

WELCOME

LEADING IN PRODUCTION EFFICIENCY

FSI + CATALYTIC FILTRATION + CONDENSING HEAT EXCHANGERS (CHX)

HOW TO MAKE POLLUTION CONTROL PROFITABLE

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MAJOR SOURCE BOILERS

Operator 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 is elusive

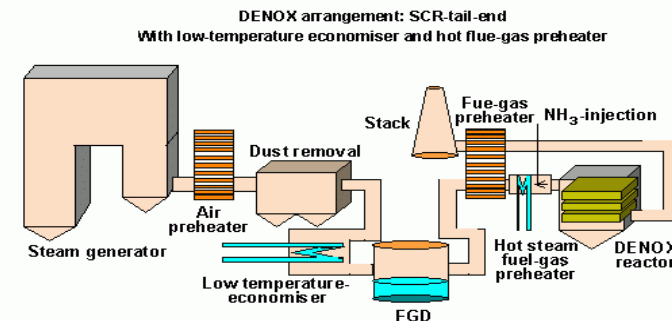
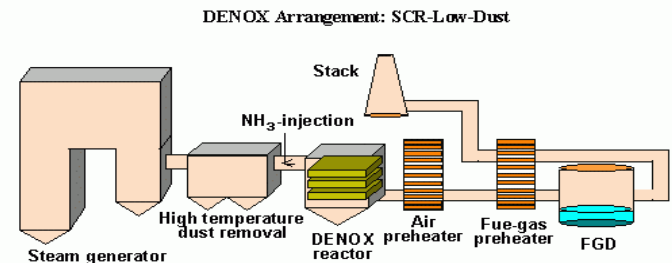
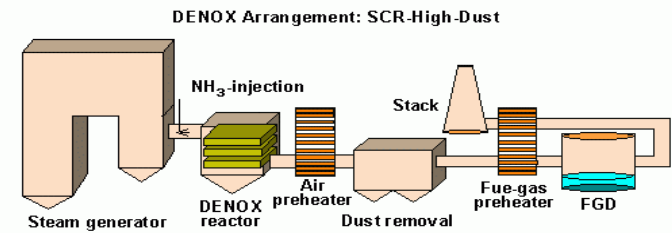


Image source: European Commission , Reference Document on Best Available Techniques in Large Combustion Plants, 2006 ---> http://eippcb.jrc.ec.europa.eu/reference/BREF/lcp_bref_0706.pdf

REGULATORY SUMMARY

Regulation	Pollutant targeted	Partial List 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 existing plants	GHG	Unknown, CHX, improved heat rate, coal drying & enzyme use, 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, double-blind landfills	Uncertain ~2020	Coal (moderate)
Regional Haze	NO _x , SO ₂ , PM	SCR/SNCR, FGD/DSI/FSI, baghouse/ESP, combustion controls, CHX	Uncertain ~2019	Coal (strong)
CSAPR	NO _x , SO ₂	SCR/SNCR, FGD/DSI/FSI/CCF, CHX, fuel switch, trading allowances	Uncertain	Coal (moderate)

¹ 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

SOLUTION OPTIONS SUMMARY

CAPEX - Individual Compliance Technologies Est. Costs

	Dust removal			NOx removal		Hg removal	Acid gas removal			Fuel
Process type	Bag house	ESP	<u>Dürr CCF²</u>	SCR	SNCR ³	ACI ^{1,3}	FGD	DSI	<u>ClearChem FSI⁷</u>	Switch to NG ⁴
USD/kW ⁶	200 – 500	55 – 100	270 - 340	175 – 450 ³	50 – 140	120 – 470	450 - 900	40 – 270 ³	10	50 ⁵ – 100++ ⁴

➤ CAPEX sum up for individual compliance technologies while following regulatory demand

✓ Conclusion:

- Optimizing CAPEX by exploiting synergies

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)**

⁶ EEI, Potential Impacts of Environmental Regulation on the U.S. Generation Fleet, January 2011 & EPA IPM 4.10 Basecase assumptions (CAPEX decreases with increasing boiler size)

⁷ ClearChem FSI's by-products preserve existing ash sales and avoid necessity for ash ponds

CHALLENGE – STRUCTURING CAPEX

SOLUTION – Utilize Synergies by Combination of Technologies

Process type	Dust removal	NOx removal	Hg removal	Acid gas removal	CAPEX ¹ , USD/kWhr	Switch to NG USD/kWhr
CAPEX Structuring	<u>Dürr CCF</u>		ACI (By others)	<u>ClearChemFSI</u>	0.0069 – 0.0142	0.0009 - 0.0018 (0.0069)
	Bag house	SNCR	ACI	DSI	0.0071 – 0.024	
	ESP	SCR	FGD		0.0118 – 0.0243	

✓ Conclusion:

- CAPEX of combined ClearChem / Dürr technologies is on the low side of compliance options
- CAPEX for switch to natural gas (NG) is lower than for other technologies

¹ Based on 15 year depreciation and 5 % annual interest rate (generic CAPEX without soft/finance costs)

CHALLENGE – STRUCTURING CAPEX

SOLUTION – Taking Advantage of OPEX

Process type	Dust removal	NOx removal	Hg removal	Acid gas removal	Heat recovery	Switch to NG	(Savings) / Cost	TCO
Technology	Dürr CCF		ACI (By others)	ClearChem FSI	Dürr CHX	(By others)		
Cost ¹ , USD/kWhr	0.00468 – 0.0059		0.00208 – 0.00815	0.00018	0.00087 – 0.00173	-	(0.00101)	0.0068 – 0.01495
	-		-	-	-	0.0009 - 0.0069	0.00337 – 0.00841	0.0043 – 0.00916

✓ 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
- 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 (generic CAPEX without soft/finance costs)

² Source: Babcock Power, Challenges When Converting Coal-Fired Boilers to Natural Gas - expected decreased boiler efficiency between 2-5% (→ <http://www.babcockpower.com/pdf/RPI-TP-0232.pdf>)

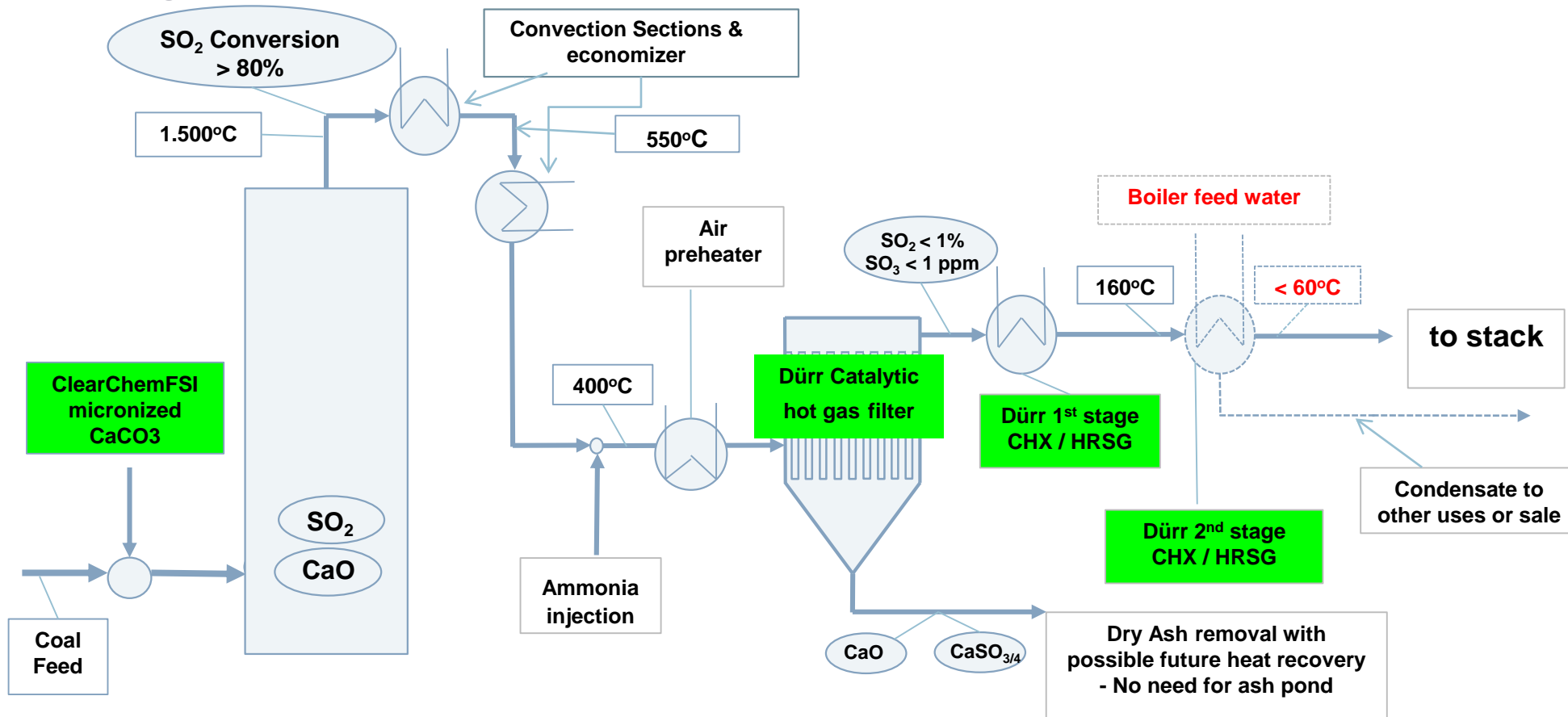
³ Published work by Consol and Lehigh indicate cooling helps capture of Hg in existing systems suggesting that the FSI + CHX combination might eliminate the ACI bringing potential savings to 0.00309 to 0.00916 USD/kWhr.

ClearChemFSI™

APC PROFIT CREATION



APC Adding Value to Plant Economics



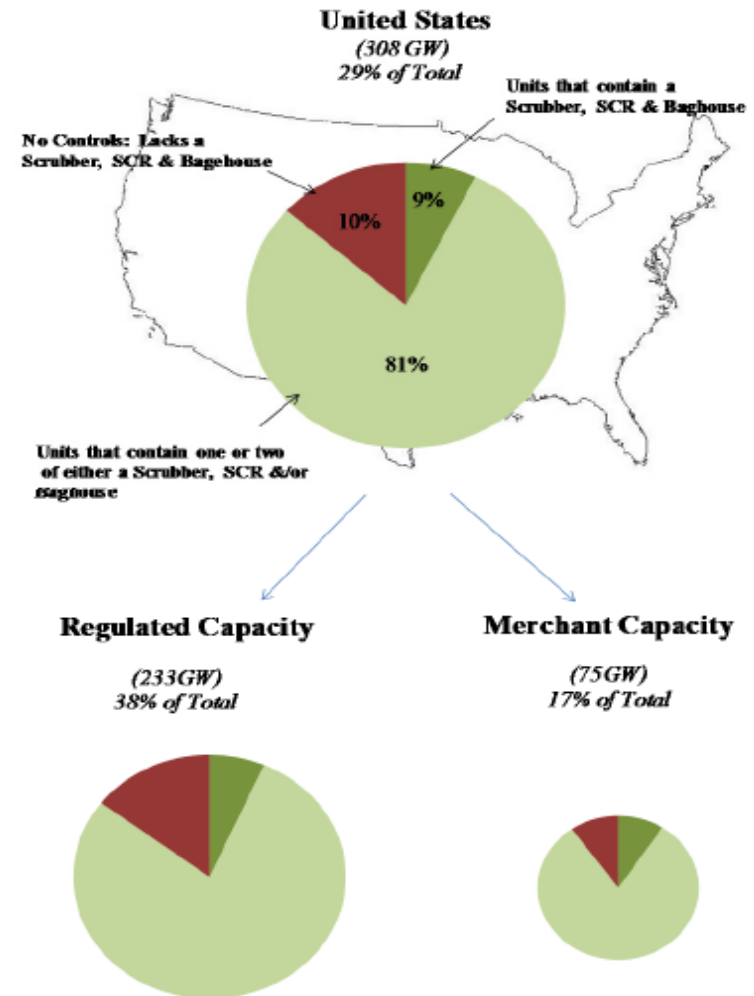
EXISTING U.S. COAL-FIRED BOILERS

Installed APC Technology Distribution

Coal-fired capacity (308 GW) represents about 1/3rd of the total generation capacity

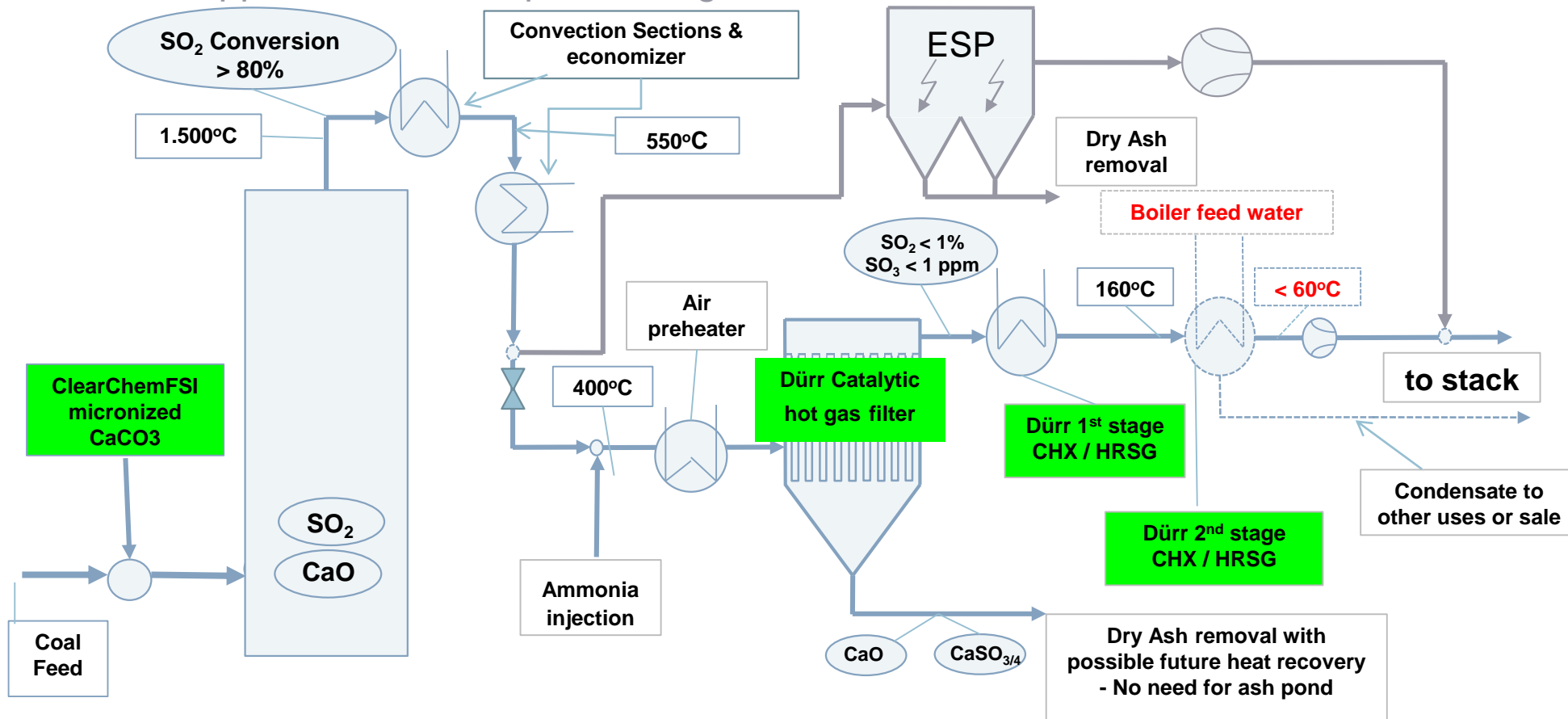
- Majority of coal capacity (233 GW) is owned by regulated companies (IOUs, munis/coops, etc.), and the rest (75 GW) is owned by merchant companies

Majority (93%) of the coal capacity lacks at least one major equipment (scrubber, SCR and baghouse) to control air emissions



EXISTING U.S. COAL-FIRED BOILERS

Side Stream Application – Example existing ESP



EXISTING U.S. COAL-FIRED BOILERS

Side Stream CAPEX

- ✓ Side stream is combined with existing APC equipment
 - FSI, DSI, ESP, SNCR, SCR or FGD
- ✓ Side stream is a perfect choice to add new APC functionality while enhancing reduction of existing equipment for
 - SO₂, NO_x, NH₃, PM and SO₃
- ✓ CAPEX for side stream installation will be reduced according to the flow distribution
- ✓ Additional savings result from partial load operation mode of existing equipment

CONCLUSION – KEEP IT SIMPLE

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	side stream		existing	ClearChem FSI	Dürr CHX
	existing		existing	ClearChemFSI	Dürr CHX

- ✓ Exploit synergies
- ✓ Create profit by releasing latent energy
- ✓ Utilize existing equipment
- ✓ Preserve existing sales channels
- ✓ Avoid additional OPEX
- ✓ **Conclusion is valuable enough having filed for patent**

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