ClearChemFSI™

DÜRR

WELCOME

LEADING IN PRODUCTION EFFICIENCY

FSI + CATALYTIC FILTRATION + CONDENSING HEAT EXCHNGERS (CHX)

HOW TO MAKE POLLUTION CONTROL PROFITABLE

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- ClearChem is working with Dürr, an international designer/supplier of Catalytic Ceramic Filtration (CCF) and condensing heat exchangers (CHX)

- Technology combination allows maximum flexibility for profitably meeting retrofit and new plant APC requirements

- Provides attractive rapid payback

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CREATING PROFIT WITH APC – KEEP IT SIMPLE

Combining the right low cost & highly efficient technologies from a single source produces economies, value and competitive paybacks

Process type	Dust removal	NOx removal	Hg removal	Acid gas removal	Heat recovery
New Plant	Dürr CCF		ACI, FSI, & CHX	ClearChemFSI	Dürr CHX
Existing Plant	existing		Existing	ClearChemFSI	Dürr CHX

Consider:

- ✓ Small foot print, easy retrofit of ClearChemFSI and Dürr CHX to existing plants
- ✓ New plants see larger savings (predominately international market)
- ✓ Cost for larger systems falls below cost for converting to Nat. Gas
- ✓ No Nat. Gas price volatility exposure with ClearChem & Dürr package
- ✓ Dry byproducts without DSI Sodium preserve ash sales and avoid ash ponds

[1] Based on 15 year depreciation and 5 % annual interest rate

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MAJOR SOURCE BOILERS

Operator Environment

- ✓ Regulatory Pressures
  - o A majority of existing Utility & Industrial solid fuel, coke oven gas or oil firing Major Source boilers or heaters are affected by increasingly tighter current & expected environmental legislation
- ✓ Typical Solutions Used or Considered
  - o Current BAT options are a mix of several processes, designed to treat a single emissions challenge and configured in many different ways in the flue gas duct
  - o Fuel switch, retirement or conversion to gas options also are in play, with all their material technical & commercial impacts
  - o Finding the optimum CAPEX and OPEX solution for the specific operation conditions of an affected boiler are elusive

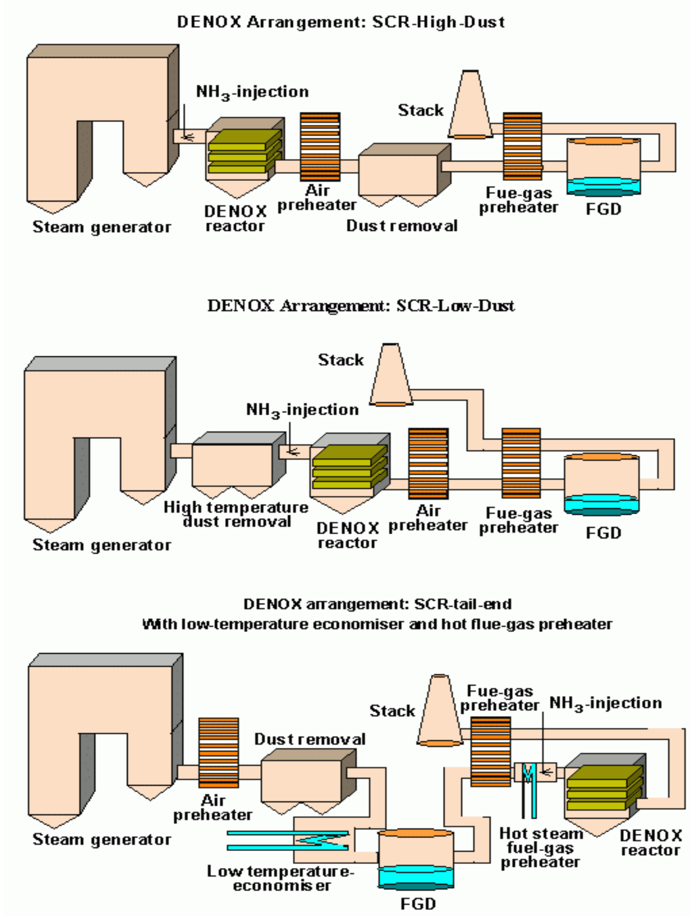

Image source: European Commission , Reference Document on Best Available Techniques in Large Combustion Plants, 2006 ---> http://eippcb.jrc.ec.europa.eu/reference/BREF/lcp_bref_0706.pdf

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REGULATORY SUMMARY

Regulation	Pollutant targeted	Compliance options[1]	Expected date of compliance	IMPACT ON FUEL
MATS MACT	HAPs (mercury, acid gases, PM)	ACI, CHX baghouse FGD/DSI/FSI	2015/16	Coal (strong)
GHG Standards for exisiting plants	GHG	Unknown, CHX Trading allowances	Uncertain ~2020	Coal (strong) Gas (moderate)
316(b)	Cooling water intake	Mesh screens, Cooling towers	Uncertain ~2018	Coal (moderate) Gas (moderate)
Combustion by-products (ash)	Ash, control equipment, waste	Bottom ash dewatering, dry fly ash silos	Uncertain ~2020	Coal (moderate)
Regional Haze	NOx, SO_2, PM	SCR/SNCR, FGD/DSI/FSI, baghouse/ESP, combustion controls	Uncertain ~2019	Coal (strong)
CSAPR	NOx, SO_2	SCR/SNCR, FGD/DSI/FSI/CCF, fuel switch, trading allowances	Uncertain	Coal (moderate)

ACI – active carbon injection, FGD – flue gas desulfurization (wet scrubber), DSI – dry sorbent injection, FSI – furnace sorbent injection, SCR – selective catalytic reduction, SNCR – selective non-catalytic reduction, ESP – electrostatic precipitator

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SOLUTION OPTIONS SUMMARY

CAPEX - Cost of Individual Compliance Technologies

	Dust removal		NOx removal			Hg removal	Acid gas removal			Fuel
Process type	Bag house	ESP	**Dürr CCF[2]**	SCR	SNCR[3]	ACI[1,3]	FGD	DSI	**ClearChem FSI**	Switch to NG[4]
USD/kW	200 – 500	55 – 100	270 - 340	175 – 450[3]	50 – 140	120 – 470	450 - 900	40 – 270[3]	10	50[5] – 100++[4]

Legend:

- Baghouse - fabric filter
- ESP - electro static precipitator
- CCF - catalytic ceramic filter, hot gas filter with SCR function
- SCR - selective catalytic reduction of NOx
- SNCR - selective non-catalytic reduction of NOx
- FGD - flue gas desulfurization (typically wet scrubber)
- ACI - active carbon injection (mercury removal, needs dust removal)
- DSI - dry sorbent injection (dry acid scrubbing in flue gas duct, needs dust removal)
- FSI - furnace sorbent injection (acid scrubbing, needs dust removal)
- NG - natural gas firing

CAPITAL COST OF CONTROL EQUIPMENT (2011 $/kW)

	Unit Size (MW)		
Equipment	**50**	**200**	**600**
Wet Scrubber	904	734	513
Dry Scrubber	774	628	448
DSI	42	39	39
SCR	273	234	188
SNCR	51	51	51
Baghouse	504	387	219
ACI	29	27	19

Source: EPA IPM 4.10 Basecase assumptions and EEI 2011 Study

[1] incl. fabric filter
[2] estimate for a unit size of 15 MW and 30 MW
[3] Coal Capacity on risk for retirement in PJM 2011 (PJM Interconnection is the largest U.S. Regional Transmission Organization with 830 members from generators and transmitters)
[4] Jeff Broderik, Peerless, McIlvaine webinar on MATS timing and technology options, Aug. 2014 – (**pure conversion costs, with infrastructure closer to 350 USD/kW)**
[5] Babcock & Wilcox, Natural Gas Conversions of Existing Coal Fired Boilers **(not including NG price volatility risk or drop in output due to NG moisture content)**

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CHALLENGE – STRUCTURE CAPEX FOR PROFITABLE APC

SOLUTION - Combine Technologies with One Provider

GENERIC CAPEX

Process type	Dust removal	NOx removal	Hg removal	Acid gas removal	Heat recovery	Total cost, USD/khr	Savings USD/kWhr
Technology	**Dürr CCF**		ACI (By others)	**ClearChemFSI**	**Dürr CHX**		
Cost[1], USD/kWhr	0.00468 – 0.0059		0.00208 – 0.00815	0.00018	0.00087 – 0.00173	0.0078 – 0.01595	0.00101

✓ Considering calorific value of the fuel:

- Cost for larger systems start falling below cost of switching to Nat. Gas
- No Nat. Gas price volatility exposure with ClearChem & Dürr package
- Range of cost fall between 0.0045 – 0.0068 US$/kWhr, depending on the requirements
- Note: ClearChemFSI & Dürr technologies in combination have the ability to lower Hg with high surface reagent and longer residence time, but more data needed [2]

1. Based on 15 year depreciation and 5 % annual interest rate 2. Published work by Consol and Lehigh indicate cooling helps capture of Hg in existing systems suggesting that the FSI + CHX combination might eliminate the ACI bringing potential savings to 0.00309 to 0.00916.

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CAPEX PROFIT CHALLENGE

CAPEX Solutions for new units or existing units needing NOx and PM equip upgrades

Process type	Dust removal	NOx removal	Hg removal	Acid gas removal	Total cost, USD/kW		Switch to NG, USD/kW
Solution 1	ESP	SCR	FGD		680 – 1,400	OR	50 – 100 (with infrastructure up to 350)
Solution 2	Baghouse	SNCR	ACI*	DSI	410 – 1,380		
Solution 3	**Dürr CCF**		ACI*	**ClearchemFSI**	400 – 820		

Capex Conclusions:

- ✓ Excluding switch to NG with its high pricing volatility and need to be near NG pipelines, **ClearChemFSI and Dürr are the lowest CapEx solution**
- ✓ ClearChem/Dürr dry byproducts, all without DSI's Sodium, preserve ash sales and avoid ash ponds

* Published work by Consol and Lehigh indicate cooling helps capture of Hg in existing systems suggesting that the FSI + CHX combination might eliminate the ACI bringing potential savings to 0.00309 to 0.00916.

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OPEX PROFIT CHALLENGE

Background & OPEX Solution

- ✓ Corrosion by acid gases prevents present boiler technology from utilizing all the available heating value of the fuel
- ✓ The latent heat of vaporization of water vapor is typically lost and not used for generation of useful energy
- ✓ For new units (& some existing plants), the combination of ClearChemFSI's furnace sorbent injection (FSI) and Dürr's catalytic ceramic filtration (CCF) ensures sufficient acid gas removal, allowing:
  - Use of condensing heat exchangers (CHX)
  - Lowering of flue gas exit temperature from ~300+^{o}F to ~140^{o}F
  - Increase the overall plant efficiency (as a rule of thumb every 40^{o}F lower flue gas temperature equals to 1% efficiency gain)
  - Maximizes flexibility for profitably meeting retrofit and new plant APC requirements
  - Most existing unit retrofits can use just ClearChemFSI & Dürr CHX for efficiency gain and avoids NSR
  - Provides attractive, simple payback terms
  - ClearChem/Dürr dry ash has no sodium, preserves ash sales & eliminates ash ponds

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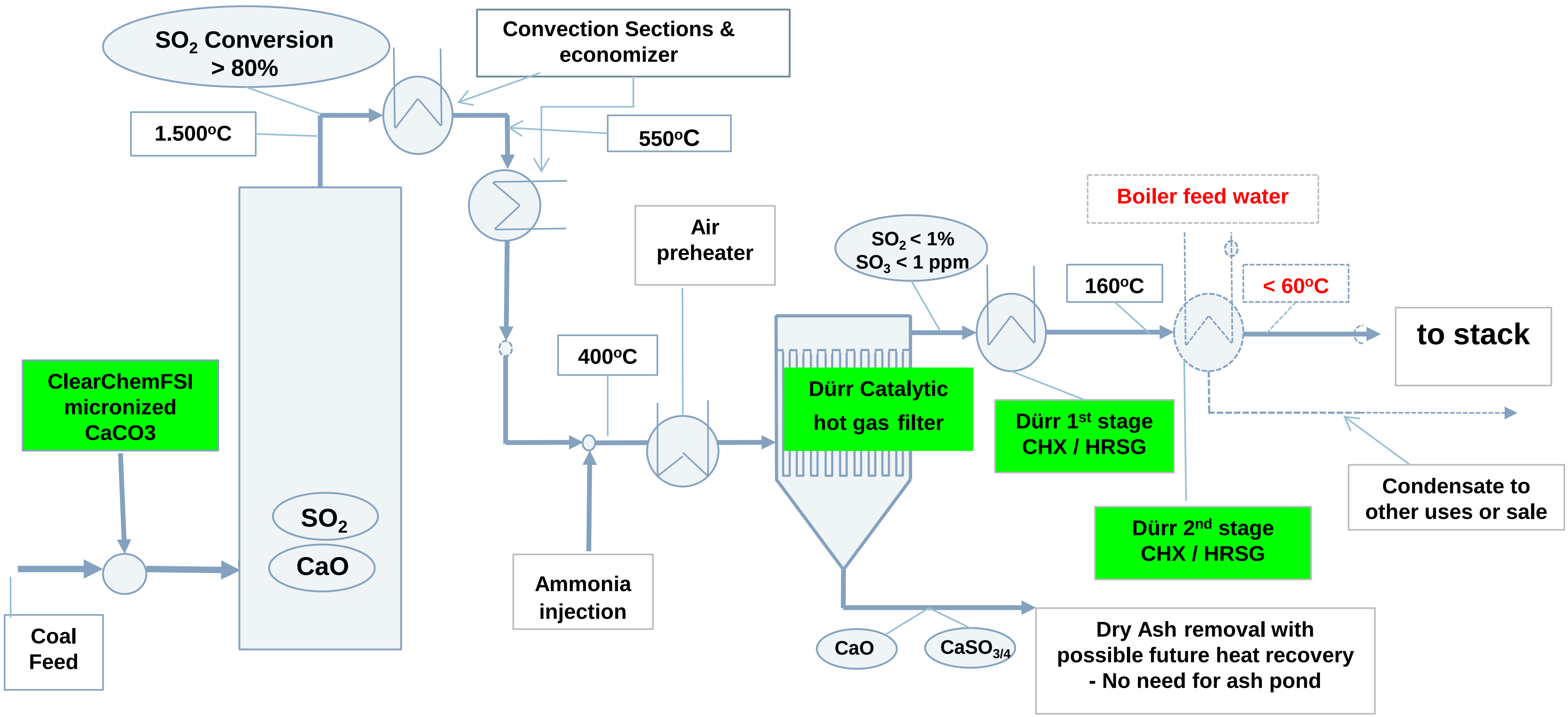
APC PROFIT CREATION

APC Adding Value to Plant Economics



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CONCLUSIONS

Removal of acidic compounds from the flue gas allows:

- ✓ Exploitation of heat of flue gas below sulfuric acid dew point
- ✓ Condensing flue gas moisture for boiler feed water
- ✓ Treated coal flue gas will act like NG flue gas and boost efficiency 6% to 8%
- ✓ Utilization of low grade steel for construction of CHX for boiler feed water pre-heating
- ✓ Combining ClearChem and Durr technologies raises efficiency (ie, latent heat of vaporization recovered, decreased coal use & GHG levels for same plant output
- ✓ Doesn't trigger NSR

For each 1,000 Nm^3/h (37,320 SCF/h) of flue gas:

- Water consumption can be reduced by about 8 kg/hr (17.7 lbs/hr) per vol.% of water vapor
- Steam consumption for boiler water pre-heating can be meaningfully reduced

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Appendix

Additional Presentation Information

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Efficiency Opportunity

- ✓ Condensing boilers are more efficient (ie, reportedly capturing 98% of fuel thermal efficiency Vs 70% to 80% for typical fossil power plants)
- ✓ Flue gas stack inlet temp has historically been >300F (to avoid acid corrosion and exotic alloy materials)
- ✓ ClearChemFSI™ is **<u>the low cost option</u>** for efficiency improvement

Efficiency Opportunity

- ✓ DOE demos by Lehigh U. captures flue gas H_2O, diverts steam to turbine from Feed H_2O heaters, then heats feed H_2O by cooling flue gas
- ✓ Economics seem viable for some plants even with costly alloy to protect against acid attack
- ✓ By capturing the SO3 & HCl in the furnace, ClearChemFSI™ allows the use of CHX surface of less costly metals (ie., Durr CHX) so more plants can gain efficiency and use or sell clean H2O for a new revenue stream

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OPEX SOLUTION

Economy

ClearChemFSI Acid Gas Removal System Economic Effect on the Levy Alloy Heat Exchanger Case Study (*)

Modeling Assumptions: Based on a 600 MW unit; power sales at $60/MWHr; 20 yr life; H2O cost $1.50/1000 Gal; 5% int. rate on capital

All cases burning PRB Coal (i.e., Powder River Basin)	PRB Unscrubbed	PRB Unscrubbed smaller HX	Condensor downstream from FGD	Condensor downstream of FGD WITH ClearChemFSI	PRB Unscrubbed smaller HX WITH ClearChemFSI	PRB Unscrubbed With ClearChemFSI
Heat Exchanger Gas Inlet, F	300	300	135	135	300	300
Heat Exch. Area, Sq. Ft.	596241	78200	100,625	100,625	78200	596241
Heat Exch. Material	Alloy 22	Alloy 22	304SS	304SS	304SS	304SS
Installed Cost ($ millions)	101.9	10.59	4.14	4.14	3,22	24.53
Cost/Benefit Summary						
Annual Costs						
CHX(**) Installed Capital Cost	$9,596,000	$998,000	$389,911	$389,911	$302,755.0	$2,308,373
CHX added operating costs	$1,058,400	$146,400	$251,108	$251,108	$146,400	$1,058,400
Ion exchange System Cap. Cost (***)	$32,831	$16,334	$32,831	$0	$0	$0
Ion exchange O&M Cost	$74,560	$29,824	$119,296	$0	$0	$0
Subtotal	$10,761,791	$1,190,558	$793,146	$641,019	$449,155	$3,366,773
Annual Benefits						
Increased Power Generation	$4,746,000	$1,575,000	$1,126,440	$1,126,440	$1,575,000	$4,746,000
Water Savings @ $0.0015/gal	$94,424	$39,280	$178,065	$178,065	$39,280	$94,424
Subtotal	$4,840,424	$1,614,280	$1,304,505	$1,304,505	$1,614,280	$4,840,424
Net Annual Benefit, $	***<$5,921,367>***	**$423,722**	**$511,359**	**$663,486**	**$1,165,125**	**$1,473,651**
Water @ $0.021/gal ***will increase savings by***	$1,226,972	$510,640	$2,314,845	$2,314,845	$510,640	$1,226,972
New Net Benefit $ @ $0.021/gal H20	***<$4,694,395>***	**$934,362**	**$2,826,204**	**$2,978,331**	**$1,675,765**	**$2,700,623**

(*) --- ClearCHem added to econ table from the Water Recovery Report of 3/31/2011 "Alloy Heat Exchanger Economic Case Study", by Ed Levy, et.al. at the Energy Research Center, Leigh University

(**) --- CHX = "condensing heat exchanger" or "heat Exchanger"

(***) --- Note that Ion Exchange System is not required with ClearChemFSI

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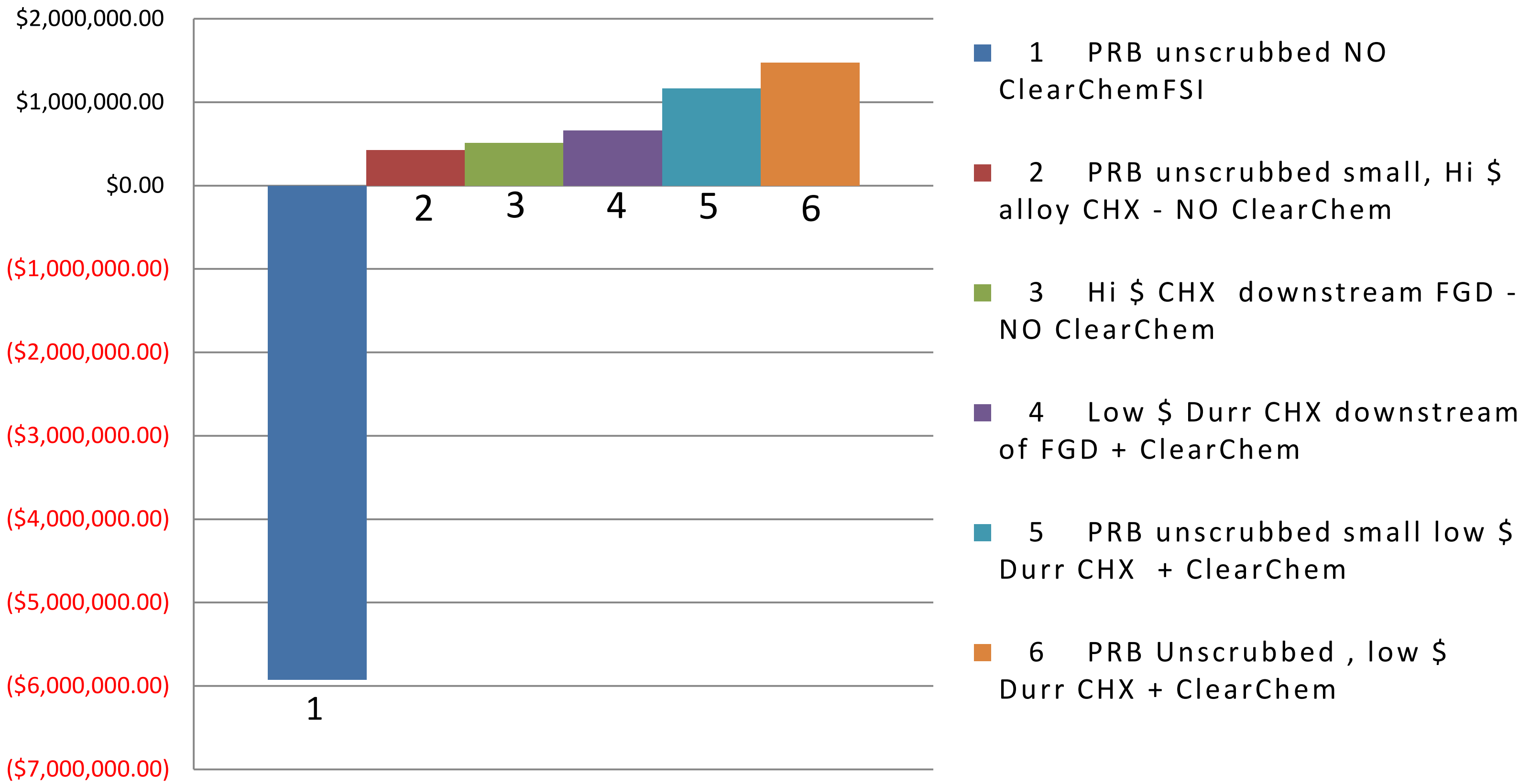
OPEX SOLUTION

Water Capture Economics – Lehigh example @ $0.0015/gal H_2O



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- ✓ ClearChemFSI provides low cost in-furnace removal of acid gases
- ✓ Allows use of condensing heat exchangers (CHX)
- ✓ Allows lowering of flue gas exit temp from ~300° F^{+} to ~140° F
- ✓ Allows increased plant efficiency (every ~40° F lower flue gas temp. equals 1% efficiency gain) plus gain 2% to 4% more from recovering the heat of vaporization of water

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New Furnace Sorbent Injection Technology

- ✓ Decades-old attempts at furnace sorbent injection (FSI) showed poor results
- ✓ ClearChem is different – it solves past problems to release the promise of FSI
  - o Sub-micron sized reagent particles are highly reactive and minimize deposits
  - o Computational Fluid Dynamic (CFD) modeling enhances sorbent furnace coverage
  - o Burner zone/fuel reagent application for longer reaction time & no sintering
  - o High efficiency reagent utilization minimized ESP/FF concerns

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Furnace Sorbent Injection Process

- ✓ Patented, based on submicron sized calcium reagents, ($CaCO_3$, $Ca(OH)_2$, flyash and industrial byproducts as dry powders or high-solids dispersions
- ✓ Very small footprint – simple, off the shelf hardware
- ✓ Low capital cost and low reagent cost

ClearChem Attributes

- ✓ Effective scavenging of SO_3, SO_2, HCl & HF
- ✓ Minimizes tube deposits & ESP/FF impact
- ✓ Dry, fully reacted reagent provides minimal Ca increase and no sodium leaching in fly ash
- ✓ High surface area for some capture of oxidized mercury, but when combined with CCF and/or CHX more capture expected
- ✓ Allows lower exit gas temps with associated benefits
- ✓ <u>Only acid gas control technology that allows emissions control during plant startup and shut down</u>

Why ClearChem is More Effective

- ✓ Surface area of 0.5 micron reagent is **88 times higher** than -325 mesh
- ✓ Number of reagent particles per pound **is 676,000 times** that of -325 mesh

Results:

(i) the probability of reagent particle finding scarce pollutant molecules in the huge volumes of flue gas is very much greater;

(ii) the sub-micron size avoids sintering concerns

Technology Overview

- ✓ Commercially available, high solids (>72%) fluid reagent dispersions or dry powders from approved suppliers can be supplemented or displaced by low cost waste or byproduct streams
- ✓ Reagent injection points based on furnace modeling (CFD program)
- ✓ Uses precipitated (PCC) or ground (GCC) sub-micron $CaCO_3$ to very efficiently capture pollutants, with PCC ~50% more reactive than GCC
- ✓ Avoids previous problem of unreacted reagent core
- ✓ Greater probability of reagent and pollutant contact
- ✓ 50% more reaction time than prior/old FSI technology

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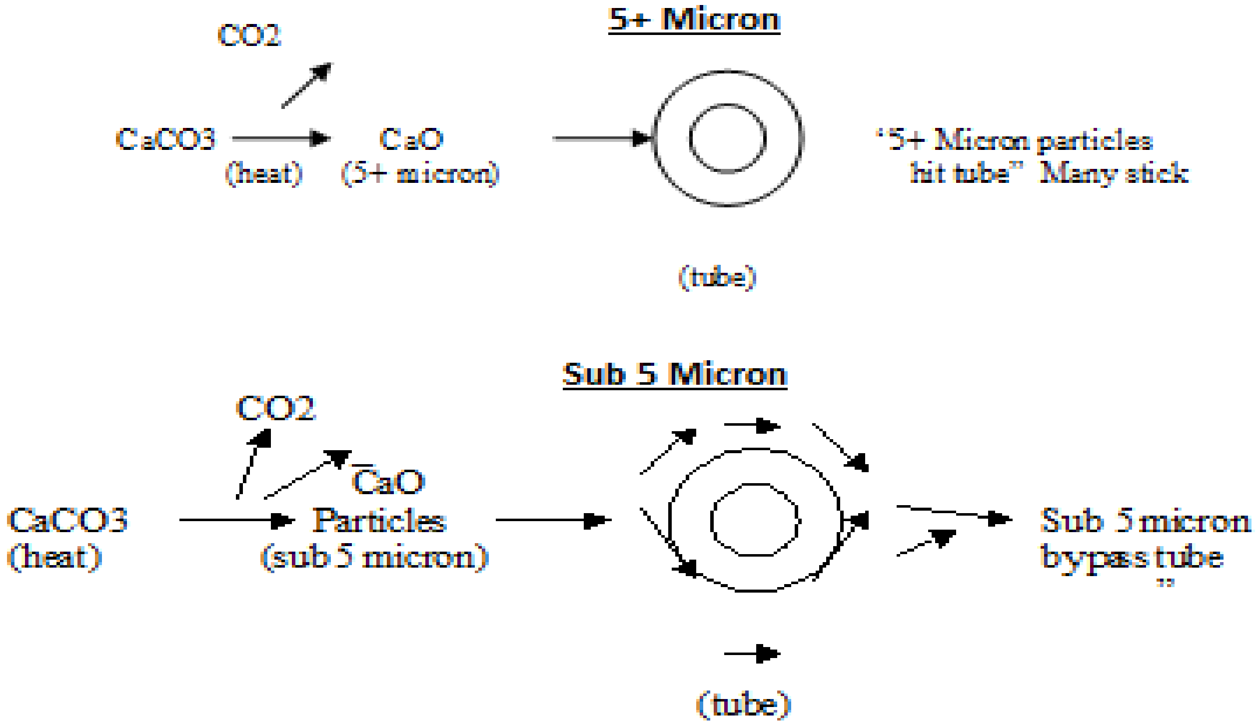
Particle size and Deposition/Capture



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Other ClearChem Boiler & Combustor SO_2 Capture Results

- ✓ Precipitated $CaCO_3$ better than ground/milled
- ✓ Carbonate modestly better than $Ca(OH)_2$
- ✓ Solutions can be used ($CaCl_2$ or CaAc)
- ✓ Droplet size key to minimizing agglomeration
- ✓ Maximizing discrete particles key to efficient acid gas capture
- ✓ 50% to 70% SO_2 capture at 1.6 stoichiometry

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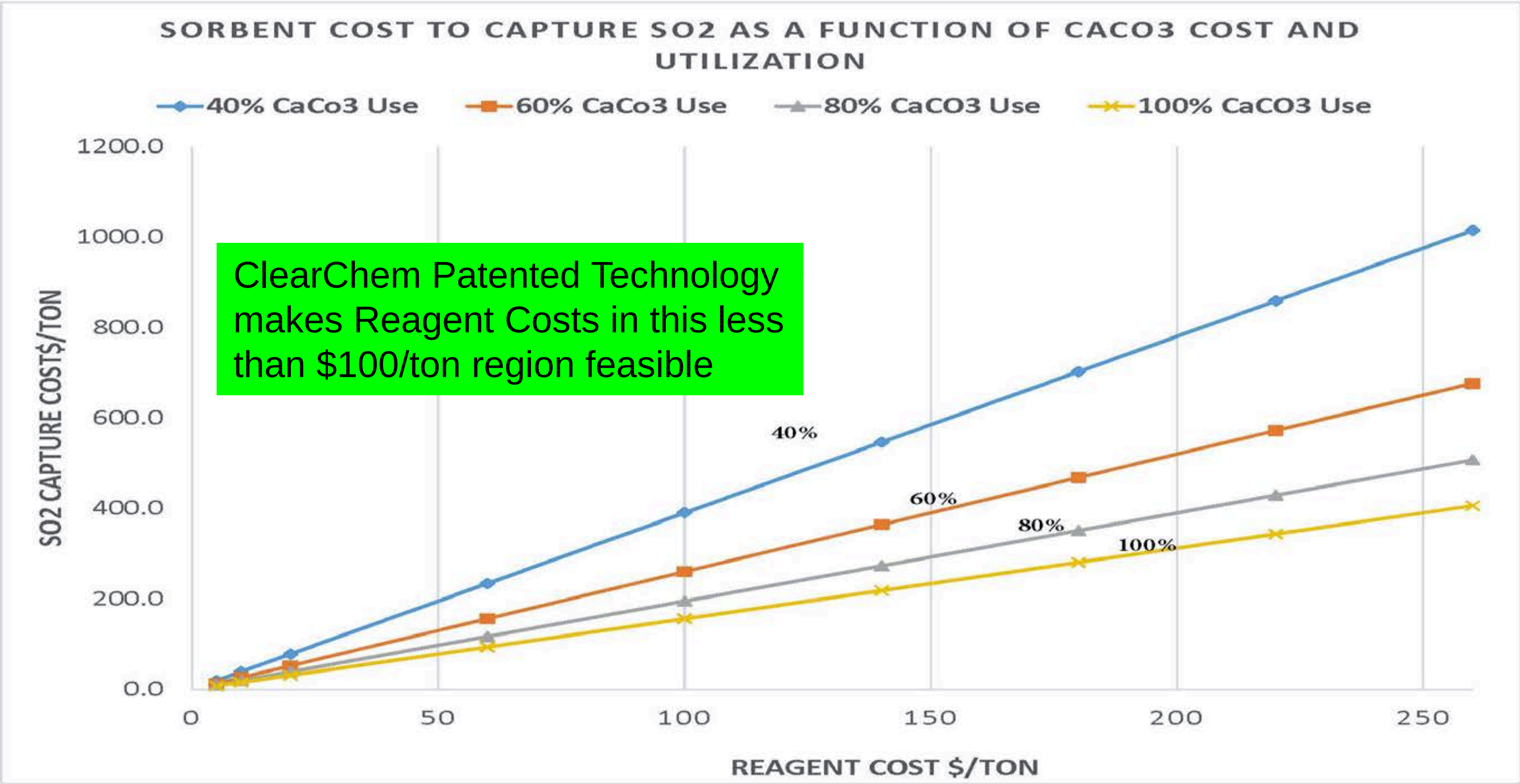

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Results of Pilot and 6 Utility and Industrial Boiler Trials

- ✓ 84% SO_2 captur**e @ Ca/S of 1.9 (SRI 1 MW)**
  - o Oxidants & lower exit gas temp can boost capture
- ✓ HCl capture demonstrated but data limited (see apdx. slide table by ADA-ES)
- ✓ CFD furnace modeling critical for optimum results
- ✓ SO3 essentially all captured in demos when targeted
  - o Allows lower exit gas temp, improved heat rate & lower CO2 release

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ClearChem Costs & Benefits (site specific)

- ✓ Capital Cost: starting at $500K for 100 MW unit
- ✓ Operating cost: $400 to $600 per ton of SO_2 removed (depending on sulfur level of fuel). Can be as low or lower than $200 when byproducts available
- ✓ Safe, widely available, easily handled & stored liquid reagent or can be supplied as dry powder

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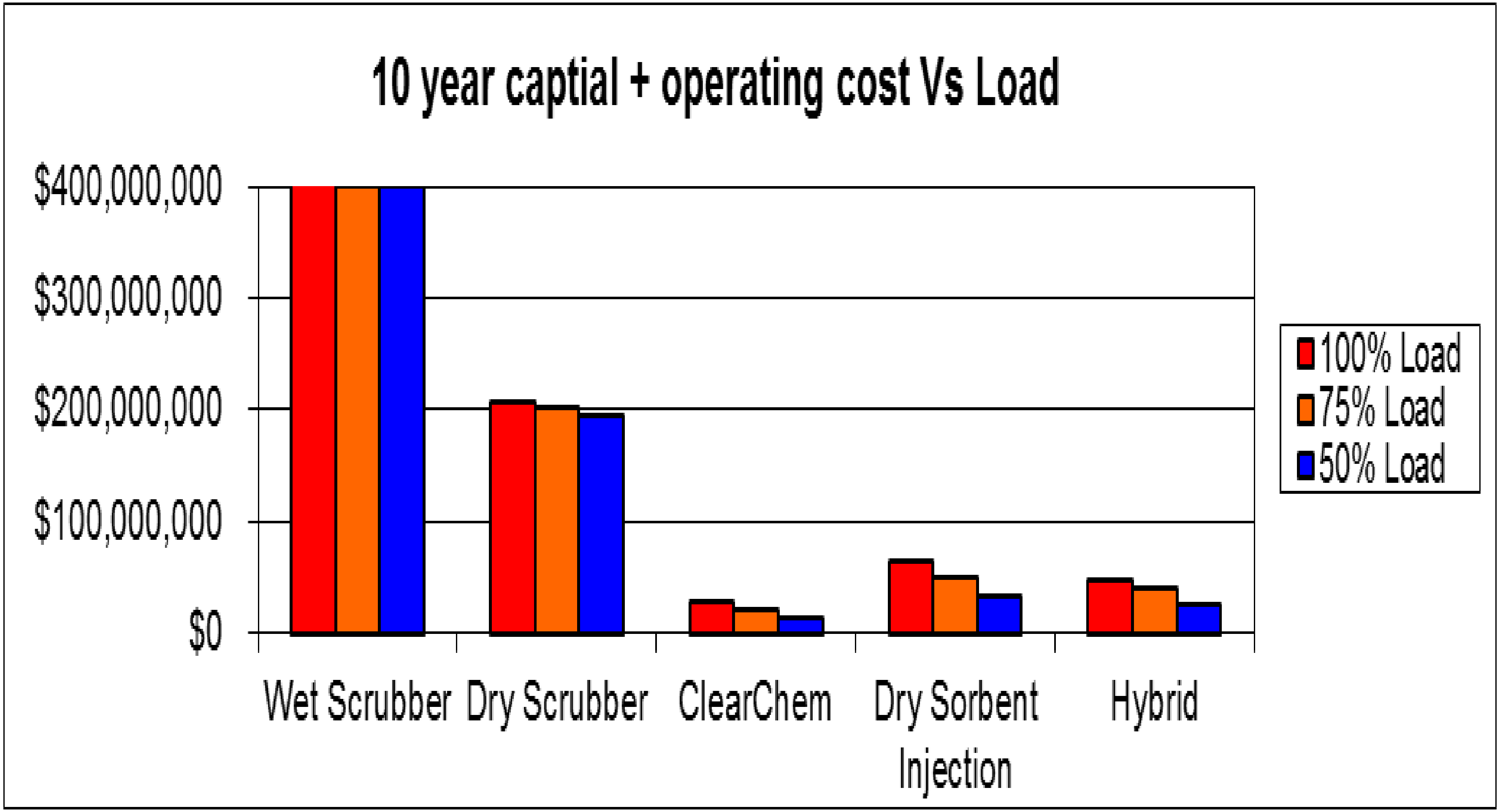
CLEARCHEMFSI COSTS



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ClearChemFSI Applications

- ✓ Coal/Coke/Oil/Biomass fired plants, kilns, incinerators & industrial processes
- ✓ Scrubbed units needing more SO_3/PM 2.5/SO_2/HCl control
- ✓ Plants with DSI & high LOI and/or Na ash disposal issues limiting ash sales or disposal options
- ✓ Scrubbed units with water supply issues
- ✓ Scrubbed units needing SO_3 and/or SO_2 polishing/trimming
- ✓ Plants with options to switch fuels to lower cost of operations

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ClearChemFSI Value & Added Benefits Summary

- ✓ Captures up to 85%+ of SO2 (and other acid gases, i.e., SO3, HCl, HF) and reduces PM2.5 particulate emissions (via SO3 removal) at low capital and operating costs. Adding CCF and/or CHX significantly boosts capture
- ✓ The only acid gas removal system that can control emissions during uncontrolled plant startup and shut down operations
- ✓ Can be installed as stand-alone application or in combination with exiting FGD, acid gas and particulate control systems, depending on specific plant emissions requirements, to vastly improve overall plant emissions performance/economics

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ClearChemFSI Value & Added Benefits Summary (cont.)

- ✓ For the new build market, when used in combination with traditional FGD, can facilitate significant reductions in the capital cost, operating cost, size and the overall footprint of all emissions control equipment
- ✓ Low capital cost: $250K-2M for ClearChem vs. $20-40M for FGD upgrade and $300M+ for new FGD for typical 300MW unit size
- ✓ Small ClearChemFSI™ footprint, short construction lead-time; minimal permitting requirements; minimal disruption to existing operations and fast system tie-in (in service 3 - 6 months after order); can enhance Hg capture

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ClearChem Channel Partner Licensee Information

Founded in 1992 and headquartered in Sandy Hook, CT, EES is a privately held provider of advanced engineering solutions for the optimization of utility and industrial combustion systems. EES works with coal and oil customers to evaluate boiler characteristics, environmental needs and operational objectives. Evaluation extends from fuel and ash analysis to corrosion and emissions evaluation. EES then designs a cost-effective strategy tailored to optimize the dynamic nature of boiler operation. The EES product portfolio includes solutions for opacity, corrosion, slagging and fouling, as well as technologies for improving heat transfer efficiency and mitigating SO_3 and other acid gas emissions.

Founded in 1997 and headquartered in Highlands Ranch, CO, ADA-ES (Nasdaq:ADES) is a publically traded provider of emissions control solutions for coal-fired power plants. The company offers products and services that enable generators to meet emissions regulations by enhancing existing air pollution control equipment, maximizing capacity and improving operating efficiencies. Its technical and chemical solutions include activated carbon injection, dry sorbent injection, flue gas conditioning, CO_2 capture technology, and pre-combustion additives. These technologies help address emissions challenges related to mercury, acid gas (SOx, HCl), particulate matter, opacity and condensables.

ClearChem Development

Creative Technology Led by Jerrold Radway, Chairman and CTO

- Invented first commercial MgO boiler additive
- Invented MgO based SO2 scrubbing/recycle process
- Wrote EPRI manual on fireside chemical additives
- ASME Fellow – chaired Corrosion & Deposits Committee – Fuel div program chair
- 1978 formed EnerChem Inc. Consulting, Industrial waste recycling
- 2006 formed ClearChem LLC to develop better FSI process
- 48 year history of success in treating fireside deposits & emissions

DÜRR GLOBAL: GROUP STRUCTURE

» Overview of Divisional Results 2013 *(2012)*

DÜRR AG

Paint and Assembly Systems

Paint and Final Assembly Systems

Aircraft and Technology Systems

Incoming orders: **1.125 Mio. €** *(1.326 Mio. €)*
Turnover: **1.177 Mio. €** *(1.125 Mio. €)*

Application Technology

Coating and Paint Application Systems

Glueing and Sealing Techniques

Incoming orders: **568 Mio. €** *(557 Mio. €)*
Turnover: **540 Mio. €** *(531 Mio. €)*

Measuring and Process Systems

Balancing, Assembly, Inspection,

Filling and Cleaning technology

Incoming orders: **561 Mio. €** *(601 Mio. €)*
Turnover: **584 Mio. €** *(648 Mio. €)*

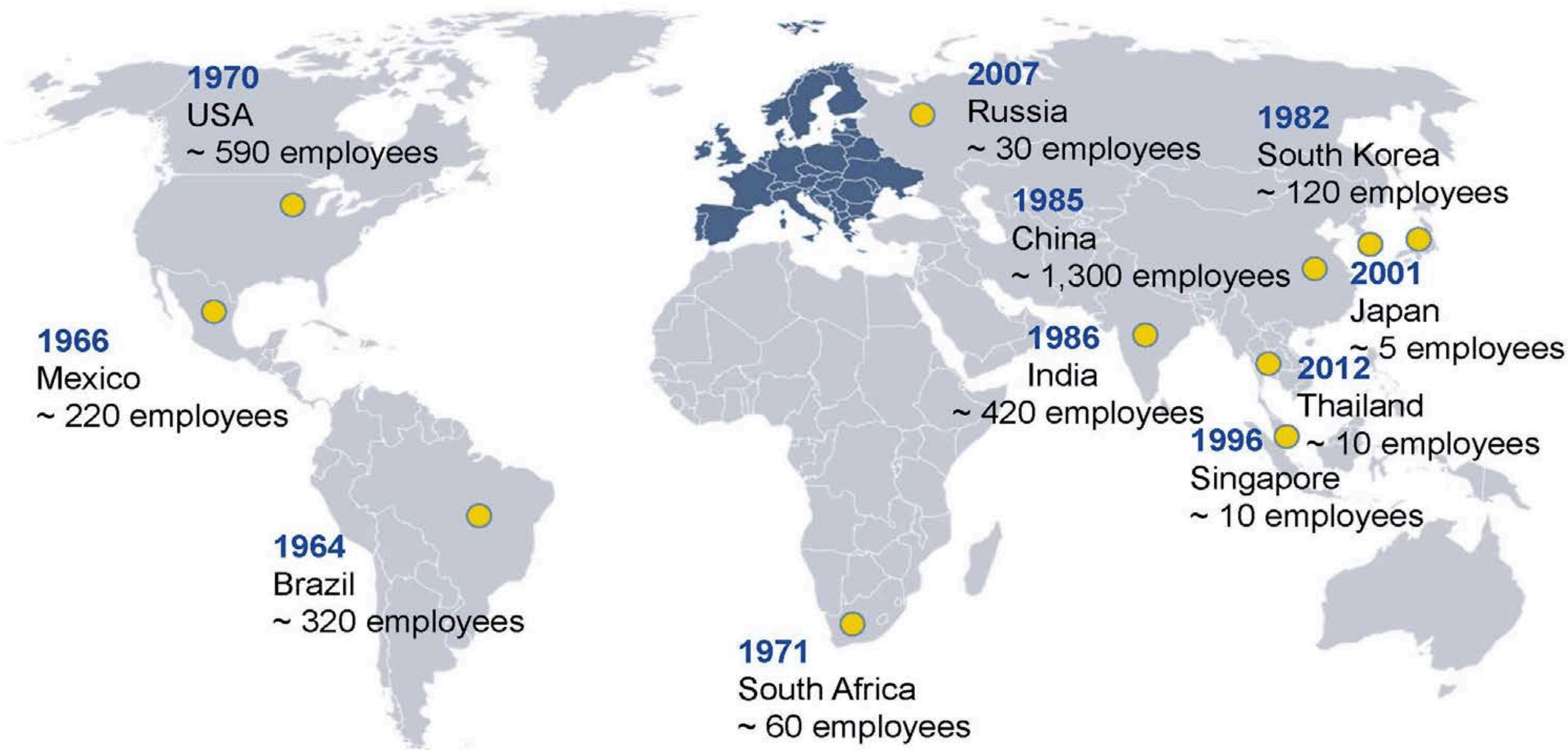
Clean Technology Systems

Air Abatement Systems

Energy Efficient Technology

Incoming orders: **134** Mio. € *(114 Mio. €)*
Turnover: **107** Mio. € *(96 Mio. €)*

DÜRR ESTABLISHED IN 24 COUNTRIES SINCE….



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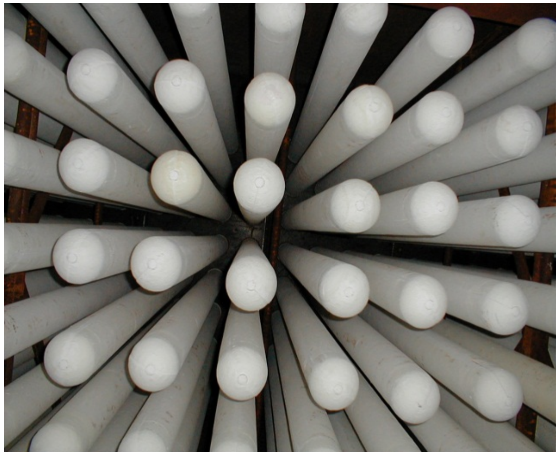
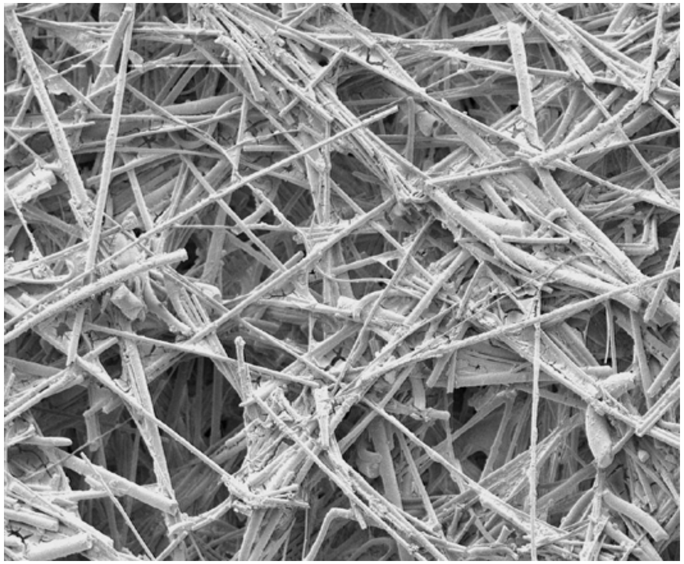
DÜRR CATALYTIC CERAMIC FILTRATION

Ceramic Filters, History & Features

- Development in the Clean Coal Program
- Combined acid gas removal
  - Medical waste incineration (dust & HCl)
- High temperature applications
  - > 250 – 400ºC (900ºC)





- Product features
  - Low density 0.4 g/cm^3 → light weight
  - 70 – 95 % porosity
  - Chemical resistant alumino silicate fibers
  - High temperature and thermal shock resistant
  - High removal efficiency to > 2 mg/Nm^3
  - Low pressure drop

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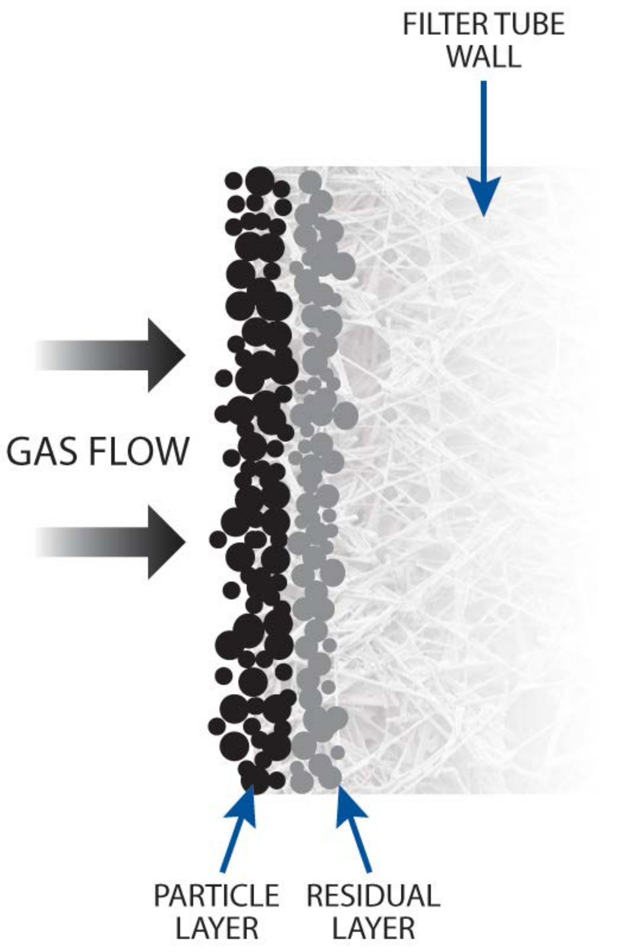
DÜRR CATALYTIC CERAMIC FILTRATION

Ceramic Filters, Operation

- Surface filtration on conditioned layer
- Dust removal by reversed pulse air
- Filter element does not expand and keeps a residual dust layer
- Negligible dust penetration into the filter body
- High filtration efficiency – HEPA* rated
- Operates with variable dust loads



* High Efficiency Particulate Airfilter

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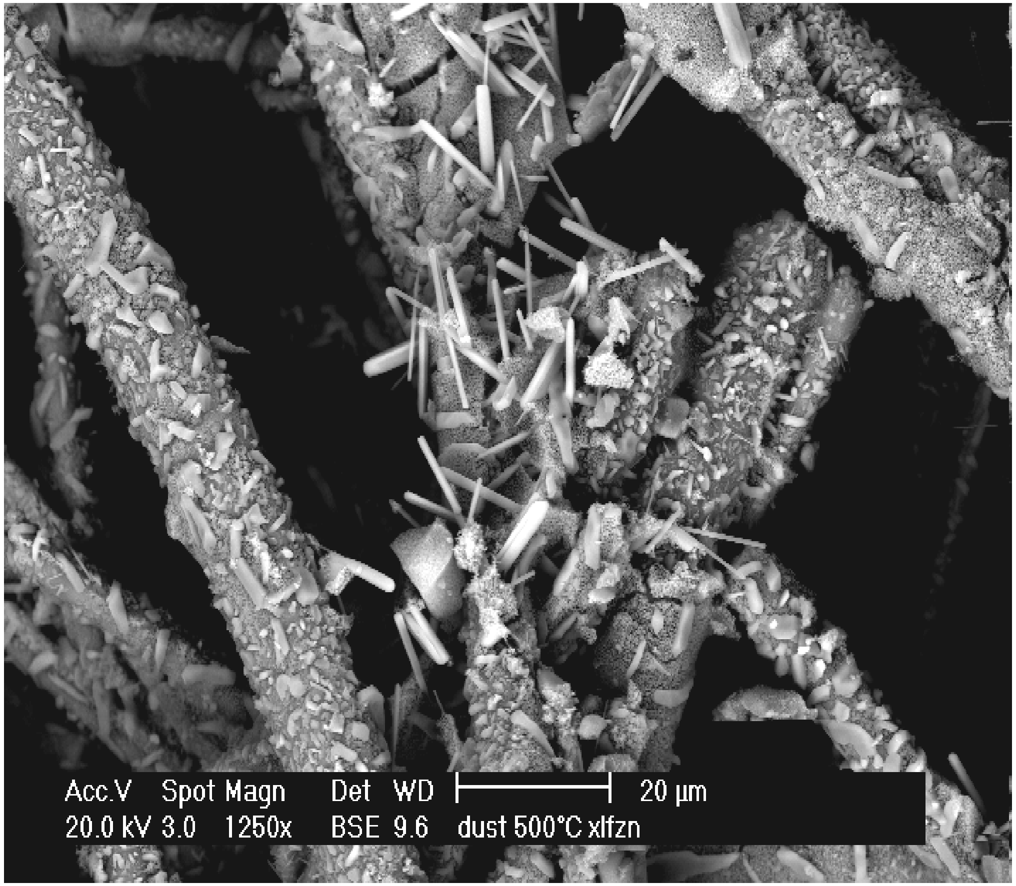
DÜRR CATALYTIC CERAMIC FILTRATION

Ceramic Filters, Catalytic Activation



- Catalyst finely dispersed throughout the wall of the filter
- No gas film limitation
- Large surface area
- Catalyst is protected from masking and poisoning by dust constituents, like alkali