

REINHOLD ENVIRONMENTAL Ltd.



**2013 NO<sub>x</sub>-Combustion Round Table  
& Expo Presentations**

February 18 & 19, 2013, in Salt Lake City, UT / Hosted by PacifiCorp

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ONE SOURCE • ONE PURPOSE • MANY SOLUTIONS



## Balancing LNB vs SCR Catalyst Layers

Bill Medeiros, P.E. Riley Power

Scot Pritchard, Cormetech

Overview of Tradeoffs in a New Era

2013 Reinhold NOx-Combustion Round Table  
Salt Lake City, Utah



# Overview

- Historical Background – How We Got Here
- What Has Changed
- Options & Trade-Offs Going Forward
- Conclusions/Recommendations



# Historical Background

- Vast Majority of Fuels – Bituminous
  - Some Powder River Basin
  - Other Fuels
    - Pet Coke
  - Fuel outlook seemed more certain except for units that were not scrubbed yet
  - Major Issues
    - Arsenic
      - High Arsenic Concentrations with Low Calcium Concentrations
      - European Experience
    - SO<sub>3</sub> Emissions
    - LPA



# Historical Background

- Operational Considerations
  - Ozone season and year round
  - All new catalyst (HC, plate, corrugated)
  - Base loaded
  - European and Japanese experience base for maintenance expectations
- Reagent
  - Anhydrous
  - Big Shift to Urea
    - Issues with Surrounding Community
  - Aqueous
    - Smaller Units



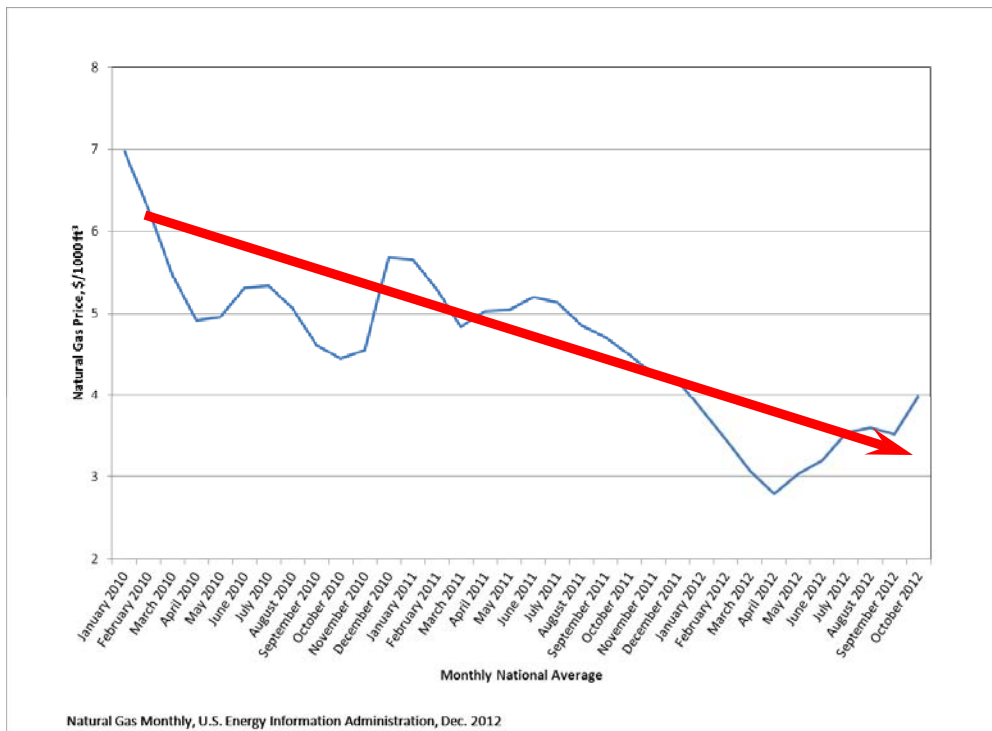
# New (and Renewed) Issues

- Fuels
  - Western Bituminous
  - Powder River Basin
  - Greater Deactivation Levels prevalent on Staged Combustion Units
- Mercury Emissions
  - SCR Hg Oxidation as a Co-Benefit
- Lower SO<sub>3</sub> Levels
  - Effect of SO<sub>3</sub> on Powder Activated Carbon Usage
  - Opacity Issues With SO<sub>2</sub> Control Equipment
    - Wet Scrubbers
  - Higher need to balance with catalyst life & Co-benefit drivers
- Longer initial catalyst life expectations
  - Up to 32k hours vs. 16-24k hours



# New (and Renewed) Issues

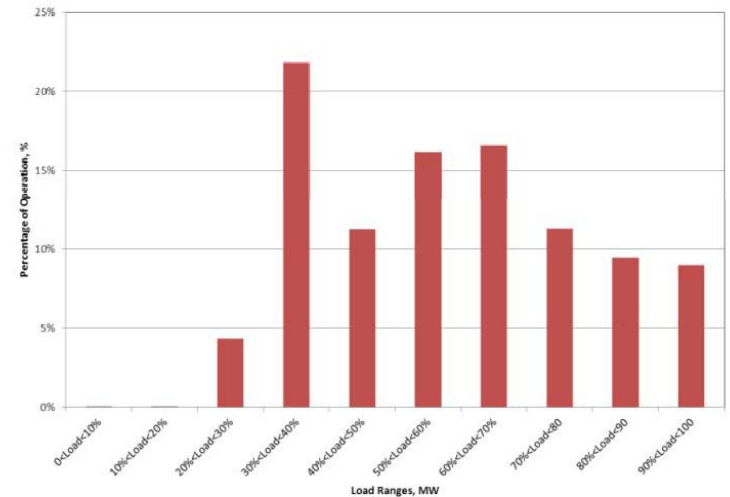
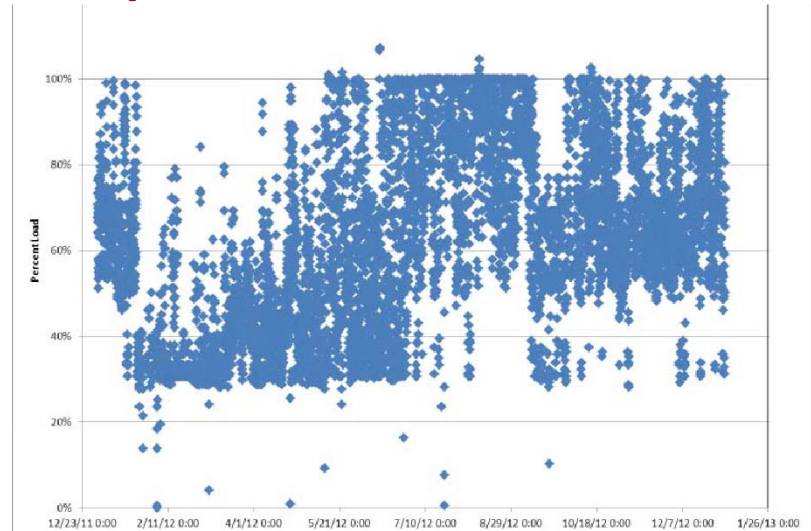
- Operational Considerations
- Base Loaded Units Being Run at Lower Load
  - Natural Gas Pricing & Renewables





# New (and Renewed) Issues

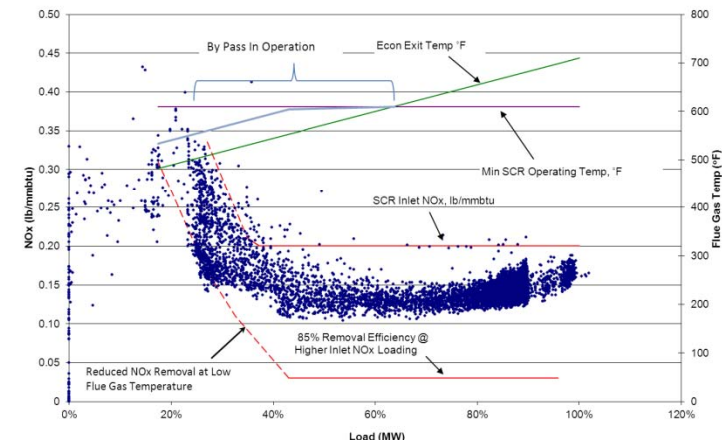
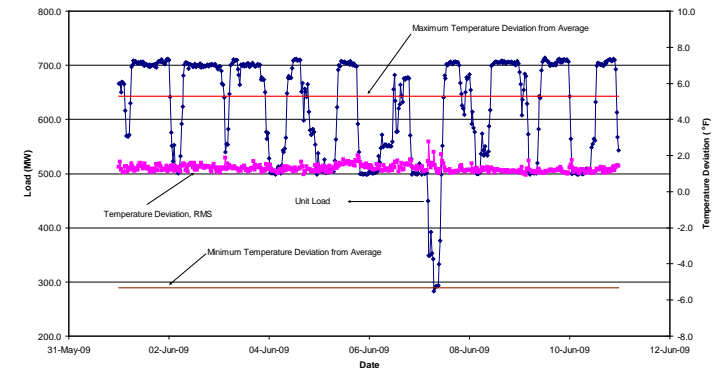
- Short-Term to intermediate-term SCR layup
  - Boiler shutdown
  - SCR bypass (tonnage vs. rate)
- Reagent
  - Renewed Interest in Aqueous and Anhydrous Ammonia





# Options for Low Load and Start UP NOx Control

- Oversize SCR/Catalyst for Increased NOx Removal
- Flue Temperature Control
  - Flue Gas Bypass, Water Side Bypass, etc. → Impact on Heat Rate
- Reduced Temperature Variation
- Reduced NOx Removal at Lower Load
  - ABS Formation Temperature = Function ( $H_2O$ ,  $SO_3$ ,  $NH_3$ )
  - Lower Ammonia Concentrations Reduces Minimum Operating Temperature





# Options for Low Load and Start UP NO<sub>x</sub> Control

- Transient SCR Operation – Temporary Operating Below ABS Formation Temperature
- Additional Combustion Control For When SCR is Not in Operation
- Extended Range For Gas Firing
- Reduction in Number of Start Ups



# Brief NO<sub>x</sub> Reduction Technology Comparison

<b>Technology</b>	<b>LNB/OFA</b>	<b>SNCR</b>	<b>SCR</b>
Reduction, %	30-60	20-50	90+
Advantages	<ul style="list-style-type: none"><li>• Cost</li><li>• simplicity</li></ul>	<ul style="list-style-type: none"><li>• Cost</li></ul>	<ul style="list-style-type: none"><li>• Reduction and emissions</li><li>• Pot. Hg co-benefits</li></ul>
Disadvantages	<ul style="list-style-type: none"><li>• LOI</li><li>• corrosion</li><li>• limited reduction</li></ul>	<ul style="list-style-type: none"><li>• Limited reduction</li><li>• Risk of NH<sub>3</sub> slip</li><li>• poor reagent util.</li></ul>	<ul style="list-style-type: none"><li>• Cost</li><li>• SO<sub>3</sub> conversion</li><li>• pressure loss</li></ul>

**Note: Technologies can be used in combination**



# Unit Design Basis

- 500 MW
- 9,500 Btu/Kwh
- Flue Gas Temperature at MCR – 670 °F
- Ammonia Slip – 2 ppm
- Arrangement – High Dust SCR, ESP/Baghouse, WFGD

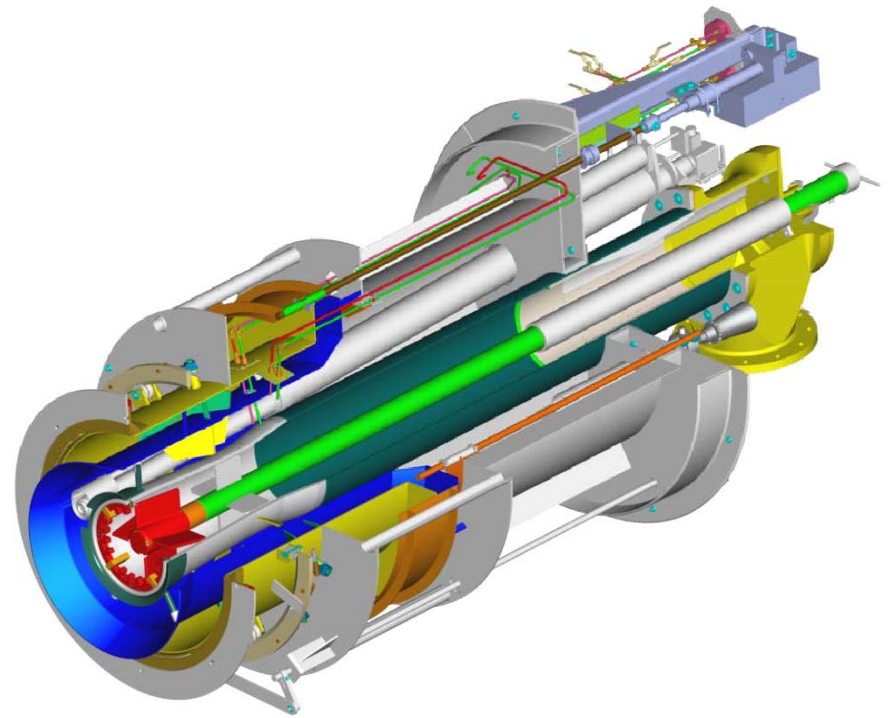
## Uncontrolled NOx (lbs/Mmbtu)

Fuel	Wall Fired	Tangential Fired
PRB	0.42	0.35
Western Bituminous	0.63	0.48



# Combustion Modifications

- Reduced Catalyst & potential reactor cost
  - Incremental Cost of Increased NOx Reduction on SCR
- Proven Technology
- Reduced Reagent Cost
- Reduced Catalyst Cost
- NOx removal at Low Load/Start Up
- Combustion Control Impact on Catalyst Life



**VS III<sup>®</sup> (Venturi Series)**



## Typical Low NOx Burner and Over fired Air Results

Coal Type	Wall Fired		Tangential Fired	
	Lbs./Mmbtu	%	Lbs./Mmbtu	%
PRB	0.22	47.6%	0.17	51.4%
Western Bituminous	0.32	49.2%	0.23	52.1%



## Catalyst Design Basis

- Fuel – PRB or Western Bituminous
- Initial Catalyst Life – 24,000 hours
- Initial Catalyst SO<sub>2</sub> Conversion Rate
  - 1% PRB
  - ½% Western Bituminous
- Catalyst Pitch = 8 mm (optional 7 mm)
- Inlet NO<sub>x</sub> & Removal Efficiency → variable based on LNB/OFA Configuration with Outlet NO<sub>x</sub> = 0.05 lb/mmbtu
- Distributions
  - NH<sub>3</sub>:NO<sub>x</sub> 5% RMS
  - Temperature +/- 20 °F
  - Velocity 15% RMS



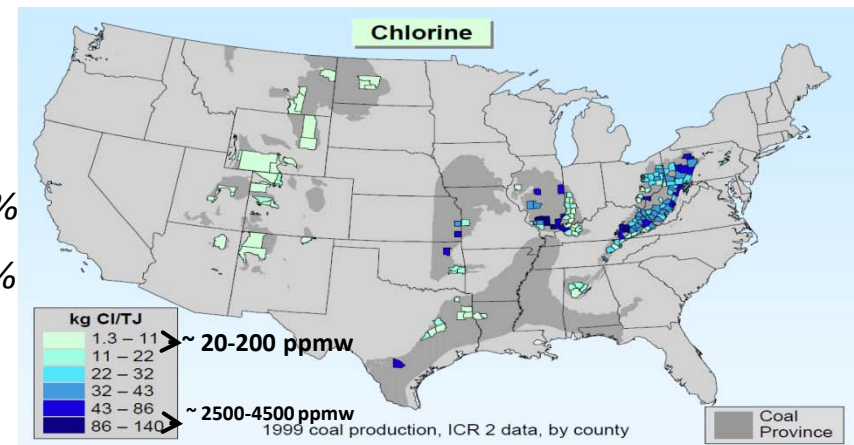
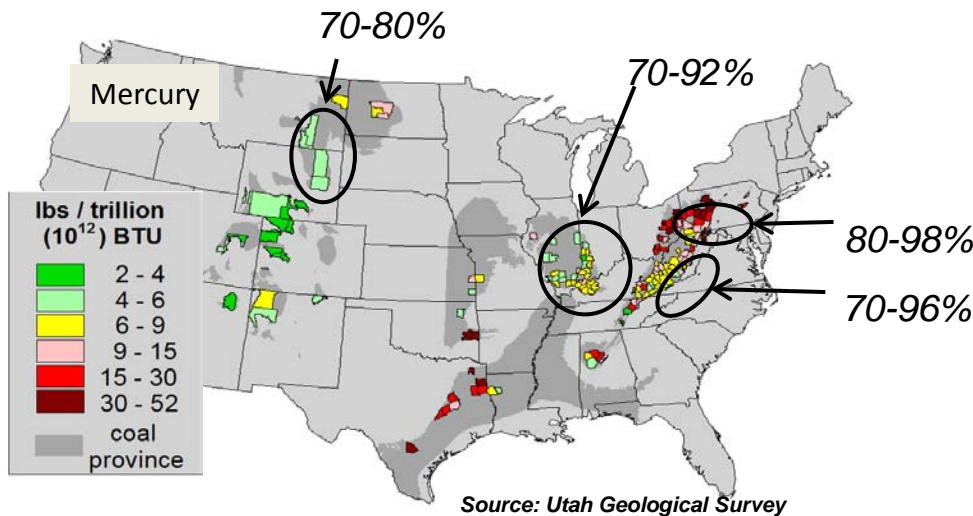
## Economic Evaluation Basis

- Electric Cost - \$0.05/Kw-hr
- Plant Life – 15 years
- Plant Load Factor – 90%
- Discount Value – 8%
- Ammonia Cost \$500/Ton
- Catalyst Cost \$5,500/m<sup>3</sup>
- Burner with Over Fired Air Cost \$12,000/MW
- Impact to PAC, halogens or other additive cost (not included)



# Hg Oxidation Considerations

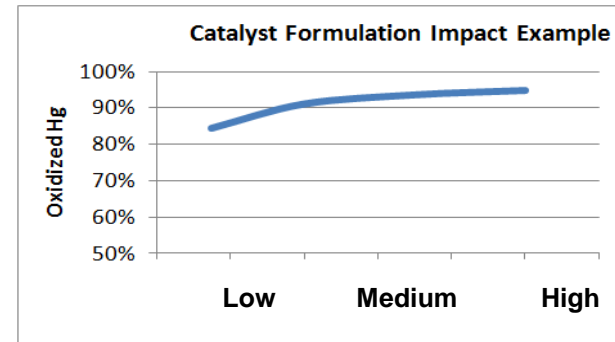
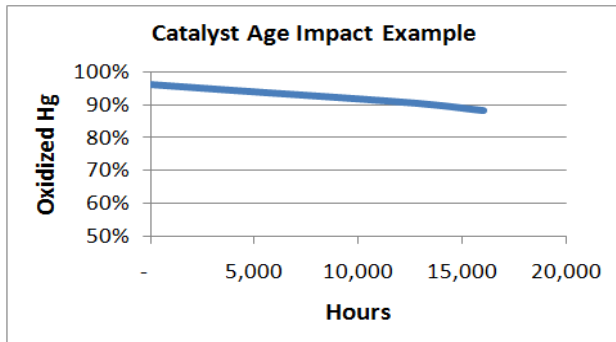
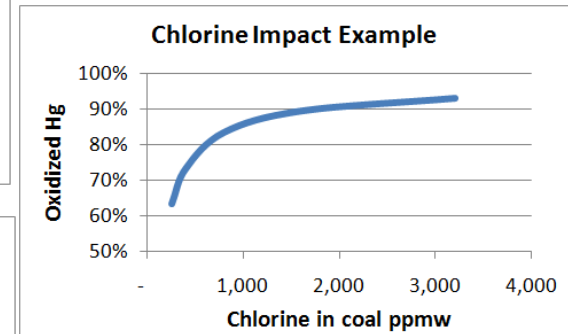
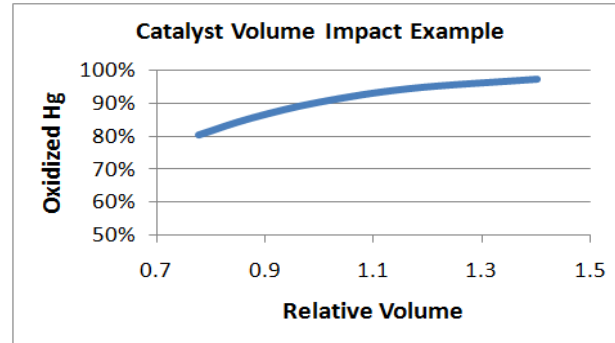
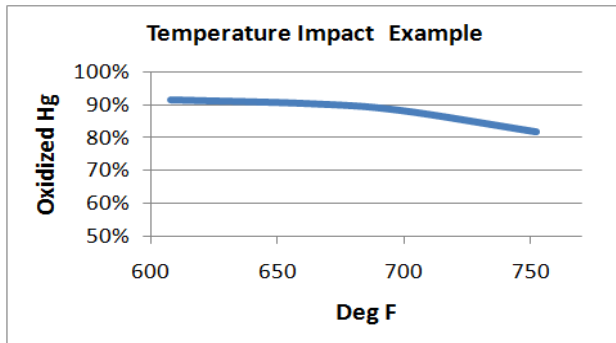
- Performance goals
  - 40% to 80+% Hg removal (not SCR Oxidation)
  - Considering APH, PM device, FGD influences translates to an SCR oxidation requirement of 20-80%





# Hg Oxidation Considerations

- Influences on performance



Others:  $H_2O$ ,  $O_2$ ,  $CO$ ,  $HC$ 's,  $NO_x$ ,  $NH_3$   
(All values at SCR outlet)

(Note: Specific example cases shown above to illustrate tendencies.)



# SCR Design With and Without LNB and OFA

- Firing Powder River Basin
- SO<sub>2</sub> Conversion Rate = 1%

Coal Type	Wall Fired		Tangential Fired	
	Without LNB-OFA	With LNB-OFA	Without LNB-OFA	With LNB-OFA
Required SCR NOx Reduction	88.1%	77.3%	85.7%	70.6%
Ammonia Flow, lbs/hr	690	320	560	227
Catalyst Volume, %	100%	129%	92%	108%
Flue Gas Pressure Drop, iwg	1.3	1.6	1.2	1.4

*Complexity of Hg oxidation performance threshold must be evaluated on a case specific basis → lower NH<sub>3</sub> assists however potential for higher deactivation may offsets.*



# Savings With and Without LNB and OFA

## Wall Fired Firing PRB Fuel

Case	SCR Only	LNB & OFA	Difference
Power NPV	\$1,450,000	\$1,780,000	\$330,000
Ammonia NPV	\$12,000,000	\$5,600,000	(\$6,400,000)
Cost of LNB & OFA	N/A	\$6,000,000	\$6,000,000
Catalyst			\$3,200,000
Total			\$3,130,000

*Additional cost assessment criteria for Hg oxidation may include one or all of the following; alternate catalyst, halogen addition, PAC.*



# Savings With and Without LNB and OFA

## Tangential Fired Firing PRB Fuel

Case	SCR Only	LNB & OFA	Difference
Power NPV	\$1,300,000	\$1,560,000	\$260,000
Ammonia NPV	\$9,450,000	\$3,800,000	(\$5,650,000)
Cost of LNB & OFA	N/A	\$6,000,000	\$6,000,000
Catalyst			\$2,500,000
Totals			\$3,110,000

*Additional cost assessment criteria for Hg oxidation may include one or all of the following; alternate catalyst, halogen addition, PAC.*



# SCR Design With and Without LNB and OFA

- Firing Western Bituminous
- SO<sub>2</sub> Conversion Rate = ½ %
- 10 X 15 Catalyst Arrangement, 3 initial Layers

Coal Type	Wall Fired		Tangential Fired	
	Without LNB-OFA	With LNB-OFA	Without LNB-OFA	With LNB-OFA
Required SCR NOx Reduction	92.1%	84.4%	89.6%	78.3%
Ammonia Flow, lbs/hr	1080	504	800	338
Relative Catalyst Volume, %	100%	98%	79%	78%
Flue Gas Pressure Drop, iwg	1.8	1.7	1.5	1.4

*Complexity of Hg oxidation performance threshold must be evaluated on a case specific basis → lower NH<sub>3</sub> assists however potential for higher deactivation may offsets.*



# Savings With and Without LNB and OFA

## Wall Fired Firing Western Bituminous Fuel

Case	SCR Only	LNB & OFA	Difference
Power NPV	\$1,560,000	\$1,470,000	(\$90,000)
Ammonia NPV	\$18,200,000	\$8,500,000	(\$9,700,000)
Cost of LNB & OFA	N/A	\$6,000,000	\$6,000,000
Catalyst			\$800,000
Totals			(\$2,990,000)

*Additional cost assessment criteria for Hg oxidation may include one or all of the following; alternate catalyst, halogen addition, PAC.*



## Savings With and Without LNB and OFA

### Tangential Fired Firing Western Bituminous Fuel

Case	SCR Only	LNB & OFA	Difference
Power NPV	\$1,200,000	\$1,200,000	(\$100,000)
Ammonia NPV	\$13,500,000	\$5,700,000	(\$7,800,000)
Cost of LNB & OFA	N/A	\$6,000,000	\$6,000,000
Catalyst			\$650,000
Totals			(\$1,250,000)

*Additional cost assessment criteria for Hg oxidation may include one or all of the following; alternate catalyst, halogen addition, PAC.*



## Conclusions/Recommendations

- Each unit will be case specific
- For Western Bituminous fuels, the installation of LNB/OFA will assist in the overall compliance cost
- However for PRB fuels, the installation of LNB/OFA may not assist in compliance cost if higher catalyst deactivation rates are not mitigated
- Optimization of staging level should be explored:
  - Reduce catalyst deactivation and related volume
  - Balance against increased ammonia/reagent cost
  - Consider impact on Hg oxidation potential
  - Consider impacts of additives (Halogen, poison mitigation, PAC) through cost/benefit analysis

