Presentation to McIlvaine Hot Topics Hour

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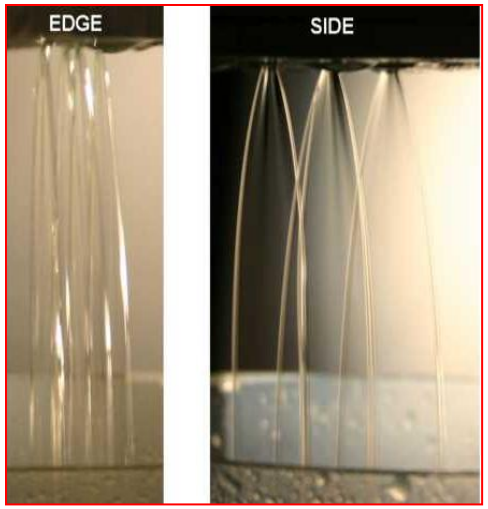
Jake Kershman, Manager, Business Development
November 8, 2012

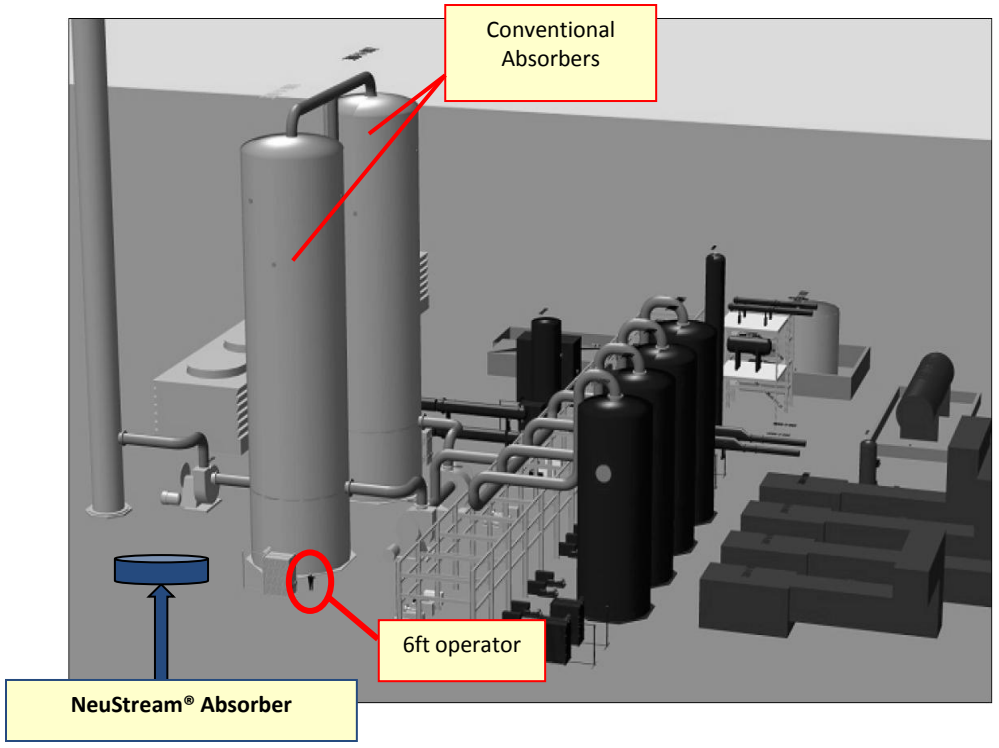
NeuStream® SO_2 Capture & Processing Systems

Flat jet technology: the original vision (2008)



Disruptive Technology

Systems Engineering



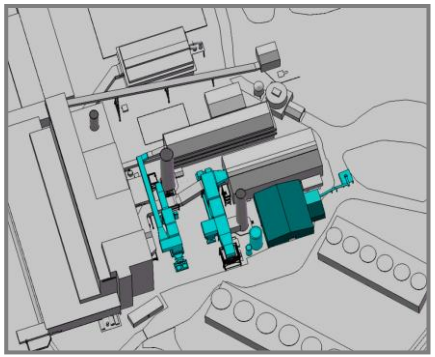
- 1/10th absorber volume
- Low Water Use
- Low Parasitic Power

- Modular Design
- >50% savings on CapEx
- >40% savings on OpEx

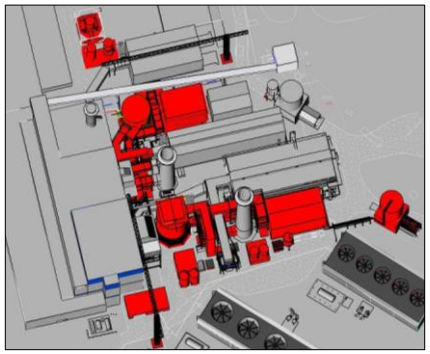
The *NeuStream*® Advantage

NeuStream® Enables Significantly Lower Cost of Ownership

Desulfurization System Comparison



NeuStream®-S



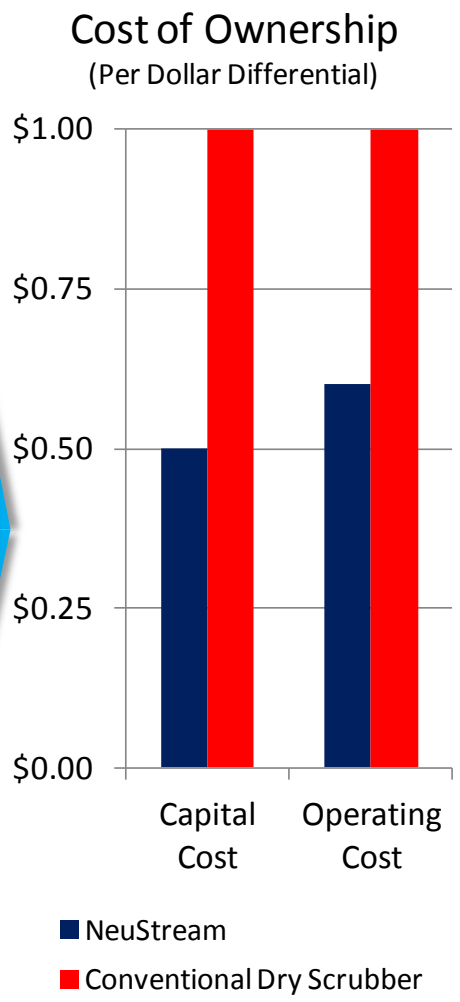
Conventional Dry Scrubber

Modular
- Reduce order to commission time
- Maximize plant availability

Compact
- Consume less plant real estate
- Minimize plant reconfiguration

Efficient
- Lower parasitic power
- Much lower water usage

Adaptable
- Site-specific conditions
- Variety of saleable by-products



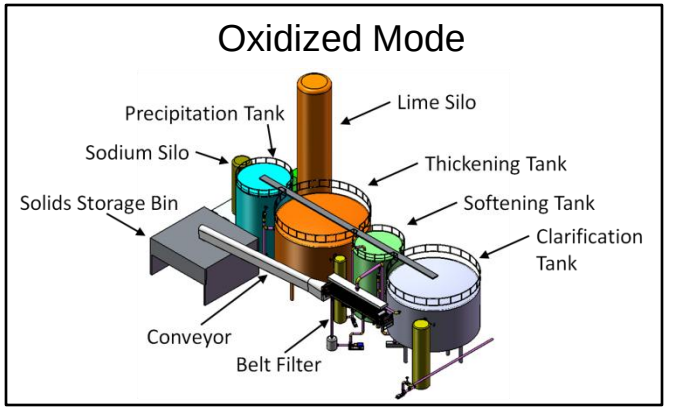
Mature, reliable SO_2 control in production today

- Demonstrated 97%+ capture low- & high-S coal
- High reliability, proven technologies
- Low parasitic power
- Low water consumption
- Robust ability to handle high S excursions
- EPRI-validated on operational power plant

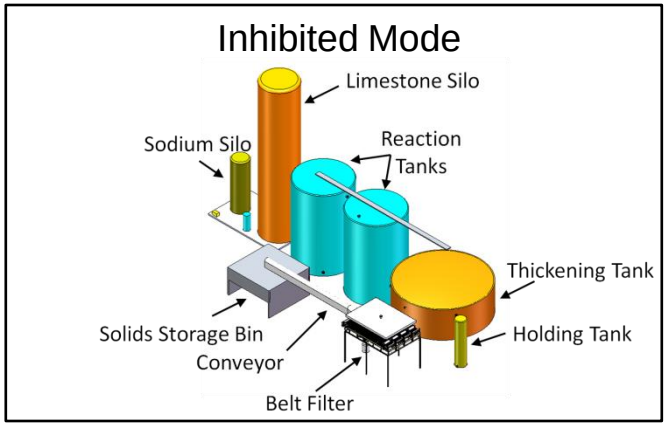
Dual Alkali Process Characteristics

Proven, Highly Reliable Design

- Well-defined, reliable process
- Commercial use since 1980 *(AB Brown)*
- Sodium-based absorbent fluid
  - Clear, low calcium (reduced fouling)
  - Regenerable (zero liquid discharge)
- Low-cost calcium reagent used for precipitation (lime, limestone)
  - Relatively inexpensive compared to sodium
  - Benign solid product, gypsum – landfill
- 2 modes of operation
  - Oxidized (dilute): low-sulfur coal
  - Inhibited (concentrated): high-sulfur coal
- Many NSG improvements via disciplined systems engineering approach

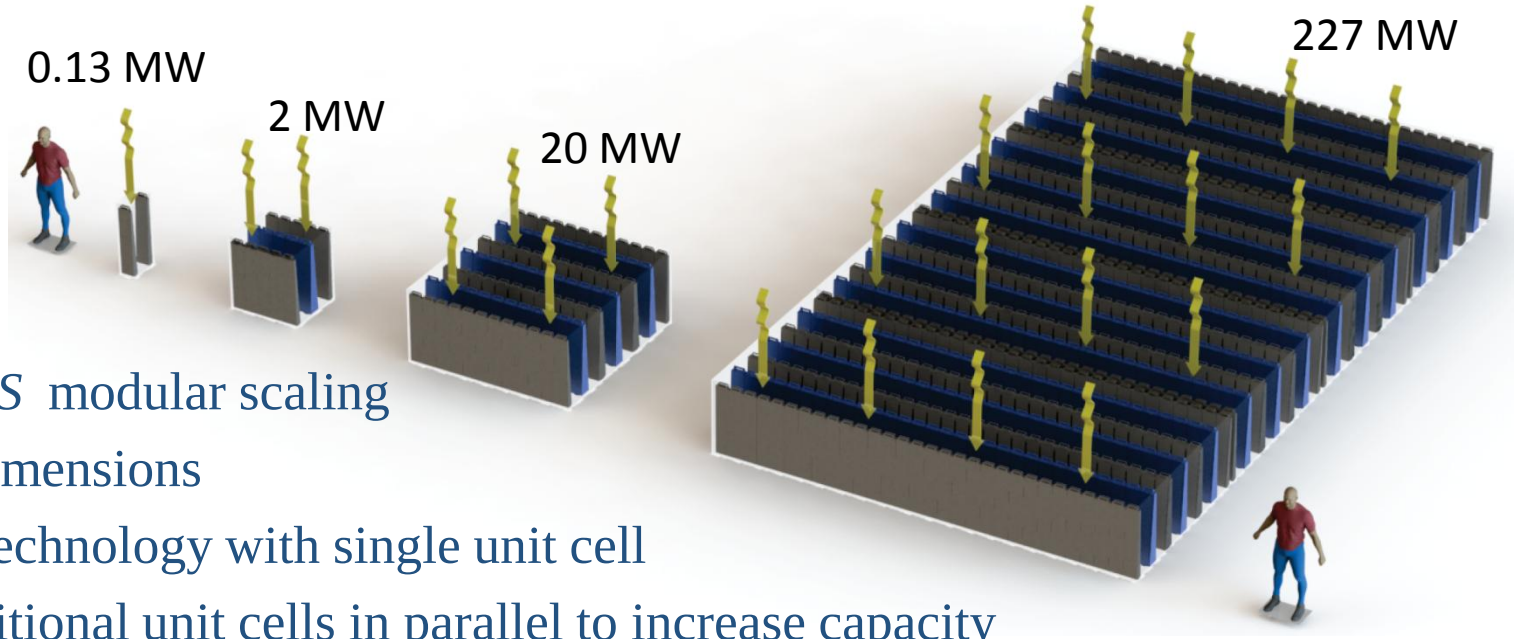


Low Sulfur coals (<1% S)

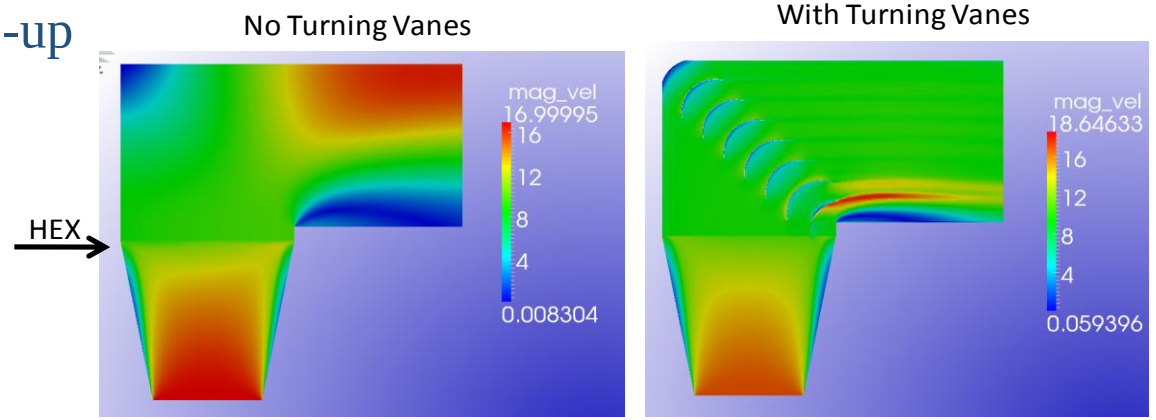


High Sulfur coals (>1% S)

Scaling with *NeuStream®-S*



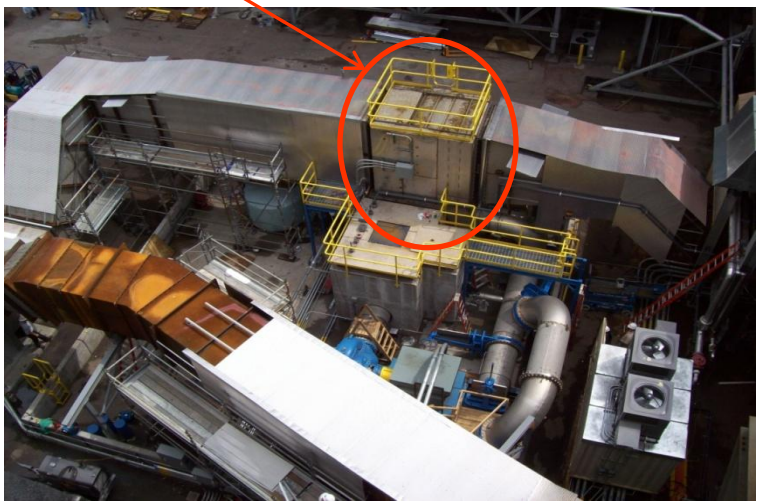
- *NeuStream®-S* modular scaling
- Scales in 2 dimensions
  - Proven technology with single unit cell
  - Add additional unit cells in parallel to increase capacity
  - No efficiency loss on scale-up
- Uniform flue gas distribution
  - Rigorous CFD analysis
  - State of the art computational capability



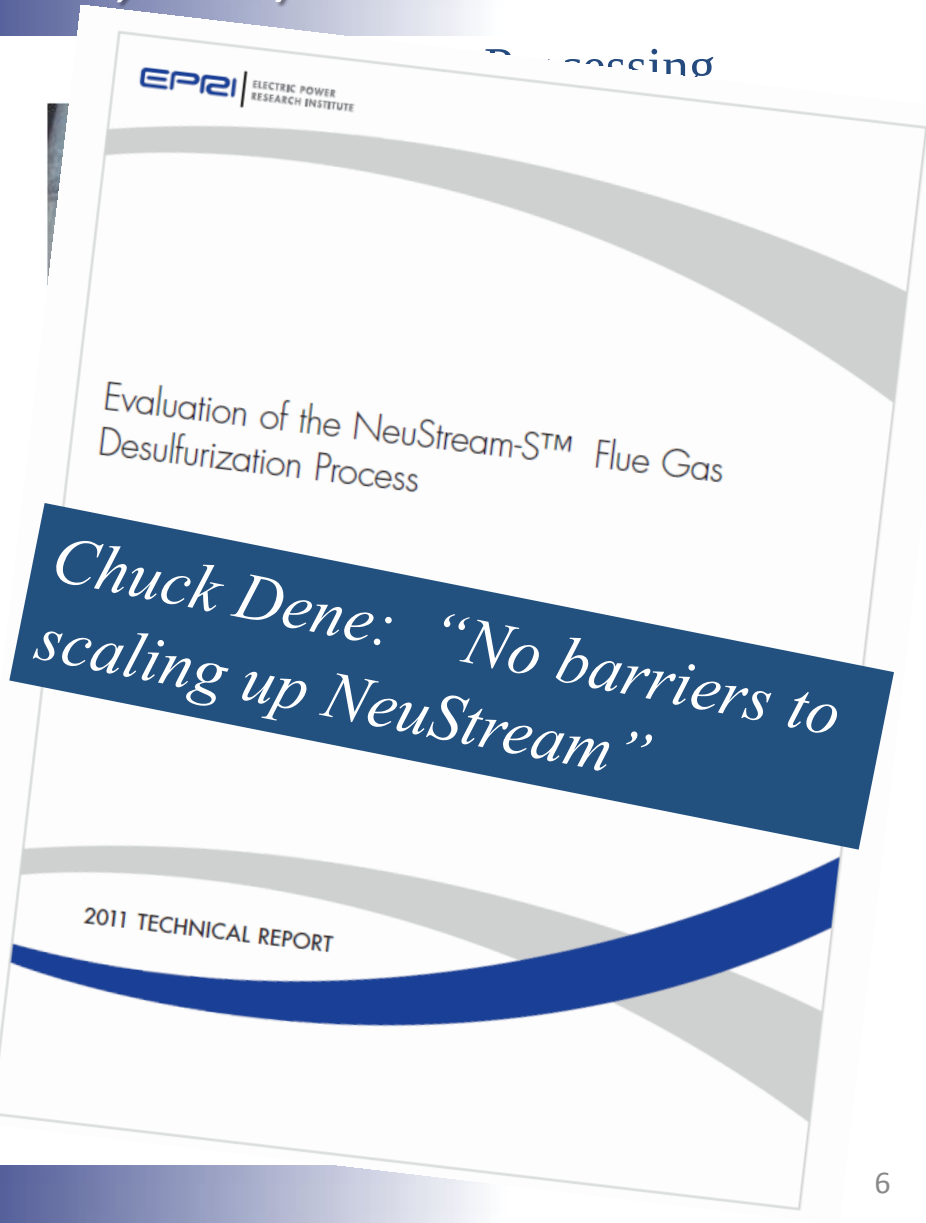
20 MW *NeuStream®-S*

Advanced wet FGD Pilot - Martin Drake 7, 2009/2010

20 MW NSG Scrubber



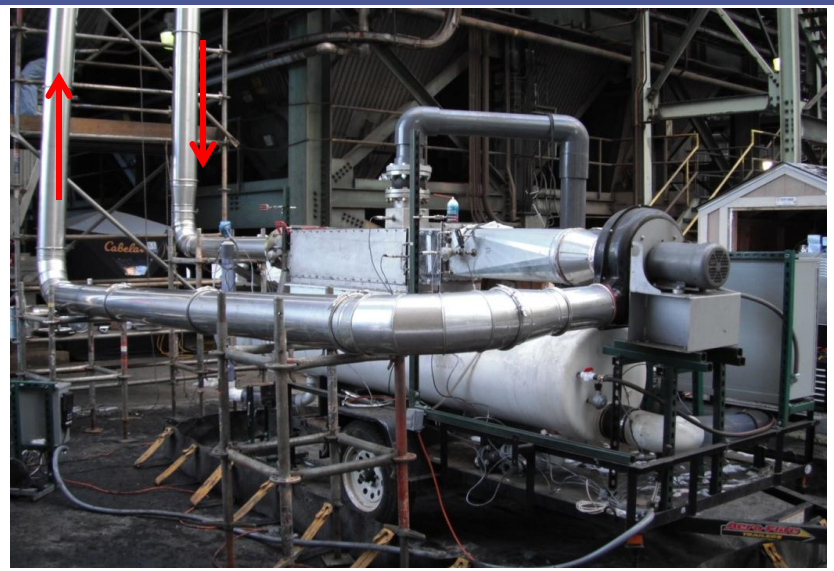
- Follows rigorous 0.13 and 2 MW pilot tests Dual alkali, 20 MW *NeuStream®* Pilot
- ~5,200 hours Scrubber Continuous Ops
- ~3,300 hours System Operations
- SO_X removal = 88% - 96% (pH = 6.5 -7.5)
- Solid Gypsum By-product
- **EPRI 3rd party validation of test results**
- **CO SIP revised based on pilot data**



Chuck Dene: "No barriers to scaling up NeuStream"

NeuStream®-S Flexibility

Demonstration on higher Sulfur coal, eastern utility



- Objective: Demonstrate SOx, HCl and Hg removal for both modes of operation:
  - Oxidized (sulfate)
  - Inhibited (sulfite)
- Coal: 100% central Pennsylvania eastern bituminous, moderate sulfur level
- Flue gas (Jan 2011 average CEMS data):
  - 10.3 % CO_2
  - ~1,100 ppm SO_2

- Sulfate (oxidized) results:
  - 94 to 96% SO_2 removal
  - 96 to 97% HCl removal
  - 90% Hg^{2+} (64% total) Hg removal
- Sulfite (inhibited) results:
  - 96% SO_2 removal
  - 98% HCl removal
  - 90% Hg^{2+} (78% total) Hg removal

Performance Comparison:
– *Lime Spray Dryer vs. NeuStream®-S*

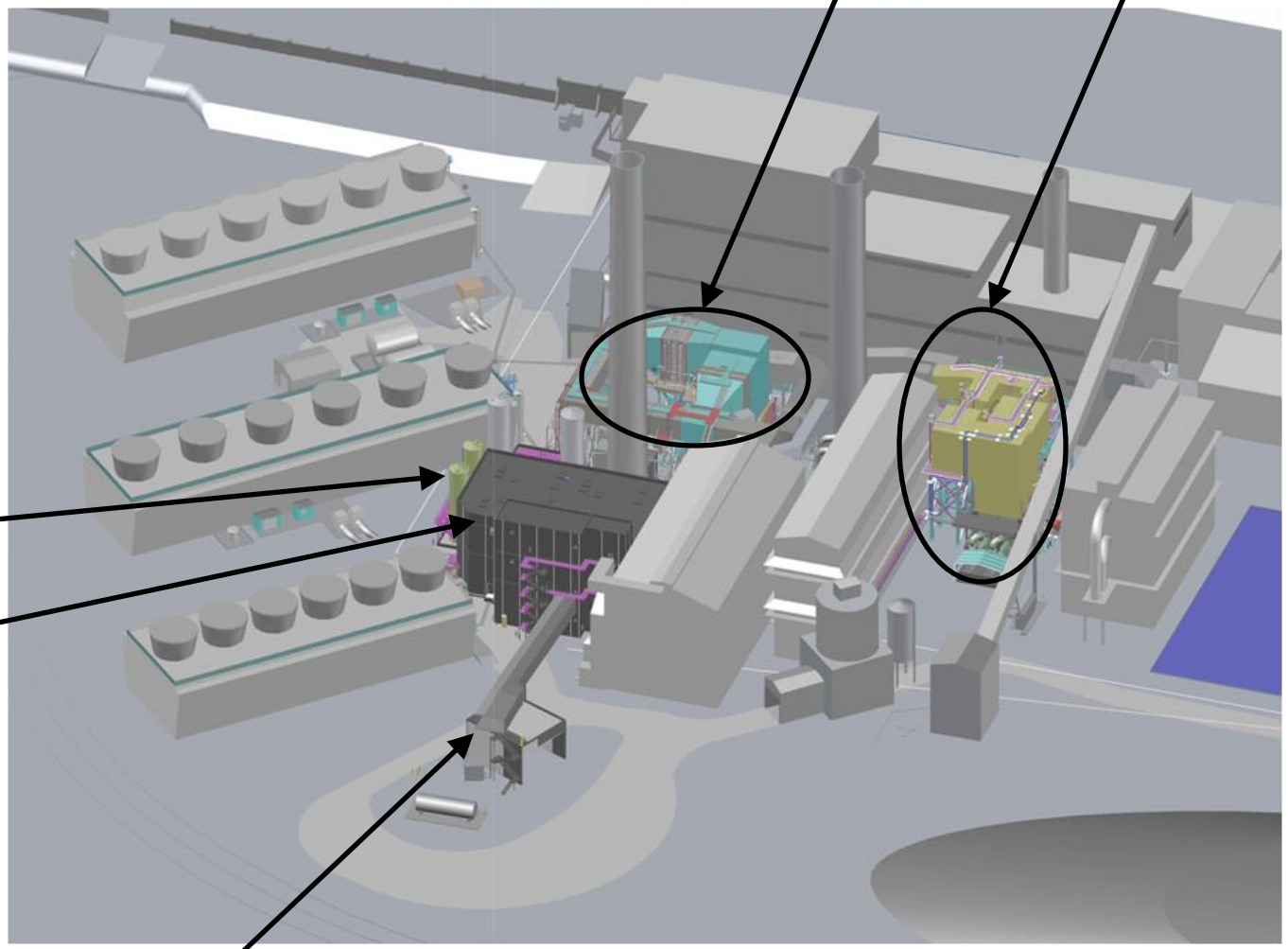
NeuStream®-S	Lime Spray Dryer*
>97% SO_2 Removal	90% SO_2 Removal
>90% Removal of Hg^{2+} post-particle capture (no impairment)	Impairs removal of Hg by removing halogens upstream
Parasitic Power: 1x	Parasitic Power: 2x
Water Usage: 1x	Water Usage: 2x
Lime Stoichiometry: 1.05 to 1.20 Ca:S + 30% excess due to softening = 1.35-1.5 (mol/mol)	Lime Stoichiometry: 1.2 – 1.5 Ca:S (mol/mol)
Trona/SO_2 captured: 0.12 : 1 (97% capture) Tons/Ton basis	No Trona requirement
Active heat management (i.e. HEX system)	No active heat management (i.e. HEX system)
Saleable By-Products: Fly Ash, Gypsum, $CaCO_3$, Fertilizer	Saleable By-Products: None
1% increase in plume visibility	2% increase in plume visibility

*Data obtained from Stanley Consultants' dry scrubber reports for CSU and Stanley Consultants' plume analysis report for NSG

Drake 6 and 7 Commercial System:

General Arrangement

Drake 6 and 7 Commercial System:
– *General Arrangement*



Planned Commissioning: Q4, 2014

Drake 6 and 7 Commercial System:

Renderings

- Commissioning 2014
- 227 MW Drake 6/7

- < half the footprint of wet FGD technology
- >97% SO_2 Capture
- Lowest annualized cost

Performance Comparison:
– *Conventional Wet FGD vs. NeuStream®-S*

NeuStream®-S	Conventional Wet FGD
1x volume	10x volume
Low corrosion/erosion clear Na sorbent liquid	High corrosion/erosion Ca slurry
High reliability/easy servicing	Low reliability/difficult servicing
0.97% to 1.2% Parasitic Power (test data)	2 to 3% Parasitic Power
Water Usage: (0.5 gpm/MW)	4x Water Usage: (2 gpm/MW)
Modular design/off-site fabrication	Large scale units/on-site fabrication
V_{gas} = 12 to 15 m/s	V_{gas} = 1 to 3 m/s
Active heat management (i.e. HEX system)	No active heat management (i.e. HEX system)
Low life cycle costs (low CapEx, low OpEx)	High life cycle costs (high CapEx, mod. OpEx)
1% increase in plume visibility	2% increase in plume visibility

The *NeuStream®-S* Advantage: smaller, more efficient, as effective, cheaper

Performance Comparison:

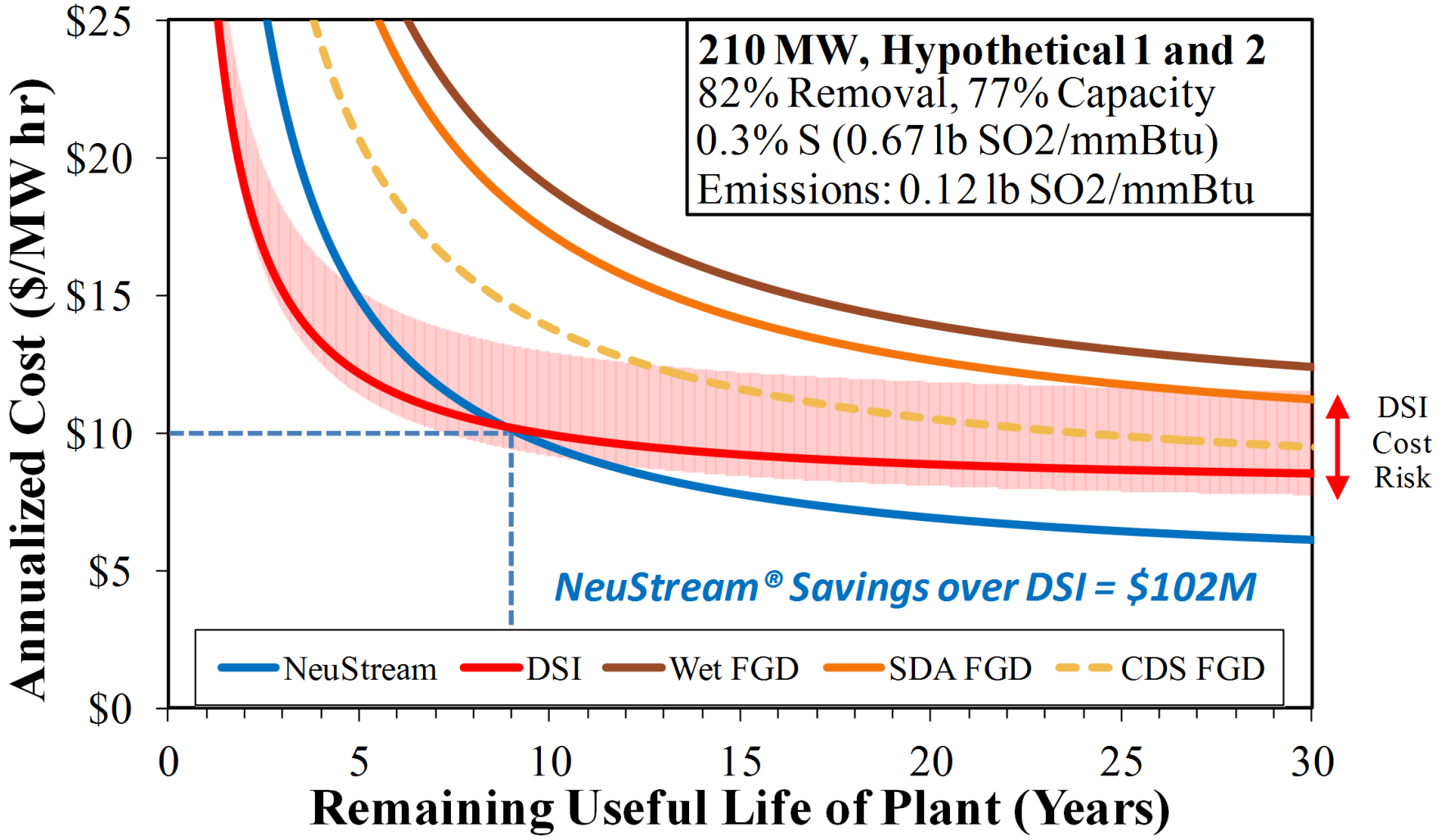
NeuStream®-S vs. Dry Sorbent Injection (trona)

NeuStream®-S	DSI*
>97% SO_2 Removal	80 to 90% SO_2 Removal
>90% Removal of Hg^{2+} post-particle capture (no impairment)	Impairs removal of Hg by removing halogens upstream; requires addition ACI
High reliability; clear Na liquor in scrubber	Poor reliability due to trona caking, scaling, pluggage
Water Usage: ~0.5 gpm/MW	Water Usage: nil
Robust ability to handle high SO_2 levels and excursions	Limited ability to handle SO_2 excursions
Trona/SO_2 captured: 0.12 : 1 (97% capture) Tons/Ton basis	Trona/SO_2 captured: 5:1 (80% capture) 8:1 (90% capture) Tons/Ton basis
Lime/SO_2 captured: 1.3 : 1 (97% capture) Tons/Ton basis	No lime usage
Saleable By-Products: Gypsum, Calcium Carbonate, Fertilizer	Saleable By-Products: None Fly ash non-salable (Na, C)
Fly ash disposal: no negative effects	**Fly ash disposal: complicated by soluble Na in solid waste

*Data from SOLVAir and ADA-ES websites ** *Power Engineering*, June 2012

Desulfurization Cost Comparison

– Two boilers, 82% removal, 2011 dispatch rates



Desulfurization Cost Comparison

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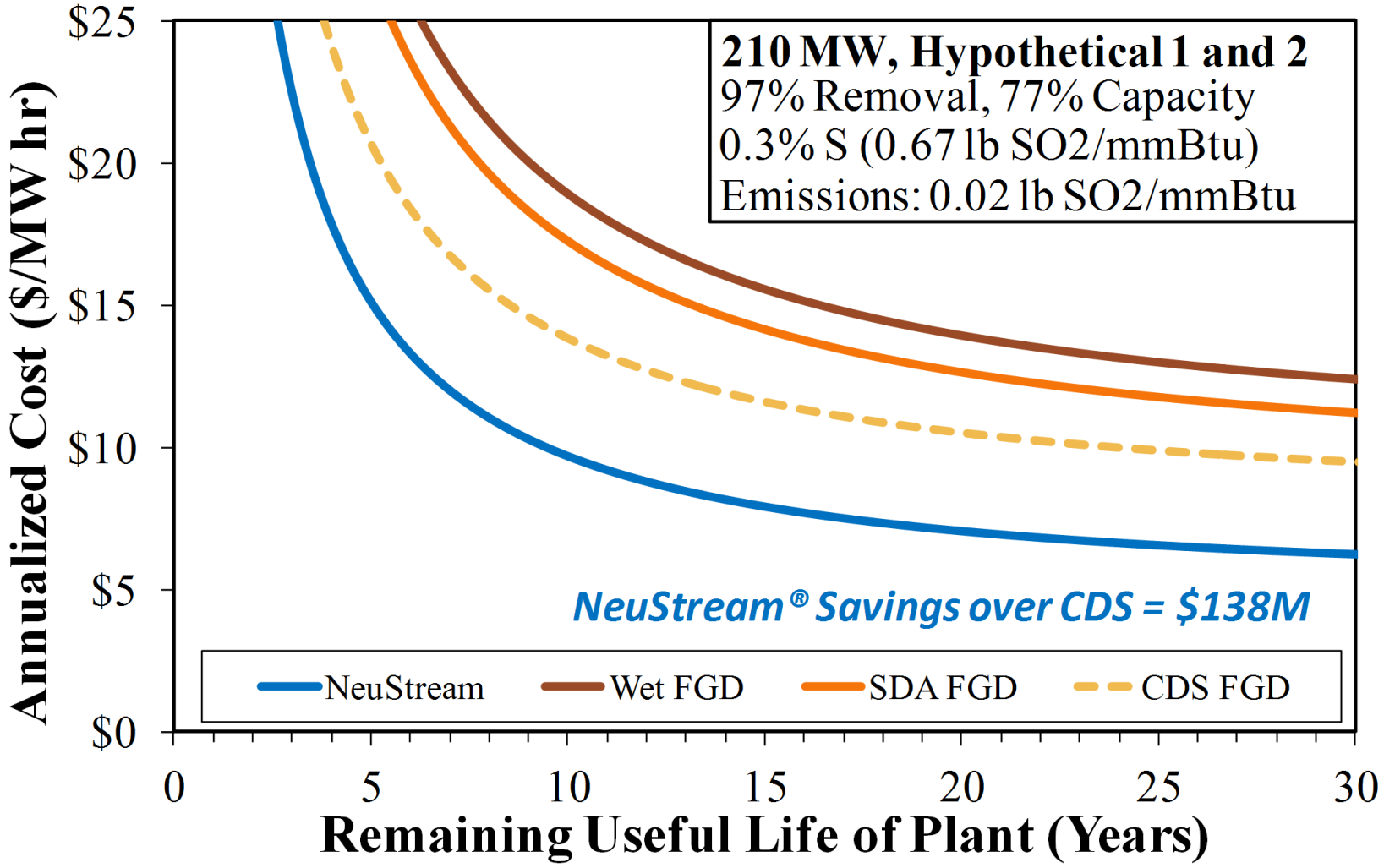
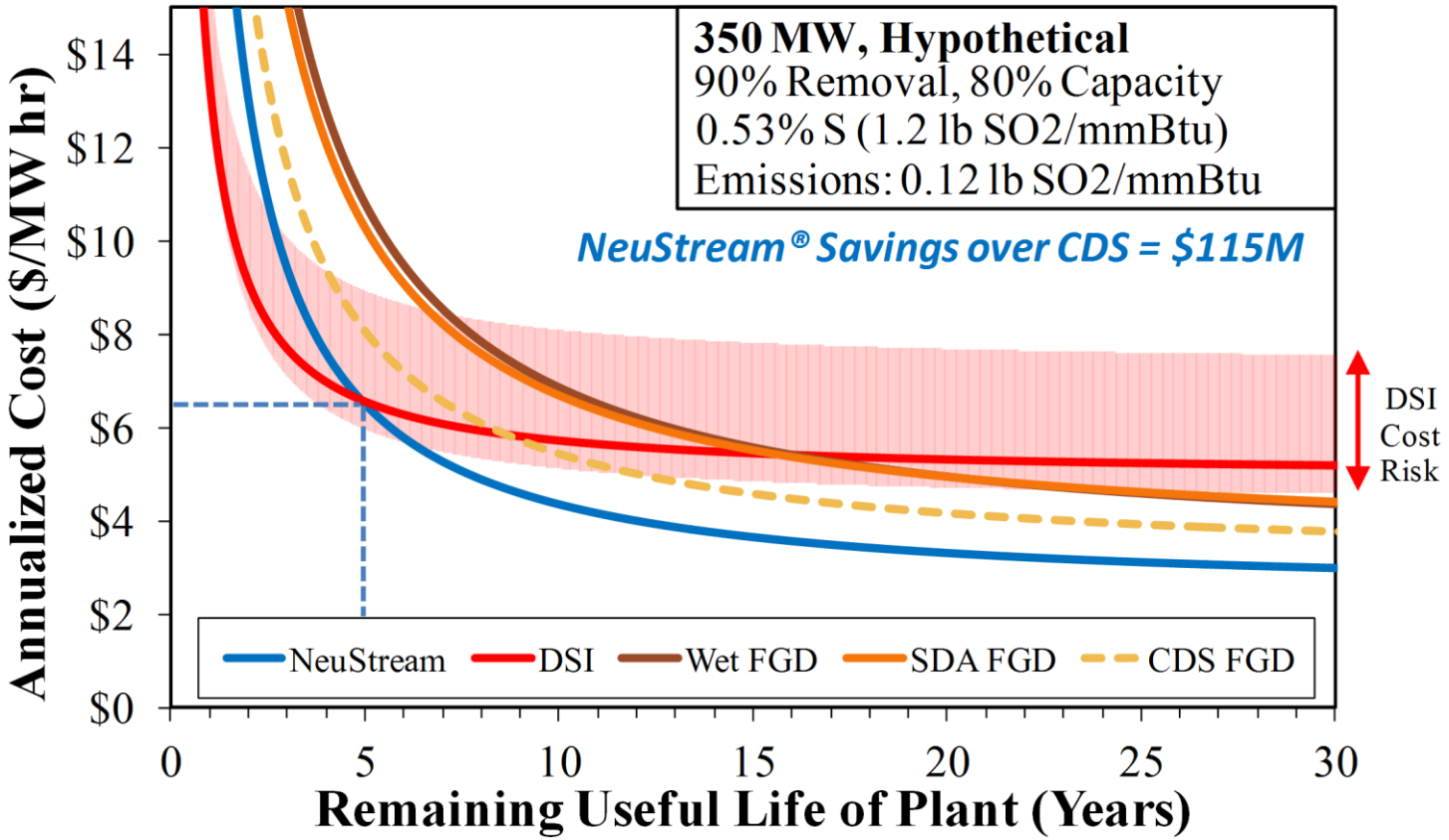


Desulfurization Cost Comparison

Low Sulfur (Western) Coal, 350 MW plant

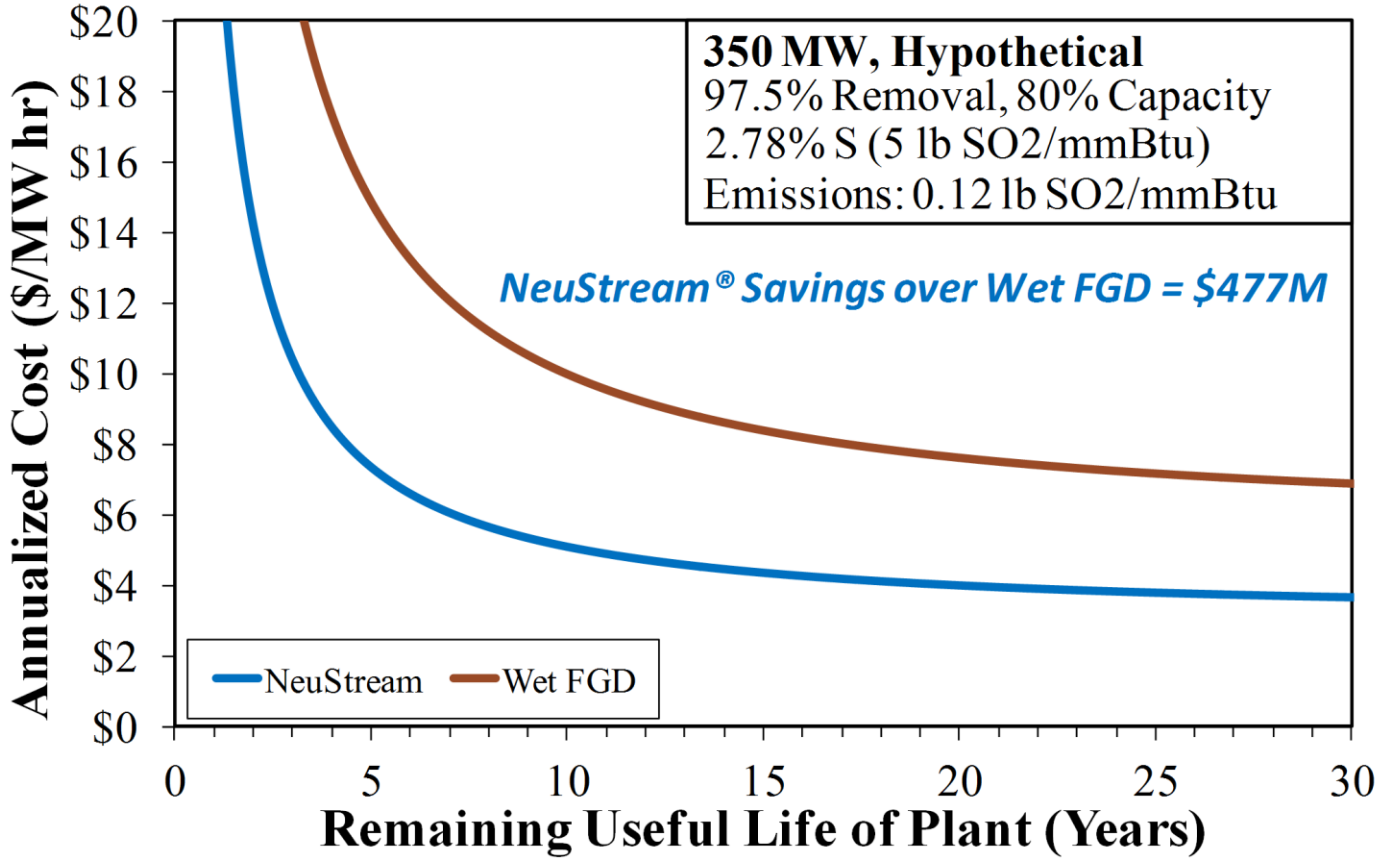
- *NeuStream®-S* is the high-performance, low cost option
- DSI (Low CapEx) suffers high OpEx, trona cost risk



Desulfurization Cost Comparison

High Sulfur (Eastern) Coal

- *NeuStream®-S* is the high-performance, low cost option
- Conventional wet FGD higher CapEx; DSI can't compete



Summary

- *NeuStream®-S*: mature, reliable SO_2 technology in production today
  - Demonstrated 97%+ capture from PRB and high-S coal
  - High reliability, proven technologies
  - Low parasitic power, low water consumption
  - Robust ability to handle high S excursions
  - EPRI-validated performance on operational power plant
- *NeuStream®-S* projected life cycle cost savings
  - $102 million over DSI (2 boilers, 210 MW, 82% capture, 0.67 lb SO_2/mmBTU)
  - $138 million over CDS (2 boilers, 210 MW, 97% capture, 0.67 lb SO_2/mmBTU)
  - $115 million over CDS (1 boiler, 350 MW, 90% capture, 1.2 lb SO_2/mmBTU)
  - $477 million over Wet FGD (1 boiler, 350 MW, 97.5% capture, 5.0 lb SO_2/mmBTU)

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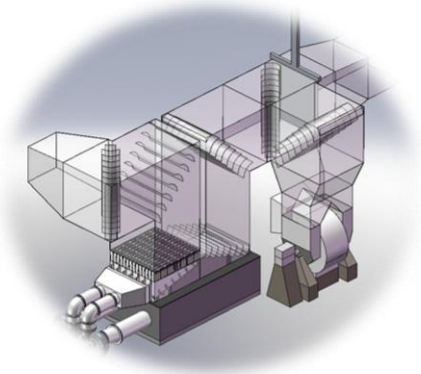
NeuStream® Systems:
Pollution-to-Products

Pollutants

- Sulfur Oxides (SO_X)
- Nitrogen Oxides (NO_X)
- Carbon Dioxide (CO_2)
- Particulates (PM)
- Heavy Metals, Organics

+

NeuStream®



SO_X

CO_2

NO_X

Pollutants captured and transformed into vital industrial products

*Potential revenue from pollutants from 550MW plant

Industrial Products

Sulfuric Acid
$27M/yr*

Gypsum
$0/yr*

Fertilizer
$50M/yr*

Enhanced Oil Recovery
$920M/yr*

Fertilizer
$1.3B/yr*

Rare Earth
Metals
$150M/yr*

Nitric Acid
$41M/yr*

Fertilizer
$41M/yr*

Backup Charts

Summary of Intellectual Property

NSG Gas-Liquid Contactor Patents- U.S.	Application/Patent No.
Two Phase Reactor	7,379,487
Two Phase Reactor, Continuation 1 (23 claims)	7,871,063
Two Phase Reactor, Continuation 2	12/956,876
Gas Liquid Contactor and Effluent Cleaning System and Method	7,866,638
Gas Liquid Contactor and Effluent Cleaning System and Method, Continuation 1	12/869,619
Gas Liquid Contactor and Effluent Cleaning System and Method, Continuation 2	8,105,419
Gas-Liquid Contactor Apparatus and Nozzle Plate	8,113,491
Apparatus and Method Thereof, Division 1	12/950,015
Apparatus and Method Thereof, Division 2	12/950,040
Apparatus and Method Thereof, Division 3	12/950,069
Method of Separating at Least Two Fluids with an Apparatus, Division 4	8,088,292
Indirect & Direct Method for Sequestering Contaminants	12/586,808
Gas Liquid Contactor and Method Thereof	12/586,806
Application for Processing Unit and Method, Provisional	61/473,651

Other NSG Patents- U.S.	Patent No.
Electric-Optical Singlet Sigma and Singlet Delta Oxygen Generator	6,570,903
System for Producing Singlet Delta Oxygen Laser	6,658,038
Optical Amplifier and Method	6,731,423
Halogen Doped Solid State Materials	6,635,557
System for Chemical and Biological Decontamination	6,797,242
System for Chemical and Biological Decontamination	7,217,935
Infrared Laser	7,286,574

Summary of Intellectual Property – Pending PCT Nationalized Countries:

Country	Gas Liquid Contactor and Effluent Cleaning System and Method	Array of Nozzles With Stable Flat Spray Patterns	Indirect and Direct Method of Sequestering Contaminates	Gas Liquid Contactor and Method Thereof
Australia	2009297005	2009296242	2009296245	2009296248
Canada	2,737,637	2,739,237	2,737,798	2,737,737
China	200980145932.2	200980145235.7	200980145931.8	200980145726.1
Europe	09816647.3	09817000.4	09817003.8	09817006.1
India	2569/CHENP/2011	2568/CHENP/2011	2575/CHENP/2011	2714/CHENP/2011
Japan	2011-529041	2011-529325	2011-529328	2011-529330
South Korea	10-2011-7009444	10-2011-7009443	10-2011-7009419	10-2011-7009420
Mexico	MX/a/2011/003098	MX/a/2011/003104	MX/a/2011/003106	MX/a/2011/003105
New Zealand	592100	592101	592098	592099