HOW TO MAKE POLLUTION CONTROL PROFITABLE

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Shuman Moore - Co-author, CEO ClearChem Development, LLC
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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.
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

<table>
<thead>
<tr>
<th>Process type</th>
<th>Dust removal</th>
<th>NOx removal</th>
<th>Hg removal</th>
<th>Acid gas removal</th>
<th>Heat recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Plant</td>
<td>Dürr CCF</td>
<td>ACI, FSI, &amp; CHX</td>
<td>ClearChemFSI</td>
<td>Dürr CHX</td>
<td></td>
</tr>
<tr>
<td>Existing Plant</td>
<td>existing</td>
<td>Existing</td>
<td>ClearChemFSI</td>
<td>Dürr CHX</td>
<td></td>
</tr>
</tbody>
</table>

**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
Operators Environment

- **Regulatory Pressures**
  - 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**
  - 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
  - Fuel switch, retirement or conversion to gas options also are in play, with all their material technical & commercial impacts
  - Finding the optimum CAPEX and OPEX solution for the specific operation conditions of an affected boiler are elusive

## REGULATORY SUMMARY

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Pollutant targeted</th>
<th>Compliance options¹</th>
<th>Expected date of compliance</th>
<th>IMPACT ON FUEL</th>
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<tbody>
<tr>
<td>MATS MACT</td>
<td>HAPs (mercury, acid gases, PM)</td>
<td>ACI, CHX baghouse FGD/DSI/FSI</td>
<td>2015/16</td>
<td>Coal (strong)</td>
</tr>
<tr>
<td>GHG Standards for existing plants</td>
<td>GHG</td>
<td>Unknown, CHX Trading allowances</td>
<td>Uncertain ~2020</td>
<td>Coal (strong) Gas (moderate)</td>
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<tr>
<td>316(b)</td>
<td>Cooling water intake</td>
<td>Mesh screens, Cooling towers</td>
<td>Uncertain ~2018</td>
<td>Coal (moderate) Gas (moderate)</td>
</tr>
<tr>
<td>Combustion by-products (ash)</td>
<td>Ash, control equipment, waste</td>
<td>Bottom ash dewatering, dry fly ash silos</td>
<td>Uncertain ~2020</td>
<td>Coal (moderate)</td>
</tr>
<tr>
<td>Regional Haze</td>
<td>NOx, SO₂, PM</td>
<td>SCR/SNCR, FGD/DSI/FSI, baghouse/ESP, combustion controls</td>
<td>Uncertain ~2019</td>
<td>Coal (strong)</td>
</tr>
<tr>
<td>CSAPR</td>
<td>NOx, SO₂</td>
<td>SCR/SNCR, FGD/DSI/FSI/CCF, fuel switch, trading allowances</td>
<td>Uncertain</td>
<td>Coal (moderate)</td>
</tr>
</tbody>
</table>

# ClearChemFSI™ SOLUTION OPTIONS SUMMARY

## CAPEX - Cost of Individual Compliance Technologies

<table>
<thead>
<tr>
<th>Process type</th>
<th>Dust removal</th>
<th>NOx removal</th>
<th>Hg removal</th>
<th>Acid gas removal</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baghouse</td>
<td>Baghouse</td>
<td>ESP</td>
<td>Dürr CCF²</td>
<td>SCR</td>
<td>FGD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SNCR³</td>
<td>DSI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ACI¹,³</td>
<td>ClearChem FSI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Switch to NG</td>
</tr>
<tr>
<td>USD/kW</td>
<td>200 – 500</td>
<td>55 – 100</td>
<td>270 – 340</td>
<td>175 – 450³</td>
<td>450 – 900</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 – 140</td>
<td></td>
<td>40 – 270³</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50⁵ – 100++⁴</td>
</tr>
</tbody>
</table>

### Legend:
- **Baghouse**: fabric filter
- **ESP**: electrostatic 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)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Unit Size (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Wet Scrubber</td>
<td>904</td>
</tr>
<tr>
<td>Dry Scrubber</td>
<td>774</td>
</tr>
<tr>
<td>DSI</td>
<td>42</td>
</tr>
<tr>
<td>SCR</td>
<td>273</td>
</tr>
<tr>
<td>SNCR</td>
<td>51</td>
</tr>
<tr>
<td>Baghouse</td>
<td>504</td>
</tr>
<tr>
<td>ACI</td>
<td>29</td>
</tr>
</tbody>
</table>

**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)
ClearChemFSI™

CHALLENGE – STRUCTURE CAPEX FOR PROFITABLE APC

SOLUTION - Combine Technologies with One Provider

GENERIC CAPEX

<table>
<thead>
<tr>
<th>Process type</th>
<th>Dust removal</th>
<th>NOx removal</th>
<th>Hg removal</th>
<th>Acid gas removal</th>
<th>Heat recovery</th>
<th>Total cost, USD/khr</th>
<th>Savings USD/kWhr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Dürr CCF</td>
<td>ACI (By others)</td>
<td>ClearChemFSI</td>
<td>Dürr CHX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost¹, USD/kWhr</td>
<td>0.00468 – 0.0059</td>
<td>0.00208 – 0.00815</td>
<td>0.00018</td>
<td>0.00087 – 0.00173</td>
<td>0.0078 – 0.01595</td>
<td>0.00101</td>
<td></td>
</tr>
</tbody>
</table>

✅ 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.
## CAPEX PROFIT CHALLENGE

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

<table>
<thead>
<tr>
<th>Process type</th>
<th>Dust removal</th>
<th>NOx removal</th>
<th>Hg removal</th>
<th>Acid gas removal</th>
<th>Total cost, USD/kW</th>
<th>Switch to NG, USD/kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution 1</td>
<td>ESP</td>
<td>SCR</td>
<td>FGD</td>
<td></td>
<td>680 – 1,400</td>
<td>OR 50 – 100</td>
</tr>
<tr>
<td>Solution 2</td>
<td>Baghouse</td>
<td>SNCR</td>
<td>ACI*</td>
<td>DSI</td>
<td>410 – 1,380</td>
<td></td>
</tr>
<tr>
<td>Solution 3</td>
<td>Dürr CCF</td>
<td>ACI*</td>
<td>ClearChemFSI</td>
<td></td>
<td>400 – 820</td>
<td></td>
</tr>
</tbody>
</table>

### 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.*
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°F to ~140°F
- Increase the overall plant efficiency (as a rule of thumb every 40°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
ClearChemFSI™

APC PROFIT CREATION
APC Adding Value to Plant Economics

SO₂ Conversion > 80%

1.500°C

SO₂ < 1%
SO₃ < 1 ppm

550°C

Boiler feed water

Air preheater

400°C

Dürr Catalytic hot gas filter

Dry Ash removal with possible future heat recovery - No need for ash pond

Coal Feed

ClearChemFSI micronized CaCO₃

SO₂

CaO

Ammonia injection

CaO

CaSO₃/4

Dry Ash removal with possible future heat recovery - No need for ash pond

Condensate to other uses or sale

to stack

Dürr 1st stage CHX / HRSG

Dürr 2nd stage CHX / HRSG

Convection Sections & economizer
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
Efficiency Opportunity

- Condensing boilers are more efficient (i.e., 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 the low cost option for efficiency improvement
Efficiency Opportunity

✓ DOE demos by Lehigh U. captures flue gas H₂O, diverts steam to turbine from Feed H₂O heaters, then heats feed H₂O 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
## 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)

<table>
<thead>
<tr>
<th></th>
<th>PRB Unscrubbed</th>
<th>PRB Unscrubbed smaller HX</th>
<th>Condensor downstream of FGD</th>
<th>Condensor downstream of FGD</th>
<th>Condensor downstream of FGD</th>
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</thead>
<tbody>
<tr>
<td>Heat Exchanger Gas Inlet, °F</td>
<td>300</td>
<td>300</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>Heat Exch. Area, Sq. Ft.</td>
<td>596241</td>
<td>78200</td>
<td>100,625</td>
<td>100,625</td>
<td>100,625</td>
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<tr>
<td>Heat Exch. Material</td>
<td>Alloy 22</td>
<td>Alloy 22</td>
<td>30455</td>
<td>30455</td>
<td>30455</td>
</tr>
<tr>
<td>Installed Cost ($ millions)</td>
<td>101.9</td>
<td>10.59</td>
<td>4.14</td>
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<td>4.14</td>
</tr>
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</table>

### Cost/Benefit Summary

#### Annual Costs

<table>
<thead>
<tr>
<th></th>
<th>CHX(***) Installed Capital Cost</th>
<th>CHX added operating costs</th>
<th>Ion exchange System Cap. Cost (**)</th>
<th>Ion exchange O&amp;M Cost</th>
<th>Subtotal</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$9,596,000</td>
<td>$998,000</td>
<td>$389,911</td>
<td>$389,911</td>
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<td>$10,761,791</td>
<td>$1,190,558</td>
<td>$641,019</td>
<td>$449,155</td>
<td>$3,366,773</td>
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</table>

#### Annual Benefits

<table>
<thead>
<tr>
<th></th>
<th>Increased Power Generation</th>
<th>Water Savings @ $0.0015/gal</th>
<th>Subtotal</th>
<th>Net Annual Benefit, $</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$4,746,000</td>
<td>$94,424</td>
<td>$4,840,424</td>
<td>&lt;$5,921,367&gt;</td>
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<tr>
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<td>$1,126,440</td>
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<td>$1,304,505</td>
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<td>$1,126,440</td>
<td>$178,065</td>
<td>$1,304,505</td>
<td>$1,165,125</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td>$1,473,651</td>
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</table>

### Savings

#### Water @ $0.021/gal will increase savings by

<table>
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<tr>
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<th>$1,226,972</th>
<th>$510,640</th>
<th>$2,314,845</th>
<th>$2,314,845</th>
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<tr>
<td></td>
<td>$510,640</td>
<td>$2,314,845</td>
<td>$510,640</td>
<td>$1,226,972</td>
</tr>
</tbody>
</table>

**New Net Benefit $ @ $0.021/gal H20**

<table>
<thead>
<tr>
<th></th>
<th>&lt;$4,694,395&gt;</th>
<th>$934,362</th>
<th>$2,826,204</th>
<th>$2,978,331</th>
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<td></td>
<td>$1,675,765</td>
<td>$2,700,623</td>
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</tbody>
</table>

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

(***): Note that Ion Exchange System is not required with ClearChemFSI
OPEX SOLUTION

Water Capture Economics – Lehigh example @ $0.0015/gal H₂O

- 1  PRB unscrubbed NO ClearChemFSI
- 2  PRB unscrubbed small, Hi $ alloy CHX - NO ClearChem
- 3  Hi $ CHX downstream FGD - NO ClearChem
- 4  Low $ Durr CHX downstream of FGD + ClearChem
- 5  PRB unscrubbed small low $ Durr CHX + ClearChem
- 6  PRB Unscrubbed , low $ Durr CHX + ClearChem
ClearChemFSI™

✅ 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
ClearChemFSI™

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
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
- Only acid gas control technology that allows emissions control during plant startup and shut down
ClearChem FSI™

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 CaCO₃ 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.
Particle size and Deposition/Capture

CO2

CaCO₃ (heat) → CaO (5+ micron)

5+ Micron

"5+ Micron particles hit tube" Many stick

(tube)

Sub 5 Micron

CaCO₃ (heat) → CaO Particles (sub 5 micron)

Sub 5 micron bypass tube

(tube)
Other ClearChem Boiler & Combustor SO₂ Capture Results

- Precipitated CaCO₃ better than ground/milled
- Carbonate modestly better than Ca(OH)₂
- Solutions can be used (CaCl₂ or CaAc)
- Droplet size key to minimizing agglomeration
- Maximizing discrete particles key to efficient acid gas capture
- 50% to 70% SO₂ capture at 1.6 stoichiometry
ClearChem FSI™

ClearChem Patented Technology makes Reagent Costs in this less than $100/ton region feasible.
Results of Pilot and 6 Utility and Industrial Boiler Trials

✓ 84% SO₂ capture @ 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
ClearChem Costs & Benefits (site specific)

- Capital Cost: starting at $500K for 100 MW unit

- Operating cost: $400 to $600 per ton of SO2 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
ClearChemFSI™

CLEARCHEMFSI COSTS

10 year capital + operating cost Vs Load

- Wet Scrubber
- Dry Scrubber
- ClearChem
- Dry Sorbent Injection
- Hybrid

- 100% Load
- 75% Load
- 50% Load
ClearChemFSI Applications

- Coal/Coke/Oil/Biomass fired plants, kilns, incinerators & industrial processes
- Scrubbed units needing more SO₃/PM 2.5/SO₂/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 SO₃ and/or SO₂ polishing/trimming
- Plants with options to switch fuels to lower cost of operations
ClearChemFSI™

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.
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
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 SO₃ and other acid gas emissions.

ADA-ES (Nasdaq:ADES) is a publicly 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, CO₂ 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

<table>
<thead>
<tr>
<th>Paint and Assembly Systems</th>
<th>Application Technology</th>
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</thead>
<tbody>
<tr>
<td>Paint and Final Assembly Systems</td>
<td>Coating and Paint Application Systems</td>
</tr>
<tr>
<td>Aircraft and Technology Systems</td>
<td>Glueing and Sealing Techniques</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Incoming orders:</strong></th>
<th><strong>Turnover:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.125 Mio. € (1.326 Mio. €)</td>
<td>1.177 Mio. € (1.125 Mio. €)</td>
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<tr>
<th>Measuring and Process Systems</th>
<th>Clean Technology Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balancing, Assembly, Inspection, Filling and Cleaning technology</td>
<td>Air Abatement Systems Energy Efficient Technology</td>
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<thead>
<tr>
<th><strong>Incoming orders:</strong></th>
<th><strong>Turnover:</strong></th>
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</thead>
<tbody>
<tr>
<td>561 Mio. € (601 Mio. €)</td>
<td>584 Mio. € (648 Mio. €)</td>
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<thead>
<tr>
<th><strong>Incoming orders:</strong></th>
<th><strong>Turnover:</strong></th>
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<tbody>
<tr>
<td>568 Mio. € (557 Mio. €)</td>
<td>540 Mio. € (531 Mio. €)</td>
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<tr>
<th><strong>Incoming orders:</strong></th>
<th><strong>Turnover:</strong></th>
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<tbody>
<tr>
<td>134 Mio. € (114 Mio. €)</td>
<td>107 Mio. € (96 Mio. €)</td>
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</table>
DÜRR ESTABLISHED IN 24 COUNTRIES SINCE....

- **1970**
  - USA
  - ~ 590 employees

- **1966**
  - Mexico
  - ~ 220 employees

- **1964**
  - Brazil
  - ~ 320 employees

- **1971**
  - South Africa
  - ~ 60 employees

- **1985**
  - China
  - ~ 1,300 employees

- **1986**
  - India
  - ~ 420 employees

- **1982**
  - South Korea
  - ~ 120 employees

- **2001**
  - Japan
  - ~ 5 employees

- **2007**
  - Russia
  - ~ 30 employees

- **2012**
  - Thailand
  - ~ 10 employees

- **1996**
  - Singapore
  - ~ 10 employees
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 – 400°C (900°C)

Product features

» Low density 0.4 g/cm³ light weight
» 70 – 95 % porosity
» Chemical resistant alumino silicate fibers
» High temperature and thermal shock resistant
» High removal efficiency to > 2 mg/Nm³
» Low pressure drop
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
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