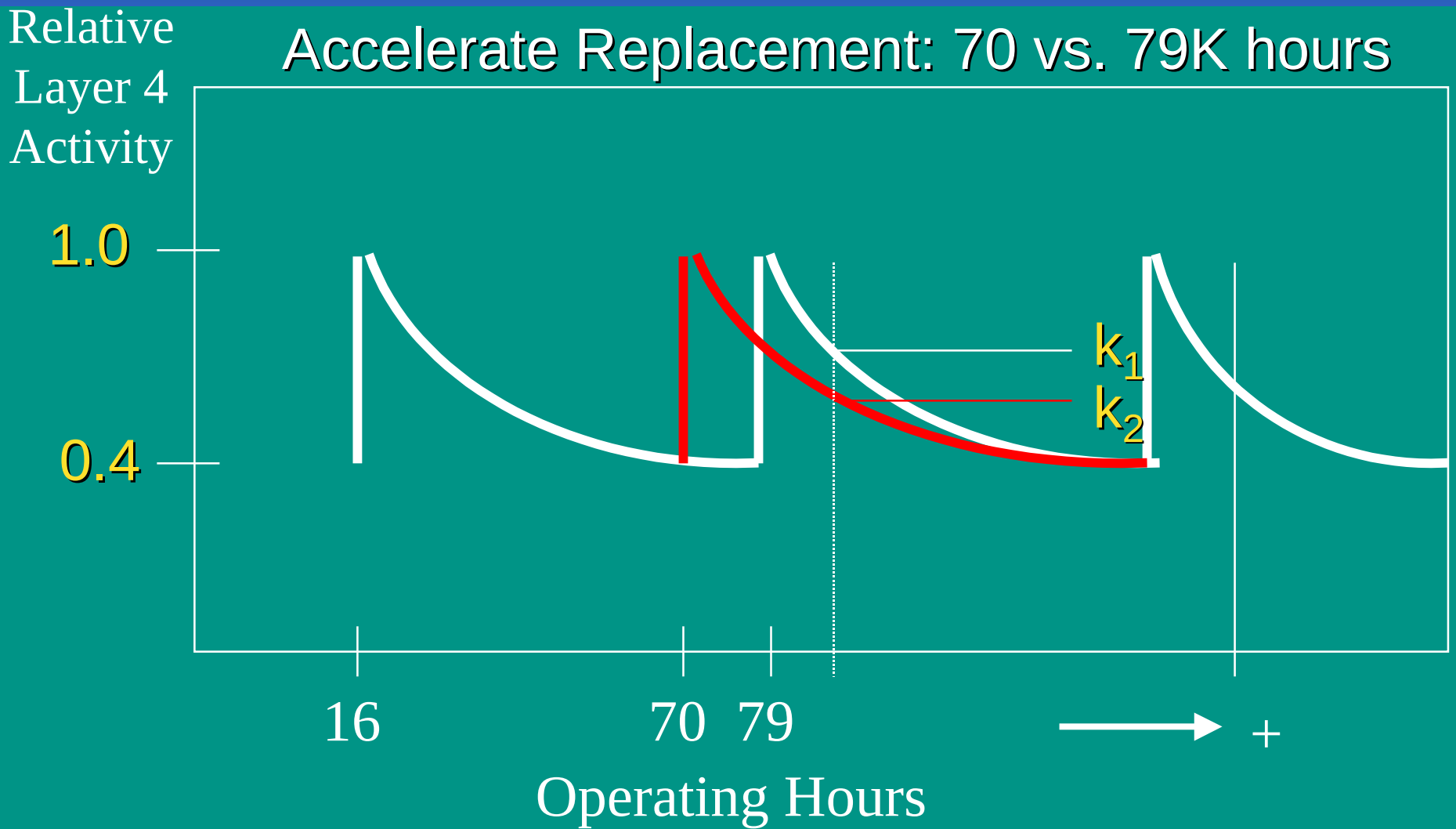
Cost Impacts Of Catalyst Options

Action	Assumption	Cost ($000)
Accelerate replacement by 15 months	Exchange catalyst 9000 hours early (70 vs 79k)	140 (change in NPV @ 115K)
In-Situ Regeneration or Cleaning	• 0.42-->0.65, for 30% catalyst price • complete within outage window	175 (change in NPV @ 115K, no outage penalty)

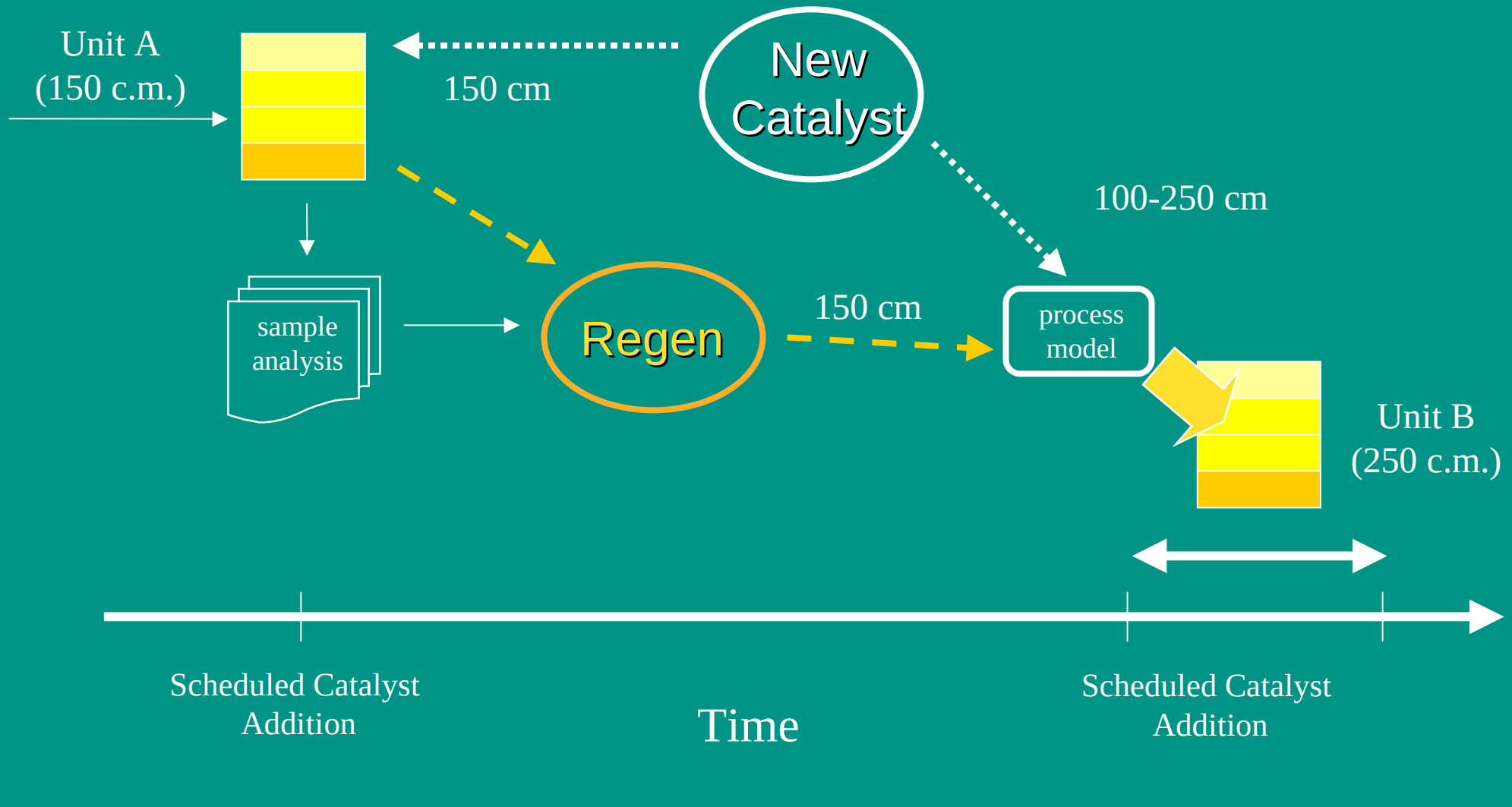
Cost Impacts Of Catalyst Options

Action	Assumption	Cost ($000)
Replace per 17 day outage	HR premium, CTs, bulk power purchase	440 -1,600
Defer 12 months, lower NH3	Compromised NOx reduction by 2.5%	418 (190 tons @ $2200/ton)
Defer 12 months, maintain NOx	• AH p limits kWh by average of 5% • higher fuel cost	885-1,630
	25% of ash cannot be sold	880

Implications of Early Replacement (10 ppm case)



Multiple Units, Multiple Complexities



Summary

- System Analysis is Critical to Determine Catalyst Management Actions for Least Cost Generation
  Replacement timing as important as catalyst unit cost
- Regeneration Savings Forfeited if Catalyst-Only Outage Required
  – $1.7-3.6 M savings over 13 years
  – One ill-timed outage: $0.44-1.6 M
- Catalyst Outage “Shuffling” An Option
  – Accelerate 15 months ($140K)
  – Defer 12 months, in-situ clean/regenerate ($175K)
  – Defer 12 months, compromise NOx removal ($320K)

Process, Catalyst Monitoring Service In Development