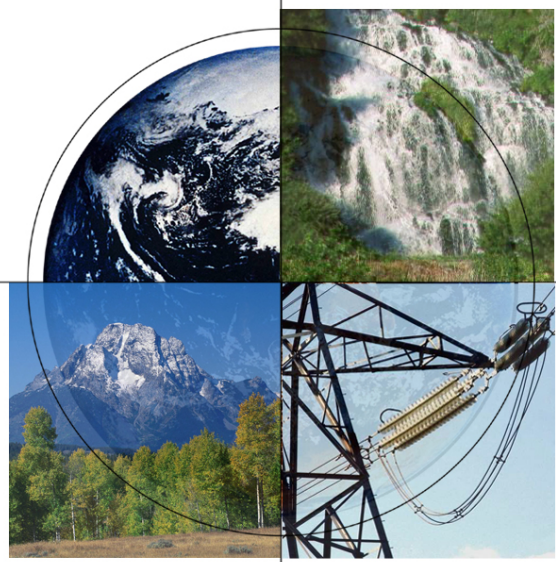
DOE/NETL's Phase II Field Testing Program
Preliminary Economic Analysis of Mercury Control via Activated Carbon Injection



DOE/NETL's Mercury Control Technology R&D Program Review

December 11, 2006
Pittsburgh, PA

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It should also be noted that the economic analyses represent “snapshots” in time based on the methodology used, assumptions made, and conditions that were specific to the time when DOE/NETL field testing occurred. Consequently, the economics presented are plant- and condition-specific and attempts to use this presentation as a tool to predict the performance of these mercury control technologies at other power plants should be conducted cautiously regardless of similarities in coal-rank and APCD configuration. In addition, the economics originate from relatively small datasets in many cases. As a result, the cost of mercury control could vary significantly with the inclusion of additional ACI performance data from current and future DOE/NETL field testing.

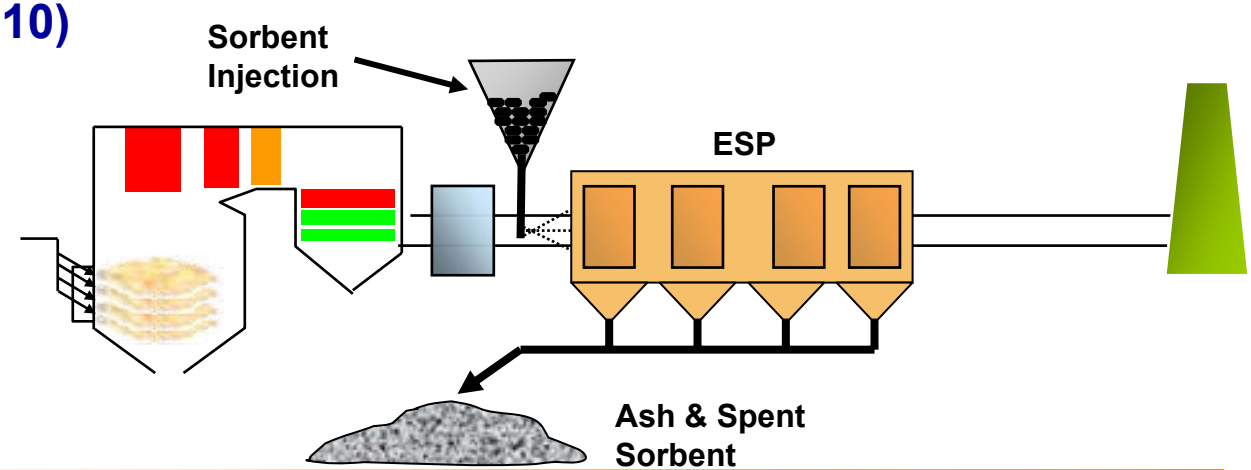
Background

Clean Air Mercury Rule (CAMR)

- Phase I (2010) Cap: 38 tons
- Phase II (2018) Cap: 15 tons (~69% total Hg reduction)

DOE/NETL's Mercury Control Field Testing Program

- Phase I (2001-2002)
- Phase II (2004-2007)
  - Sorbent injection & mercury oxidation control technologies
  - Long-term (30 days or more @ optimum conditions), full-scale field testing
  - Focus on low-rank coals
- Phase III (2006-2010)



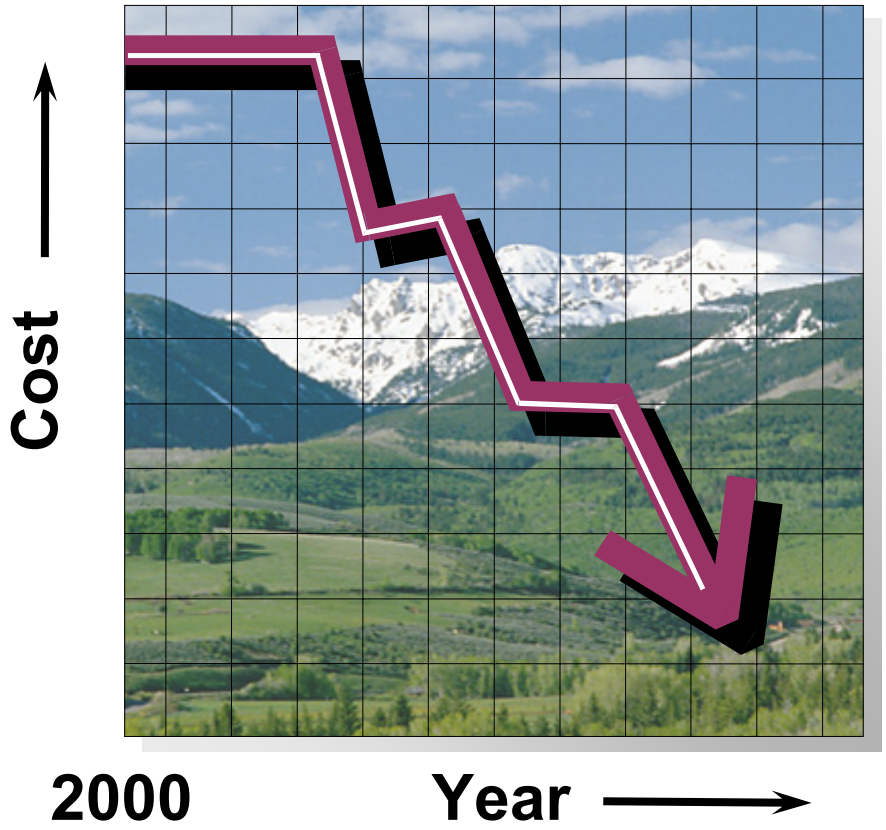
Mercury Control Technology Field Testing Program

Performance/Cost Objectives

- Have technologies ready for commercial demonstration by 2007 for all coals

- Reduce "uncontrolled" Hg emissions by 50-70%

- Reduce cost by 25-50% compared to baseline cost estimates



Baseline (1999) Costs: $50,000 - $70,000 / lb Hg Removed

Preliminary Economic Analysis of ACI

Purpose & Objectives

Purpose

- Develop *plant-specific* cost estimates for Hg control via:
  - Conventional (untreated) ACI
  - Chemically-treated (or brominated) ACI
  - Conventional ACI with Sorbent Enhancement Additives (SEA)
- Gauge NETL's success in achieving cost target (25-50% reduction)

Objectives

- Discern the level of Hg capture that is attributable to ACI
- Incorporate the long-term (~30 days) field testing results
- Quantify the potential impacts of ACI on byproduct reuse & disposal

Economics represent "snapshots" in time based on the methodology used, assumptions made, and conditions present when DOE/NETL field testing occurred

DOE/NETL's Phase II Mercury Control Technology Field Testing Program

Preliminary Economic Analysis of Activated Carbon Injection

Prepared for

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory
Innovations for Existing Plants Program

Prepared by

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April 2006

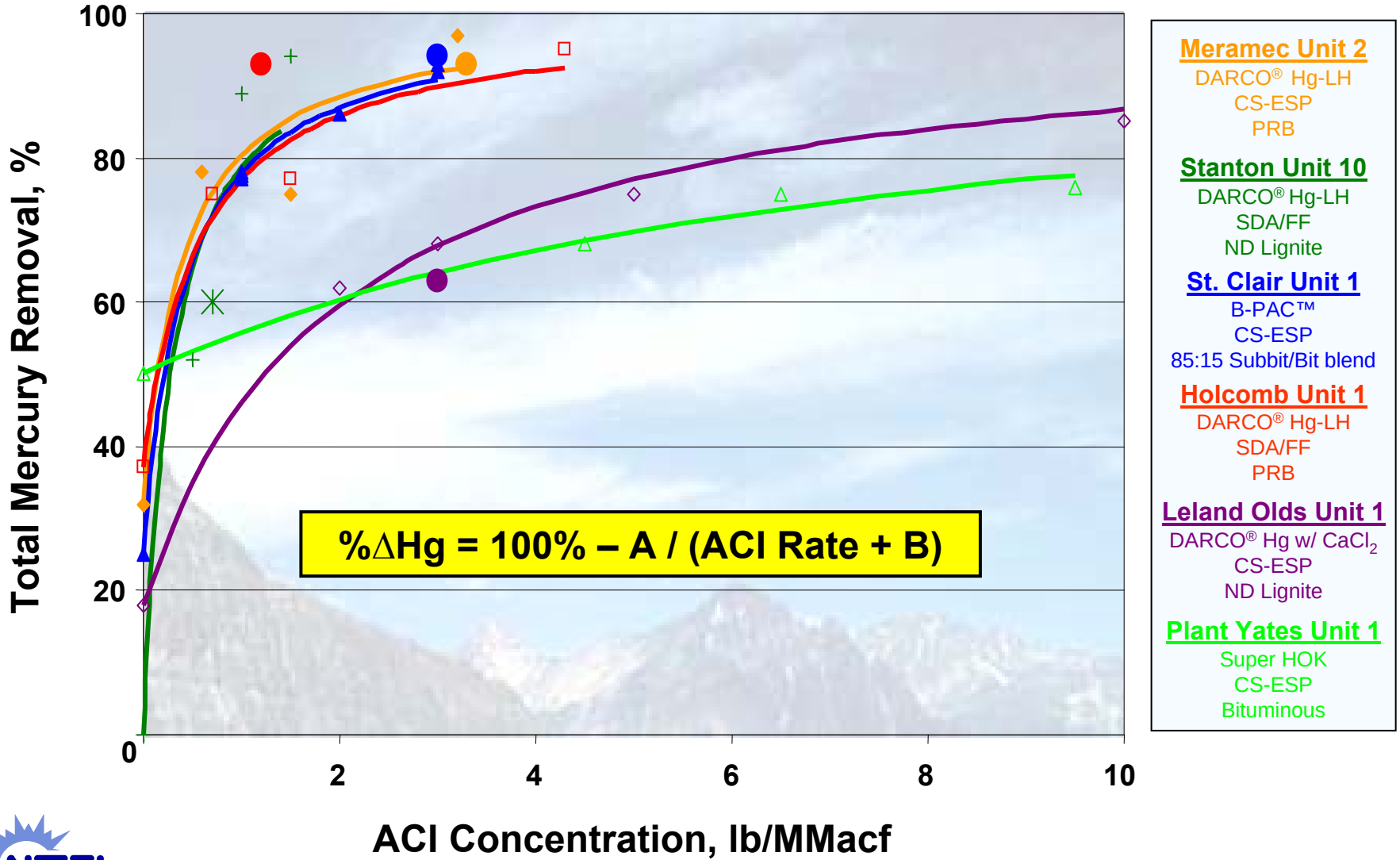
Complete report available at:

http://www.netl.doe.gov/technologies/coalpower/ewr/index.html

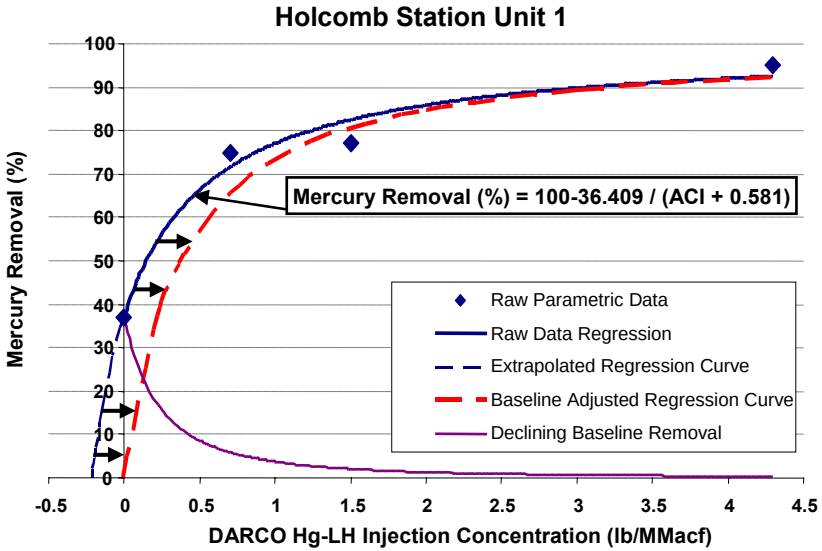
Phase II Site Descriptions

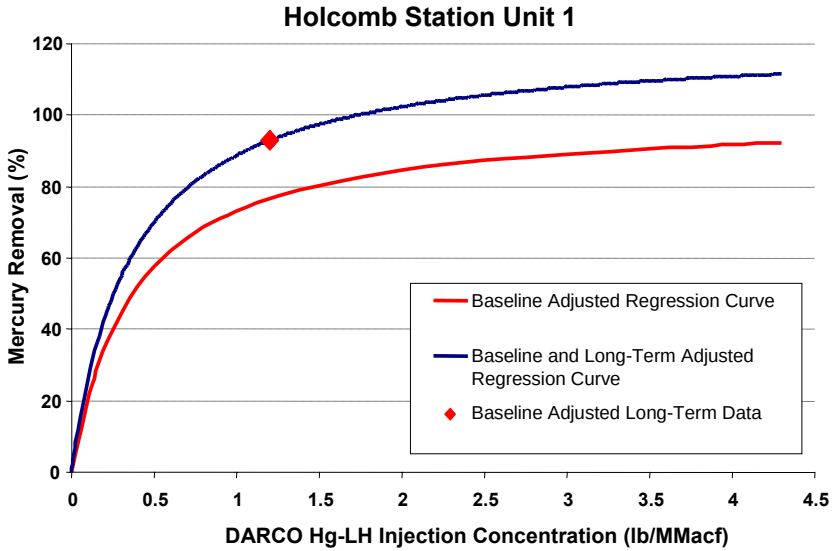
Site	Holcomb Unit 1	Meramec Unit 2	Stanton Unit 10	St. Clair Unit 1	Leland Olds Unit 1	Yates Unit 1
Capacity, MW	360	140	60	145	220	100
Coal Rank	PRB	PRB	ND Lignite	85:15 PRB/ Bituminous blend	ND Lignite	Bituminous
APCD Configuration	SDA/FF	CS-ESP	SDA/FF	CS-ESP	CS-ESP	CS-ESP / Wet FGD
$T_{ACI,}$ °F	290	310	300	290	340	310
Flue Gas Flow Rate, ACFM	1,194,444	555,556	251,789	751,000	878,049	480,000
Hg in Flue Gas, lb/hr	0.0383	0.0128	0.0050	0.0087	0.0216	0.0071
Co-benefit Hg Capture, lb/hr	0.0142 (37%)	0.0041 (32%)	0.0000 (0%)	0.0022 (25%)	0.0039 (18%)	0.0035 (50%)
Hg Control Technology	DARCO® Hg-LH	DARCO® Hg-LH	DARCO® Hg-LH	B-PAC™	DARCO® Hg w/ $CaCl_2$	Super HOK

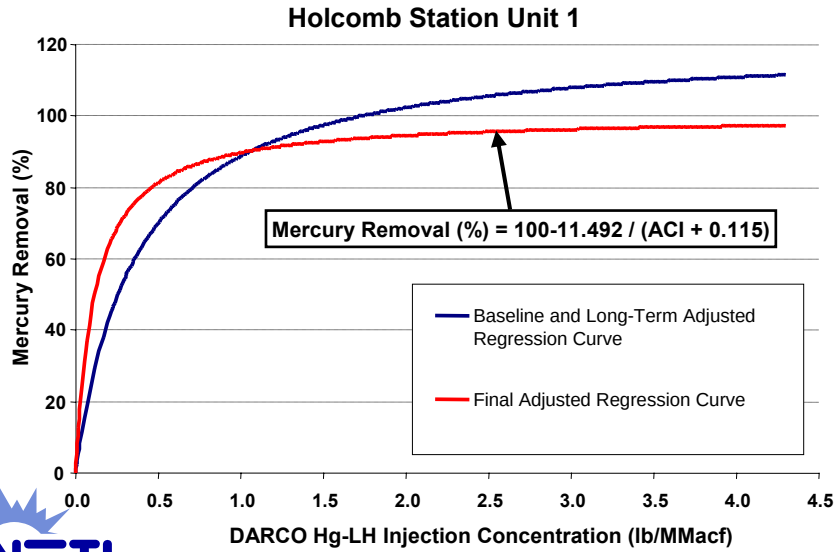
Phase II Raw Data Regression

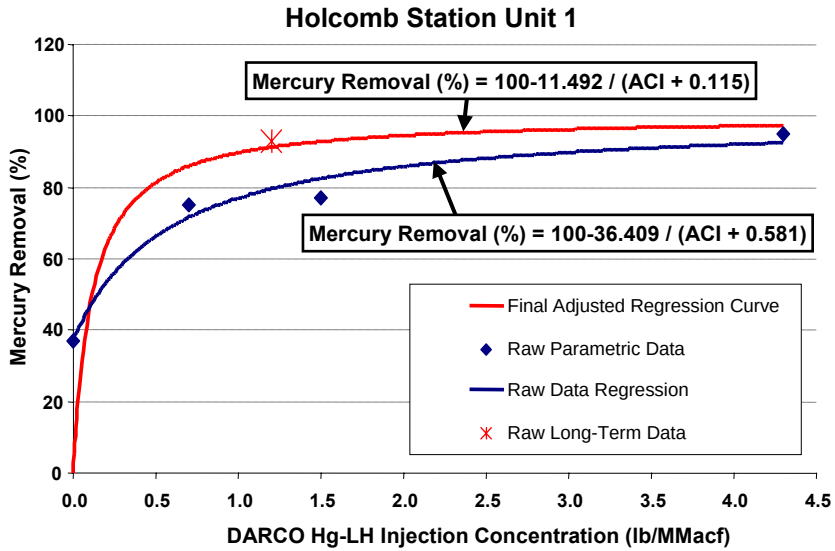


Phase II Data Adjustment Methodology

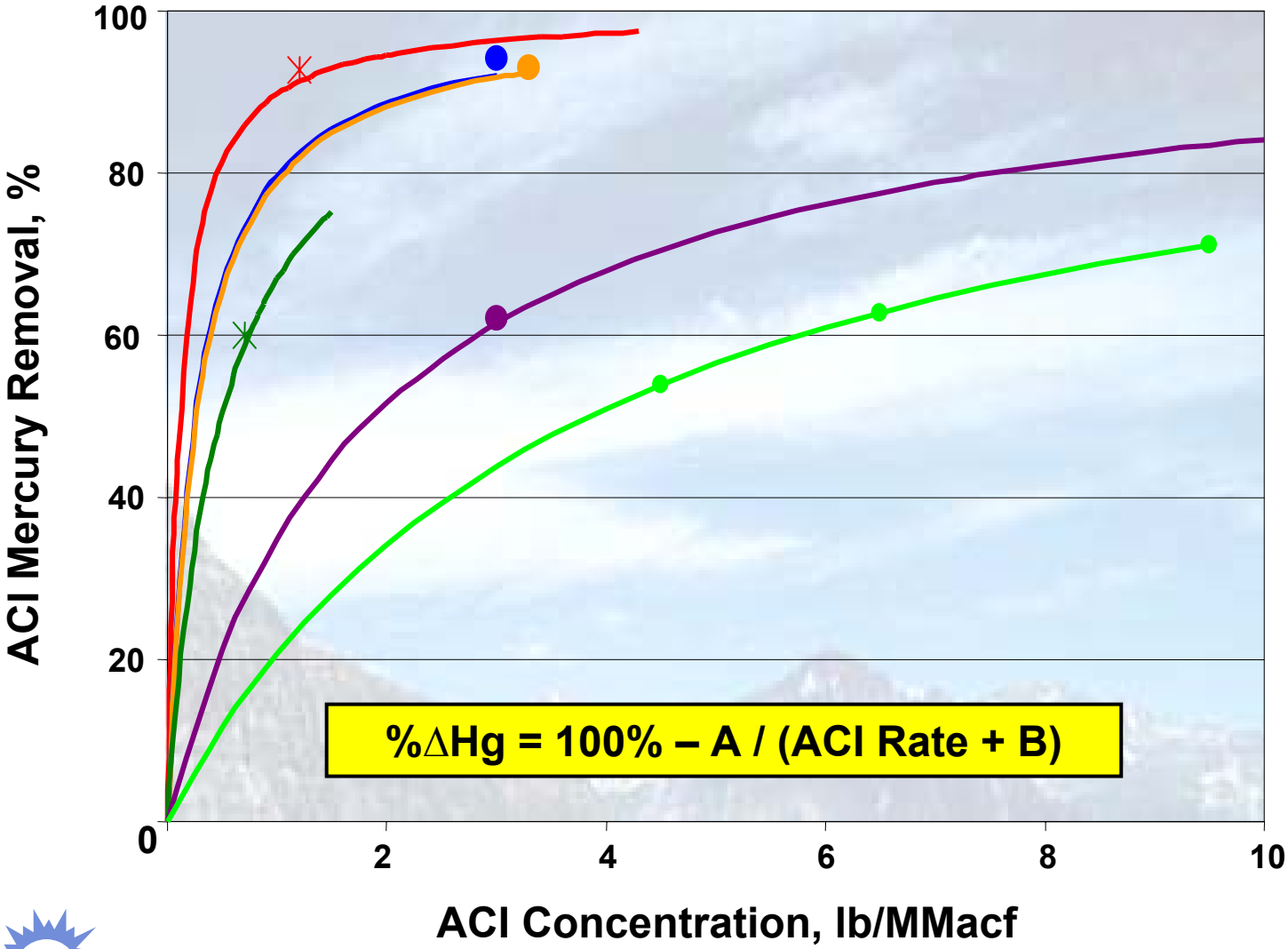








Phase II Adjusted Regression Curves



Holcomb Unit 1
DARCO® Hg-LH
SDA/FF
PRB

St. Clair Unit 1
B-PAC™
CS-ESP
85:15 Subbit/Bit blend

Meramec Unit 2
DARCO® Hg-LH
CS-ESP
PRB

Stanton Unit 10
DARCO® Hg-LH
SDA/FF
ND Lignite

Leland Olds Unit 1
DARCO® Hg w/ $CaCl_2$
CS-ESP
ND Lignite

Plant Yates Unit 1
Super HOK
CS-ESP
Bituminous

Capital Cost

- Equipment cost based on estimates provided by ADA-ES
- Minimum equipment cost of $690,000
- Cost of retrofit installation is site-specific
  - ~15% of uninstalled equipment cost
- No adjustment for interest during construction

Equipment, FOB Holcomb	$711,116
Site Integration (materials and labor)	$51,884
Taxes (6%)	$45,780
Installation	$124,000
General Facilities (10%)	$93,278
Engineering Fees (10%)	$93,278
Project Contingency (15%)	$139,917
Process Contingency (5%)	$46,639
Total Capital Requirement (TCR)	$1,305,892
TCR, $/kW	$3.63

Annual Operating & Maintenance (O&M) Costs

1) **Sorbent Consumption**
   - **ACI Concentration (lb/MMacf) & Delivered Sorbent Prices**
2) **Sorbent Disposal**
   - **$17/ton**
3) **SEA Consumption (Leland Olds only)**
   - **Delivered Price of $0.15/lb for aqueous $CaCl_2$ solution**
4) **"Other" Costs[a]**

Byproduct Impacts

For All Units

- $17/ton for fly ash & SDA byproduct disposal

For Units with ESP

- $18/ton for lost revenue from fly ash sales (assuming 100% utilization prior to ACI)

Sorbent Name	Manufacturer	Description	Delivered Price ($/lb)[b]
DARCO® Hg	NORIT Americas	Conventional (untreated)	0.54
Super HOK	RWE Rhinebraun	Conventional (untreated)	0.39
DARCO® Hg-LH	NORIT Americas	Brominated	0.95
B-PAC™	Sorbent Technologies	Brominated	0.85

[a] Includes power consumption ($0.05/kW); operating labor (4 hrs/day @ $45/hr); ACI equipment maintenance (5% of uninstalled equipment cost); and spare parts ($10,000 annually).

[b] Includes $0.10/lb for transportation expenses.

Cost Estimates for 50% ACI Mercury Control

	Holcomb Unit 1	St. Clair Unit 1	Meramec Unit 2	Stanton Unit 10	Leland Olds Unit 1	Plant Yates Unit 1
PAC / SEA	DARCO® Hg-LH	B-PAC™	DARCO® Hg-LH	DARCO® Hg-LH	DARCO® Hg & $CaCl_2$	Super HOK
ACI Rate, lb/MMacf	0.11	0.26	0.27	0.49	1.88	3.85
Total Capital Requirement (TCR), ($1,000)	$1,310	$1,280	$1,280	$1,270	$1,390	$1,270
Unit TCR, $/kW	$3.63	$8.79	$9.16	$21.10	$6.33	$12.66
First-Year Annual O&M Costs (80% capacity factor)						
PAC Consumption, $/yr	$54,800	$68,800	$59,200	$49,500	$374,000	$303,000
PAC Disposal, $/yr	$490	$688	$529	$443	$5,890	$6,600
SEA Consumption, $/yr	NA	NA	NA	NA	$388,000	NA
Other, $/yr	$105,000	$104,000	$104,000	$104,000	$107,000	$107,000
Total O&M, $/yr	$160,000	$174,000	$164,000	$154,000	$875,000	$417,000
Byproduct Impacts, ($1,000/yr)	$1,430	$792	$1,060	$579	$3,240	$1,080

[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

20-Year Levelized Cost Estimates for 50% ACI Mercury Control

	Holcomb Unit 1	St. Clair Unit 1	Meramec Unit 2	Stanton Unit 10	Leland Olds Unit 1	Plant Yates Unit 1
PAC / SEA	DARCO® Hg-LH	B-PAC™	DARCO® Hg-LH	DARCO® Hg-LH	DARCO® Hg & $CaCl_2$	Super HOK
ACI Rate, lb/MMacf	0.11	0.26	0.27	0.49	1.88	3.85
20-Year Levelized Cost *without* Byproduct Impacts						
COE Increase, mills/kWh	0.14	0.36	0.37	0.82	0.83	0.97
$/lb Hg Removed	$4,220	$16,200	$11,800	$19,500	$20,600	$54,600
20-Year Levelized Cost *with* Byproduct Impacts						
COE Increase, mills/kWh	0.86	1.36	1.75	2.57	3.50	2.94
$/lb Hg Removed	$25,700	$60,100	$56,400	$61,300	$86,900	$166,000

[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

Cost Estimates for 70% ACI Mercury Control

	Holcomb Unit 1	St. Clair Unit 1	Meramec Unit 2	Stanton Unit 10	Leland Olds Unit 1	Plant Yates Unit 1
PAC / SEA	DARCO® Hg-LH	B-PAC™	DARCO® Hg-LH	DARCO® Hg-LH	DARCO® Hg & $CaCl_2$	Super HOK
ACI Rate, lb/MMacf	0.27	0.60	0.62	1.15	4.39	8.98
TCR, ($1,000)	$1,310	$1,280	$1,280	$1,270	$1,390	$1,270
Unit TCR, $/kW	$3.63	$8.79	$9.16	$21.10	$6.33	$12.66
First-Year Annual O&M Costs (80% capacity factor)						
PAC Consumption, $/yr	$128,000	$160,000	$138,000	$116,000	$875,000	$707,000
PAC Disposal, $/yr	$1,140	$1,610	$1,230	$1,040	$13,800	$15,400
SEA Consumption, $/yr	NA	NA	NA	NA	$388,000	NA
Other, $/yr	$105,000	$105,000	$105,000	$104,000	$111,000	$111,000
Total O&M, $/yr	$234,000	$267,000	$244,000	$221,000	$1,390,000	$833,000
Byproduct Impacts, ($1,000/yr)	$1,430	$792	$1,060	$579	$3,240	$1,080

[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

20-Year Levelized Cost Estimates for 70% ACI Mercury Control

	Holcomb Unit 1	St. Clair Unit 1	Meramec Unit 2	Stanton Unit 10	Leland Olds Unit 1	Plant Yates Unit 1
PAC / SEA	DARCO® Hg-LH	B-PAC™	DARCO® Hg-LH	DARCO® Hg-LH	DARCO® Hg & $CaCl_2$	Super HOK
ACI Rate, lb/MMacf	0.27	0.60	0.62	1.15	4.39	8.98
20-Year Levelized Cost *without* Byproduct Impacts						
COE Increase, mills/kWh	0.18	0.48	0.47	1.02	1.25	1.72
$/lb Hg Removed	$3,810	$15,200	$10,800	$17,400	$22,200	$69,500
20-Year Levelized Cost *with* Byproduct Impacts						
COE Increase, mills/kWh	0.90	1.47	1.85	2.77	3.92	3.69
$/lb Hg Removed	$19,200	$46,600	$42,700	$47,300	$69,600	$149,000

[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

Cost Estimates for 90% ACI Mercury Control

	Holcomb Unit 1	St. Clair Unit 1	Meramec Unit 2
PAC	DARCO® Hg-LH	B-PAC™	DARCO® Hg-LH
ACI Rate, lb/MMacf	1.03	2.31	2.40
TCR, $	$1,310,000	$1,280,000	$1,280,000
Unit TCR, $/kW	$3.63	$8.79	$9.16
First-Year Annual O&M Costs (80% capacity factor)			
PAC Consumption, $/yr	$493,000	$619,000	$532,000
PAC Disposal, $/yr	$4,420	$6,190	$4,760
Other, $/yr	$107,000	$107,000	$106,000
Total O&M, $/yr	$605,000	$732,000	$643,000
Byproduct Impacts, $/yr	$1,430,000	$792,000	$1,060,000

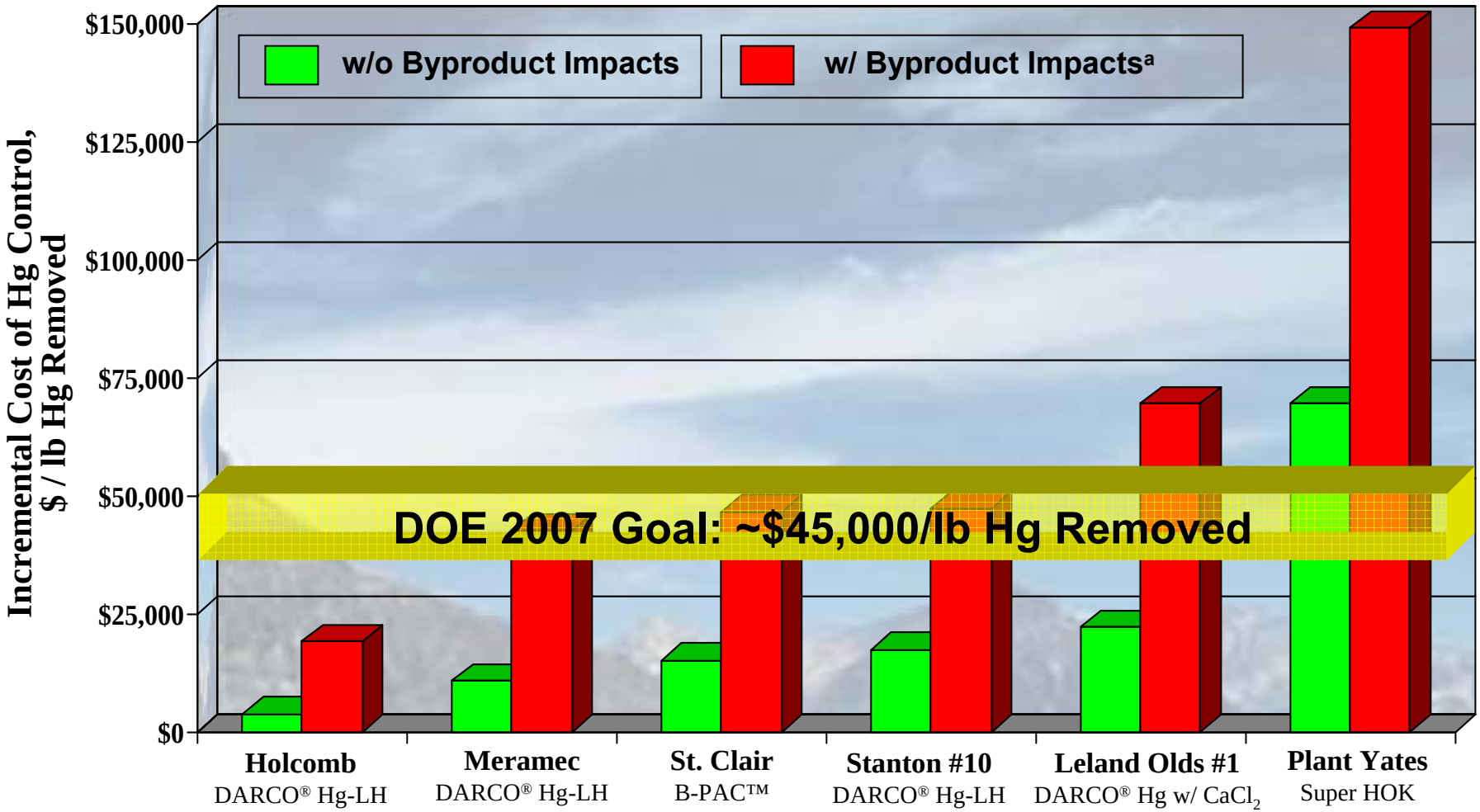
[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

20-Year Levelized Cost Estimates for 90% ACI Mercury Control

	Holcomb Unit 1	St. Clair Unit 1	Meramec Unit 2
PAC / SEA	DARCO® Hg-LH	B-PAC™	DARCO® Hg-LH
ACI Rate, lb/MMacf	1.03	2.31	2.40
20-Year Levelized Cost *without* Byproduct Impacts			
COE Increase, mills/kWh	0.37	1.06	0.99
$/lb Hg Removed	$6,060	$26,200	$17,700
20-Year Levelized Cost *with* Byproduct Impacts			
COE Increase, mills/kWh	1.09	2.05	2.37
$/lb Hg Removed	$18,000	$50,600	$42,500

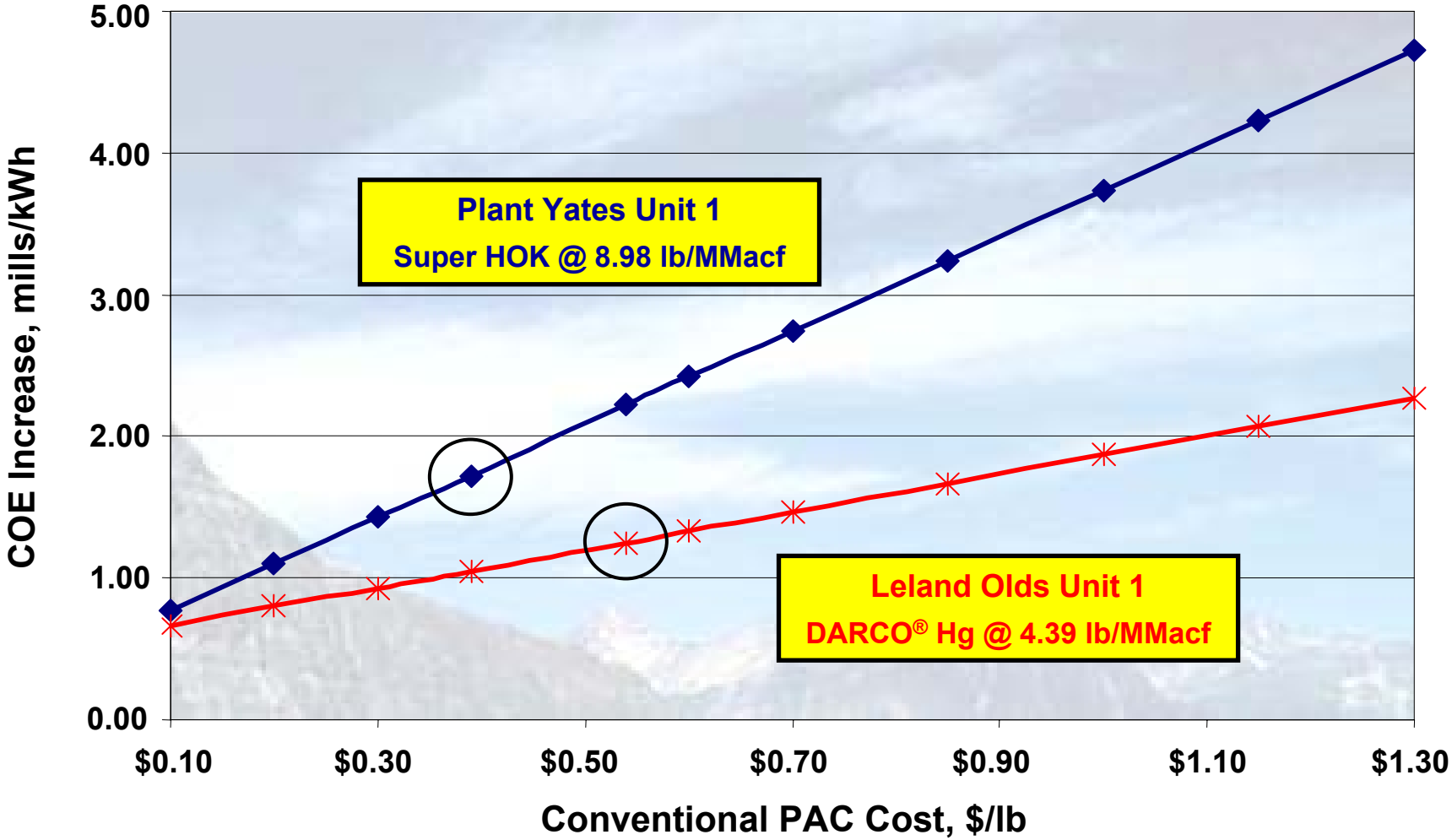
[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

Incremental Cost of 70% ACI Mercury Control



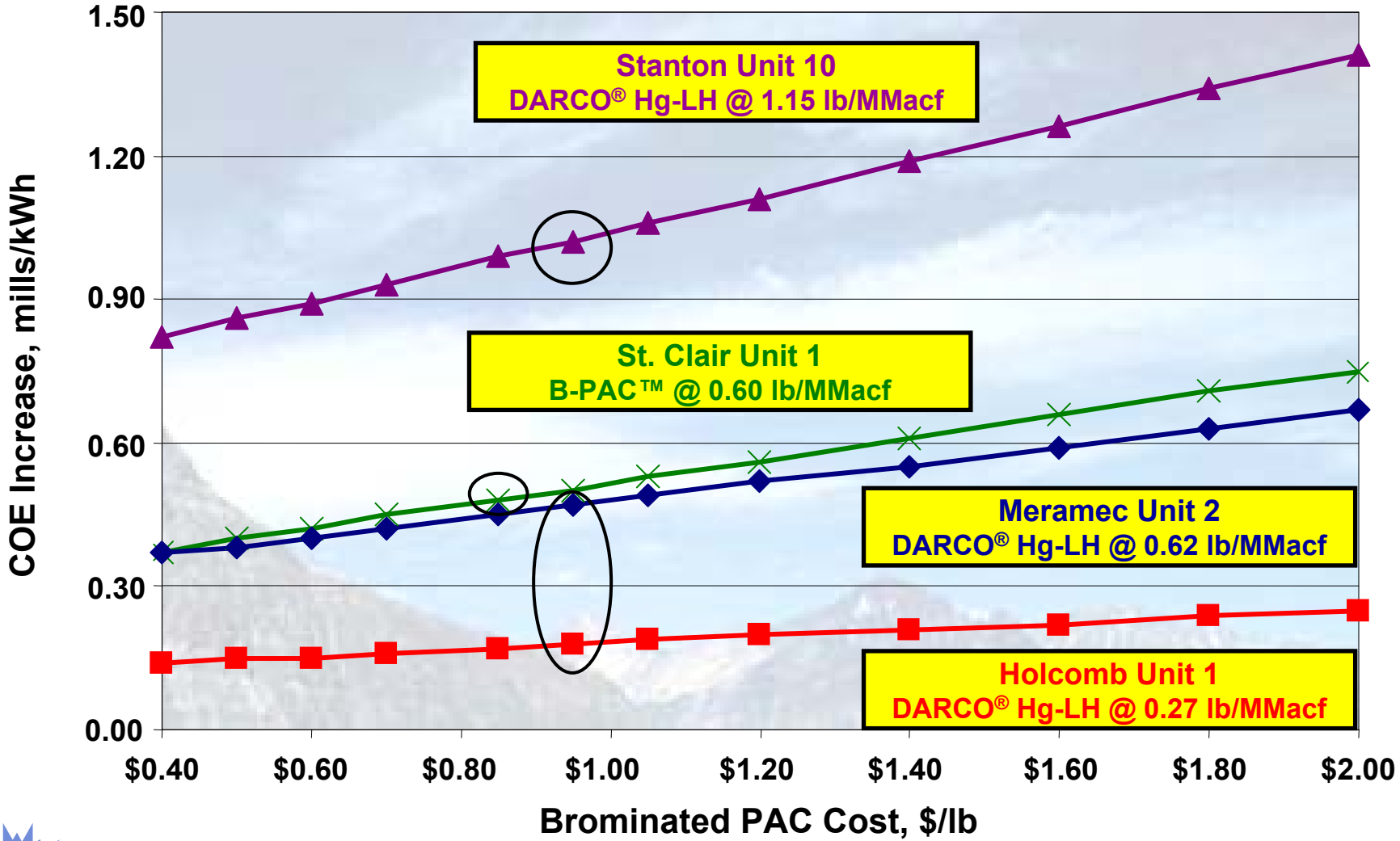
[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

Sensitivity of Incremental COE Increase[a] for 70% ACI Mercury Control to Variations in Conventional PAC Cost



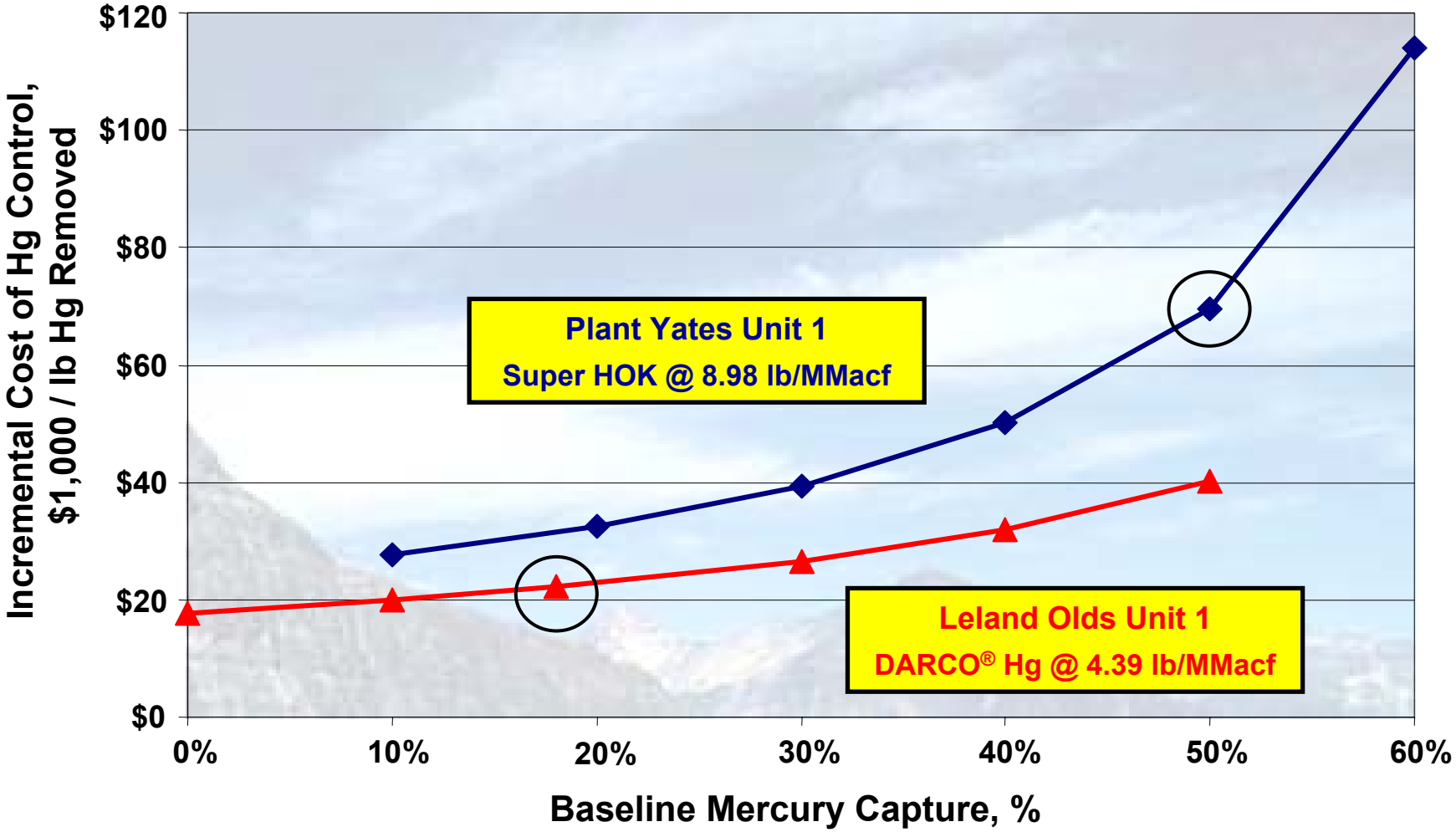
[a] Economic data excludes byproduct impacts.

Sensitivity of Incremental COE Increase[a] for 70% ACI Mercury Control to Variations in Brominated PAC Cost



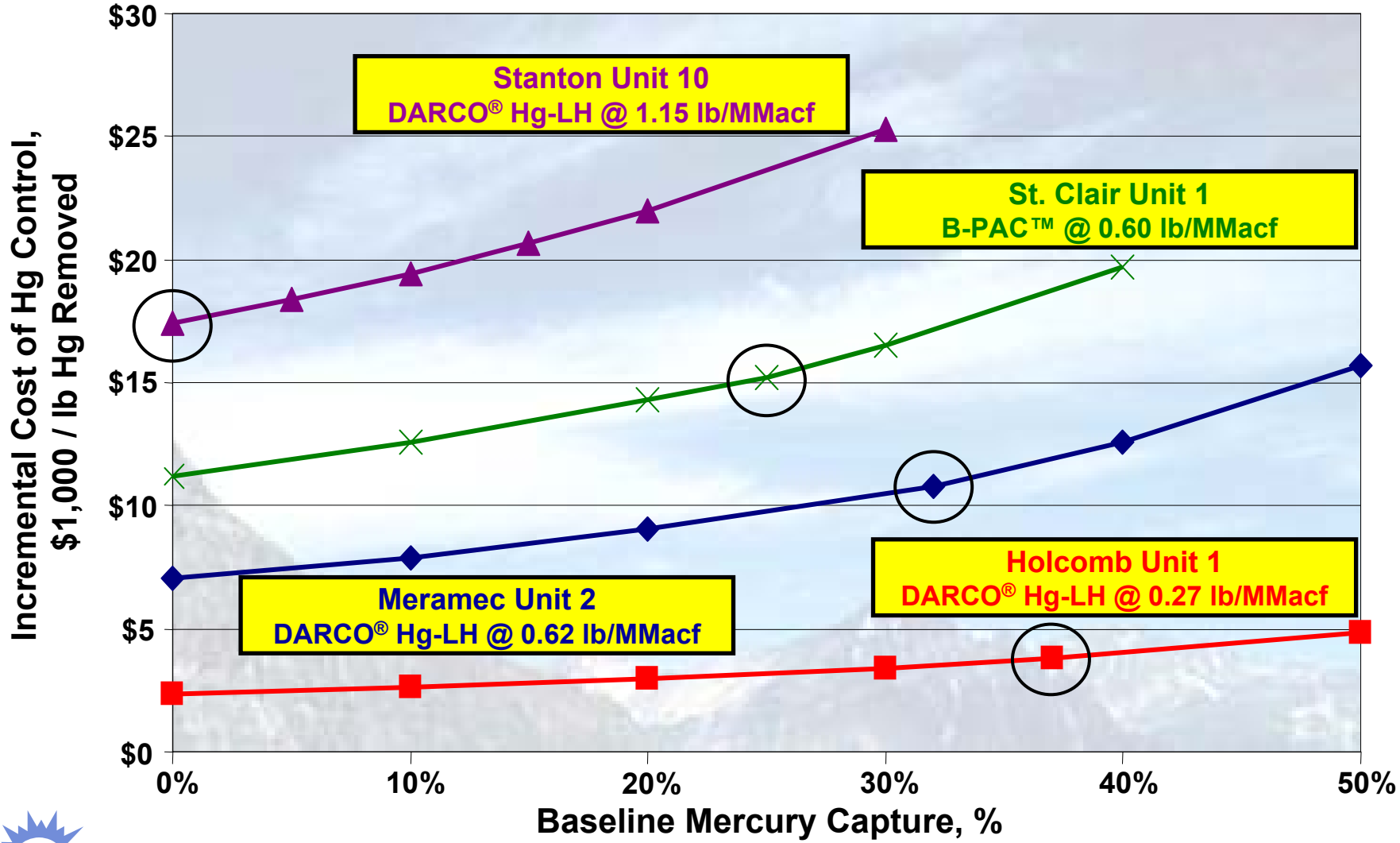
[a] Economic data excludes byproduct impacts.

Sensitivity of the Incremental Cost[a] of 70% ACI Mercury Control to Changes in Baseline Mercury Capture



[a] Economic data excludes byproduct impacts.

Sensitivity of the Incremental Cost[a] of 70% ACI Mercury Control to Changes in Baseline Mercury Capture



[a] Economic data excludes byproduct impacts.

Preliminary Conclusions

- ***Estimated cost of mercury control on a $/lb removed basis continues to decline*** **under "no byproduct impact" scenario**
- **Excluding byproduct impacts, *economics of mercury control via ACI are dominated by PAC consumption costs* when FF retrofit is not required**
- ***Brominated ACI* shows promise for effective mercury removal on low-rank coals**
- ***Incremental Cost of Mercury Control ($/lb Hg Removed)*** **can be influenced by a number of factors including:**
  - **Baseline mercury removal**
  - **Coal mercury content**

Thank You!!!

Co-Authors

- Thomas Feeley, III (DOE/NETL); Jeffrey Hoffmann (DOE/NETL); Dennis Smith (DOE); James Murphy (SAIC)

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Host Utilities

- AmerenUE; Basin Electric; Detroit Edison; Great River Energy; Southern Company; Sunflower Electric