CEFCO GLOBAL CLEAN ENERGY, LLC

McIlvaine Hot Topic Hour

PRODUCTION OF FERTILIZERS AND ACIDS AS BY-PRODUCTS AT COAL FIRED POWER PLANTS

Robert E. Tang, CEO and Co-Inventor

January 17, 2013

CEFCO

CEFCO's Innovative Solution

CO_2 Capture + All-Pollutant Capture = Regulatory Compliance + Renewable & Sustainable Technology + Recovering CAPEX and OPEX

- Use Ewan's shockwave "free-jet collision scrubbing" (recognized by EPA/DOE as HWC MACT in US Regs. 40 CFR §63.1209 et al.) to capture all pollutants

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- Cooper Process to convert all "captured pollutants" with Appropriate Reagents into recovered, segregated, valuable, and sellable End-Products

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- Accomplished using Supersonic Shockwave Reaction Mechanism under USPTO Patent issued on November 30, 2010 under: **US 7,842,264B2**

- **CEFCO Users:**
  - **1) Comply with all EPA's MACT, MATS, NSPS and NESHAPs Requirements**
  - **2) Benefit of selling End-Products ≈ no longer "cost-center" ↔ recover OPEX + CAPEX**
  - **3) New Economic Paradigm in the Power Co-generation World.**

Ewan Technology: EPA MACT Compliant

Date	Reference No.	Report Title	Emissions Targets	Description of Tests	Performance Conclusion
April 1, 1974	EPA-650/2-74-028 (Dale L. Harmon, EPA-NERC-RTP)	Steam-Hydro Air Cleaning System Evaluation	0.03 micron to 5.0 micron (EPA Method 5)	Steam-Hydro Patent invented by T.K. Ewan sold and assigned to Lone Star Steel (Div. of US Steel)	"90.0% at 0.01 micron . . . . 99.9% at 0.5 micron and 99.99% at 1.0 micron"
Oct. 1976	NCASI — Special RTP	Kraft Recovery of TRS Emissions	Total Reduced Sulfur, H_2S, CO_2	". . . near instantaneous . . . tremendous surface area for gas-liquid contact . . . 50 x 10^{-3} sec."	"TRS emissions were reduced to less than 2 ppm during total run", "quite successful . . . it is recommended to test for SO_2 removal also"
Sept. 1977	EPA- 600/2-77 -193 under Dennis C. Drehmel, EPA, Research Triangle Park	EPA/600/13 Code	Contract 68-02-2190: Particulates, H_2S, SO_2	"High performance with low energy requirement is achieved by the use of free-	" . . . well below the 0.0052 grains /SCF...effective removal of hydrophobic fumed silica having ...article diameter ...s. This material ...analysis of the ...rial shows the ...t wetted, but ...a film of water." ...apital cost and ...perating cost ...spray scrubbing ...ither ESP or FF ...ter collection"

Date	Reference No.	Report Title	Emissions Targets	Description of Tests	Performance Conclusion
July, 1986	EPA- 600/S2-86 -011 [this is a head-to-head test vs. equipment and technology provided by ETS, Inc. and Vulcan Engineering]	EPA Hazardous Waste Engineering Research Lab, Cincinnati, OH	APCD, PM, HCl, SO_2, SO_3	"supersonic tandem nozzle . . .", "most effective of the versions tested for control of submicron particulate matter"	Page 2: "uranium hexafluoride and its hydrolysis products with particulate removal efficiency consistently exceeding 99%"; Page 3: "chloride removal of 99% or better should be expected for any version of this unit [vs. both competitors]."
Sept. 1992	DOE PNL-8281	DE-AC06-76RlO 1830 by Battelle Memorial Institute	Hanford Radioactive Waste Incineration	Performance per Office of Solid Waste Emergency Response (OSWER) Directive 9335.3-01	" . . . cesium-137 was greater than 99.98%"; other metals, acids and organics "greater than 99.99%"
August 1993	DE-AC01-EW300-30				
1993	WSRC-TR-93-00623				
Feb. 1996	EPA Contract No. 68-D2-0164				

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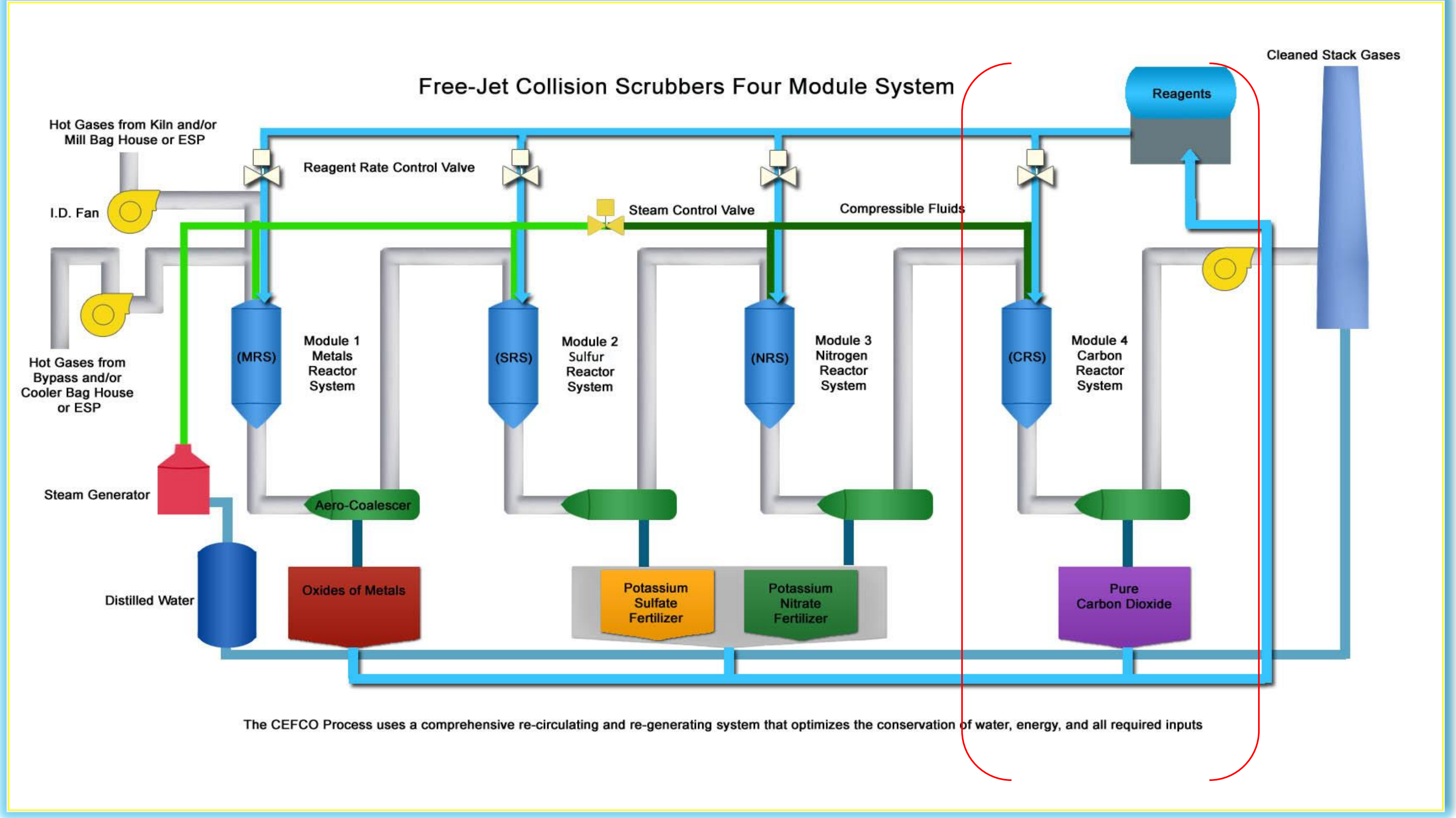
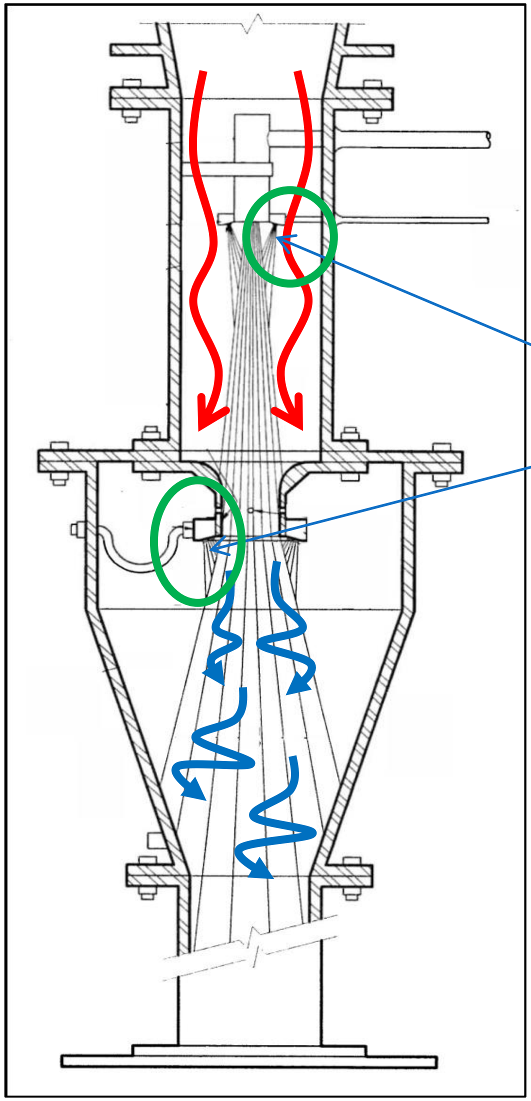
1997	**CERCLIS #**: MOD980685226 EPA Remedial Project Manager: Robert W. Field U.S. EPA Region 7 Kansas City, KS 66101	On-Site Incineration at the Times Beach Superfund Site (Times Beach, Missouri)	Dioxins, TCDD ("Agent Orange")	CEMS measures: O2, CO2, NOx, CO, and SO2. Acids, metals and minerals. Continuous recording.	MACT Compliance. "Resource Conservation and Recovery Act (RCRA): DRE of 99.9999% for TCDD. Stack gas monitoring was conducted for oxygen and carbon monoxide in accordance with 40 CFR Part 264, Subpart O."
July 1998	DOE/ID-10651, Rev.1	Hazardous and Radioactive Waste Treatment Technologies Handbook	PM, Hg, ROW (Radioactive Organic Waste), BRW (Blended Radioactive Waste)	Consolidated Incineration under SVM (Semi-Volatile Metals) + LVM (Low Volatile Metals) Standards	MACT Compliance, and Toxic Substances Control Act Incinerator (TSCAI)
May 22, 2002	40 CFR §63.1209 (m) and §63.1209 (o)	A Guide to Phase I MACT Compliance — May 22, 2002	PM, acids, HCl and Chlorine Gas		"hydrosonic, collision, or free-jet wet scrubber"
unspecified	DOD/DOE docs		controlled	At National Labs	Internal GOV official and formal EPA request

- EPA published its "Guide to Phase I MACT Compliance" for Hazardous Waste Combustors MACT — May 22, 2002
- Ewan's Technology was Federally recognized and codified in 40 CFR §63.1209 et al.

CEFCO — System Flow Diagram



CEFCO's Unique Reaction Mechanism



- All flue gas must pass downward through Shockwaves ➔ "no escape" from "free-jet collision" reaction mechanism
- Shockwave-generated molecular collision causes Energy Transfer in the immediate Endothermic Reaction
- Shockwave collision smashes fine Reagent droplets into micro-droplets
- Molecular Surface Chemistry between Target-Molecule with Reagent-Molecule within "split-second"
- Under Shockwave is very Adiabatic Condition catalyzing and driving the reaction completion and ending in Exothermic Reaction "locking in Product"
- Pollutants are captured using Physics first, then converted into valuable end-products using Chemistry

Profit from Valuable End-Product Sale

Sequenced modules selectively capture distinct and Valuable Products from Pollutants.

	CEFCO Module 1: Metals	CEFCO Module 2: SO_2	CEFCO Module 3: NO_X	CEFCO Module 4: CO_2
Final Products	Metal Compounds (Mercury & Trace Metals) Significantly below $PM_{10.0}$	Potassium Sulfate (Fertilizer)	Potassium Nitrate (Fertilizer)	Pure CO_2
Potential Revenue Streams	• Metals Market • Alloy-Steel Users • Industrial Market • Trace Metals for Hi-Tech Electronics Users • Catalysts and Additives for Refining & Petrochemical Sectors	• Fertilizers & Agricultural Applications • Industrial Market • Feedstock for Petrochemical Sector	• Fertilizers & Agricultural Applications • Industrial Market • Feedstock for Petrochemical Sector	• Enhanced Oil Recovery • Sequestration Market • Carbon Credit • Methanol, Ethanol & Diesel Fuels • Feedstock for Petrochemical Sector

Captured Toxic and Trace Metals from Coal Gases - Very Valuable

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MRS — Trace Metal Capture Mechanism

- Analysis of Coal-Fired and Pet-Coke Emissions show ~40 different kinds of metals and minerals → Neutralized Valuable Trace Metals and Minerals can be recovered and could reduce Importation from Overseas Countries

- Capture Mechanism: molecular surface area interaction between Pollutant and Reagent
  - Use of Steam: Shockwave shattering Steam's or Reagent's contact surface area to become multiplied thousands and thousands of times
  - Micro-droplets contact and envelope Targeted Pollutant and reform as moisture-encapsulated droplets
  - Capturing Product Reactions completed in split-seconds
- Molecular surface chemistry overcomes conventional mass transfer limitations — virtually all Metals and Particulates are captured (per EPA/DOE)

Reaction Speeds under Shockwave Reaction Condition and Priorities in CEFCO Modules

#	Priority of Reaction Preference	Enthalpy [ΔH_f^{θ}]	Time (Sec.)
1 SRS	Prior SOx + H_2O + O_2 Reactions[1] all Produce H_2SO_4 Acids (very exothermic): $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$	Definitely will react very fast. [H_2SO_4 ΔH = –811.3 kJ/mol] + [ΔH = –342 kJ/mol] = Combined: [ΔH = –1,153.3 kJ/mole]	10^{-4}
2 NRS H_2O_2	(Eq. 1) $2 NO + 3 H_2O_2 \rightarrow$ ~~$2 HNO_3$~~ $+ 2H_2O$ (Eq. 2) ~~$2 HNO_3$~~ $+ 2 KOH \rightarrow 2 KNO_3 + 2 H_2O$ (Eq. 3) $2 NO + 3 H_2O_2 + 2 KOH \rightarrow 2 KNO_3 + 4 H_2O$	[ΔH = –940 kJ/mol] Definitely will react fast.	10^{-3}
NRS_{O2}[2] Oxid. 2a	(Eq. 1) $2 NO + O_2 \rightarrow$ ~~$2 NO_2$~~ (Eq. 2) ~~$2 NO_2$~~ + ~~$2 H_2O$~~ $\rightarrow$ ~~$2 HNO_3$~~ $+ H_2$ (Eq. 3) ~~$2 HNO_3$~~ $+ 2 KOH \rightarrow 2 KNO_3$ + ~~$2 H_2O$~~ (Eq. 4) $2 NO + O_2 + 2 KOH \rightarrow 2 KNO_3 + H_2$	Hess's Law Bond Enthalpy Calculations (gas as neutral): [ΔH = – 172 kJ/mol]	10^{-2}
NRS_{O2} 2b	$2 NO + O_2 + 2 KOH \rightarrow 2 KNO_3 + H_2$	Bond Enthalpy Calcs (+ adding gas bonds): [ΔH = – 234 kJ/mol]	10^{-2}
NRS_{O2} 2c	$2 NO + O_2 + 2 KOH \rightarrow 2 KNO_3 + H_2$	Standard Enthalpy Text Book Calculations: [ΔH = –205.76 kJ/mol]	10^{-2}
NRS_{O2} 2d	$HNO_3 + KOH \rightarrow KNO_3 + H_2O$	Empirical Test Data: [ΔH = –181 kJ/mol]	10^{-2}
NRS_{O2}	Average of 4 O_2 Oxid. Routes	–198.19 kJ/mole	10^{-2}

[1] # 1a: $SO + H_2O \rightarrow SO_2 + H_2 + O_2 \rightarrow H_2SO_4$ [ΔH = –811.3 kJ/mol]
1b: $SO_2 + H_2O \rightarrow H_2SO_3 + ½ O_2 \rightarrow H_2SO_4$ [ΔH = –811.3 kJ/mol]
1c: $SO_3 + H_2O \rightarrow H_2SO_4$ [ΔH = –811.3 kJ/mol]

[2] Substituting O_2 Gas in place of H_2O_2 Peroxide may save Chemical Input Cost. The NRS reactions will be less exothermic and a bit slower. Will produce the same K_2NO_3 Fertilizer results.

Fertilizer Making — SRS (SO_X) Module

Endo-then-Exothermic Reactions inside the Aerodynamic Reactor System:

- SO and SO_3 may exist in very small quantities in Flue Gas — can be oxidized very rapidly by injecting O_2 (or H_2O_2)
- Vast Majority ends up as SO_2 in Flue Gas:
- $SO_2 + H_2O \rightarrow H_2SO_3$
- $2H_2SO_3 + O_2$ (or H_2O_2) $\rightarrow 2H_2SO_4$ (Sulfuric Acid)
- $H_2SO_4 + 2\ KOH_{(reagent)} \rightarrow K_2SO_4 + 2\ H_2O$ (Valuable and Sellable Reaction Products, especially in dry-climate farming areas)
- See: "Oxidation" and "Exothermic" Reactions

Any cheaper Alkaline (Na) or Alkaline Metal (Ca) Base Reagent will work for Regulatory Compliance making a salt by-product for disposal, but only Potassium Reagent makes high-value and sellable Fertilizer-Product

Fertilizer Making — NRS (NO, NO_X) Module

Endo-then-Exothermic Reactions inside the Aerodynamic Reactor System :

- $2\ NO + 2\ H_2O_{2\ (reagent)}$ (or O_2) → $2\ NO_2 + H_2O$
- $2\ NO_2 + H_2O$ → $HNO_2 + HNO_3$
- $2\ NO_2 + H_2O_{2\ (reagent)}$ (or injecting O_2) → $2\ HNO_3$ (Nitric Acid itself is a Product, but of lesser value than Fertilizer)
- $KOH_{(reagent)} + HNO_3$ → $KNO_3 + H_2O$ (Valuable Fertilizer and Water Products, as better choice than Ammonium Nitrate being banned in EU)

Transient Reactions (Hess's Law is verified):

- $KOH_{(reagent)} + HNO_2$ → $KNO_2 + H_2O$
- $KNO_2 + H_2O_{2\ (reagent)}$ (or injecting O_2) → $KNO_3 + H_2O$ (Valuable Fertilizer and Water Products)
- See: "Oxidation" and "Exothermic" Reactions

Any cheaper Alkaline (Na) or Alkaline Metal (Ca) Base Reagent will work for Regulatory Compliance making a salt by-product for disposal, but only Potassium Reagent makes high-value and sellable Fertilizer-Product

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Successful Capture of Potassium Fertilizers

SO_2 and NOx are Captured and Converted into Valuable and Sellable Fertilizers

Potassium Sulfate Fertilizer = K_2SO_4 (Solid)

Potassium Nitrate Fertilizer = KNO_3 (Solid)

- 99+% Pure K_2SO_4 (Solid) is sold around $3,000/ton to Wholesale Distributors in the dry-climate farming areas of the world.
- 99+% Pure KNO_3 (Solid) is sold around $2,000 to $3,000/ton to Wholesale Distributors, being a likely substitute or blend-in for Ammonium Nitrate in the global market, starting with the EU.

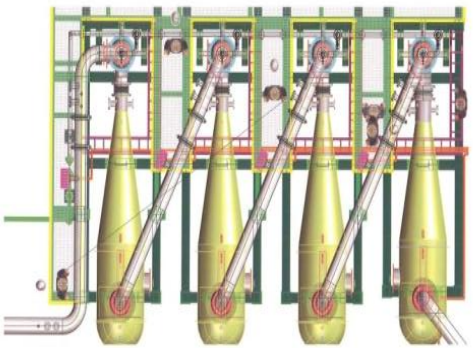
Potential Range of $ Revenue from Products at 3 Kinds of Typical 1,000 MW Coal-Fired Power Plant

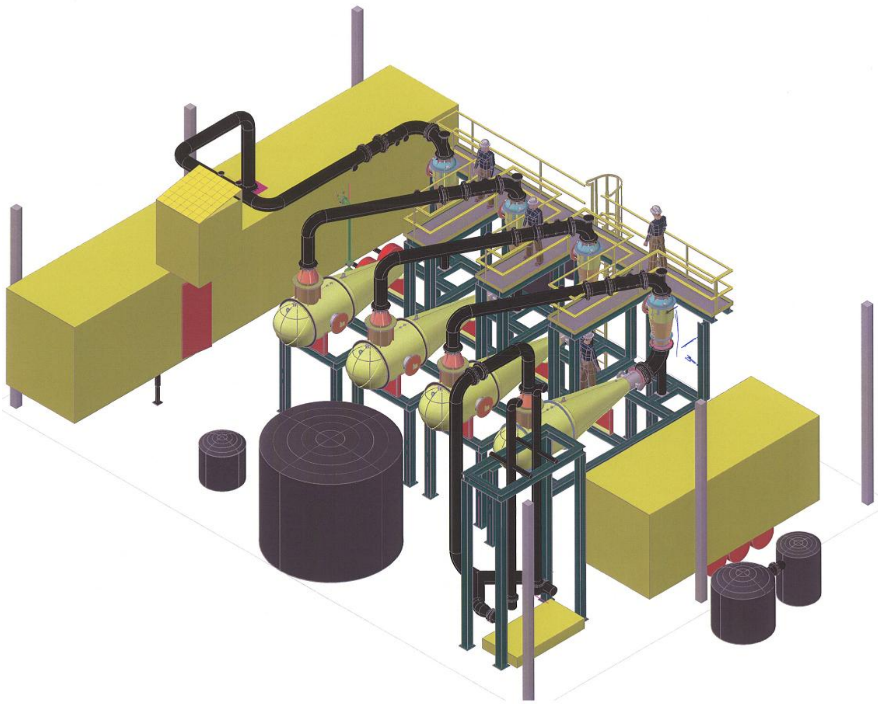
PRB Coal: End-Products Manufactured for Sale						
Produced Item	Tons /1,000 MW Capacity	Tons / MWe Cap.	Ton/Per ACFM	Ton/Per Oper. Hour	$ Selling Price/Ton	$ Revenue/8,000 Hrs.
Trace Metals	1,144	1.14	0.002383	0.142952	$20,000	$22,872,333
K2SO4 Fertilizer (pure)	69,238	69	0.144246	8.654750	$3,000	$207,714,000
KNO3 Fertilizer (pure)	22,500	23	0.046875	2.812500	$2,500	$56,250,000
CO2 (pure = KHCO3 solid)	7,919,705	7,920	16.499385	989.963125	$0	$0
H2O Produced	3,241,893	3,242	6.753944	405.236625	$3.00	$9,725,679
K2CO3	24,870,470	24,870	51.813479	3,108.808750	$0	$0
Totals:						**$296,562,012**

Illinois-Ohio Basin Hi-Sulfur Coal: End-Products Manufactured for Sale						High Quantity S
Produced Item	Tons /1,000 MW Capacity	Tons / MWe Cap.	Ton/Per ACFM	Ton/Per Oper. Hour	$ Selling Price/Ton	$ Revenue/8,000 Hrs.
Trace Metals	1,372	1.37	0.002859	0.171543	$25,000	$34,308,500
K2SO4 Fertilizer (pure)	533,238	533	1.110913	66.654750	$3,000	$1,599,714,000
KNO3 Fertilizer (pure)	41,587	42	0.086640	5.198375	$2,500	$103,967,500
CO2 (pure = KHCO3 solid)	7,593,345	7,593	15.819469	949.168125	$0	$0
H2O Produced	3,108,299	3,108	6.475623	388.537375	$3.00	$9,324,897
K2CO3	23,845,592	23,846	49.678317	2,980.699000	0	$0.00
Totals:						**$1,747,314,897**

No. Dakota Lignite Coal: End-Products Manufactured for Sale						Med. Quantity S
Produced Item	Tons /1,000 MW Capacity	Tons / MWe Cap.	Ton/Per ACFM	Ton/Per Oper. Hour	$ Selling Price/Ton	$ Revenue/8,000 Hrs.
Trace Metals	754.787	0.75	0.001572	0.094348	$30,000	$22,643,610
K2SO4 Fertilizer (pure)	193,200	193	0.402500	24.150000	$3,000	$579,600,000
KNO3 Fertilizer (pure)	22,529	23	0.046935	2.816125	$2,500	$56,322,500
CO2 (pure = KHCO3 solid)	10,464,578	10,465	21.801204	1,308.072250	$0	$0
H2O Produced	4,283,625	4,284	8.924219	535.453125	$3.00	$12,850,875
K2CO3	32,862,206	32,862	68.462929	4,107.775750	0	$0.00
Totals:						**$671,416,985**

Pilot Plant at Peerless in Wichita Falls, TX
(Modules → Ready for Commercialization)





- Phase I Success announced in November 9, 2011 Press Release by Peerless Mfg. Co.
- Seeking Phase II Demo-Partner for Carbon Capture in CRS

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Pilot Plant in Wichita Falls, TX

10-Minute Video available in Website: www. cefcoglobal.com

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Executive Summary

- CEFCO's Modules Commercialization → MACT, MATS, CAIR and NESHAPs Compliance on a timely basis
- Pollution Control = "profit-generation" business; ≠ "cost-center"
- Reliable and affordable:
  - Game-changing "transformative" (described by DOE) reaction mechanism technology = low-cost substitute for traditional thermodynamics and catalysts
- **SO_2** and **SO_x** can be Captured as a Potassium Sulfate Fertilizer, and Sold to Distributors and Users
- **NO_x** can be Captured as a Potassium Nitrate Fertilizer, and Sold to Distributors and Users
- "Virtuous Recycling" — of a Toxic Pollutants into a meritorious Fertilizer at Coal-Fired and Gas-Fired Power Plants to become Co-Generation of Electricity and Sellable Products in "renewable + sustainable" cycles

Questions & Answers

Thank you very much for your attention.

Please Contact Us At:

For Robert Tang: robert.tang@cefcoglobal.com

Website: www.cefcoglobal.com

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Appendix 1a — EPA and DOE Reports on Ewan Technology (1974 to 1986)

Date	Reference No.	Report Title	Emissions Targets	Description of Tests	Performance Conclusion
April 1, 1974	EPA-650/2-74-028 (Dale L. Harmon, EPA-NERC-RTP)	Steam-Hydro Air Cleaning System Evaluation	0.03 micron to 5.0 micron (EPA Method 5)	Steam-Hydro Patent invented by T.K. Ewan sold and assigned to Lone Star Steel (Div. of US Steel)	"90.0% at 0.01 micron . . . . 99.9% at 0.5 micron and 99.99% at 1.0 micron"
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Feb. 10, 1986	DCN 86-213-071-03	Radian Corp. Technical and Economic Evaluation for MSW Incineration	MSW, PM, HCl, SO_2, SO_3	"proven below 0.02 grains/scf", "achieved 99% HCl removal". "using slaked lime reagent . . . 95% SO_2 removal"	"shows overall capital cost and total annual operating cost advantage over spray scrubbing systems, using either ESP or FF particulate matter collection"

Appendix 1b — EPA and DOE Reports on Ewan Technology (1986 to 1996)

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August 1993	DE-AC01-EW300-30	DOE/MWIP-3 by SAIC	PNL — Idaho Labs	undisclosed	undisclosed
1993	WSRC-TR-93-00623	Final Report: Consolidated Incineration Facility by Westinghouse Savannah River Corporation	CIF, POHCs (Principal Organics Hazardous Constituents), Metals, TVOC, Chlorides, PAH (Polynuclear Aromatic Hydrocarbons)	CEMS measures: O2, CO2, NOx, CO, and SO2. Continuous recording by strip charts. The CEMS monitored both the PCC and SCC flue gases	Destruction "greater than 99.99998%"
Feb. 1996	EPA Contract No. 68-D2-0164	Technical Support Document for HWC MACT Standards, Vol. I		Page 3-17, Section 3.4.2.2, Page 3-58, Figure 3-14	

Appendix 1c — EPA and DOE Reports on Ewan Technology (1997 to 2002)

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Ewan's Technology was Federally recognized and codified in U.S. Regulations: 40 CFR §63.1209 et al.

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