REINHOLD ENVIRONMENTAL Ltd.

2013 APC Round Table & Expo Presentation

July 8-9, 2013, in St. Louis, MO / Hosted by Ameren

The Value Proposition of Circulating Fluidized Bed Scrubbing Technology

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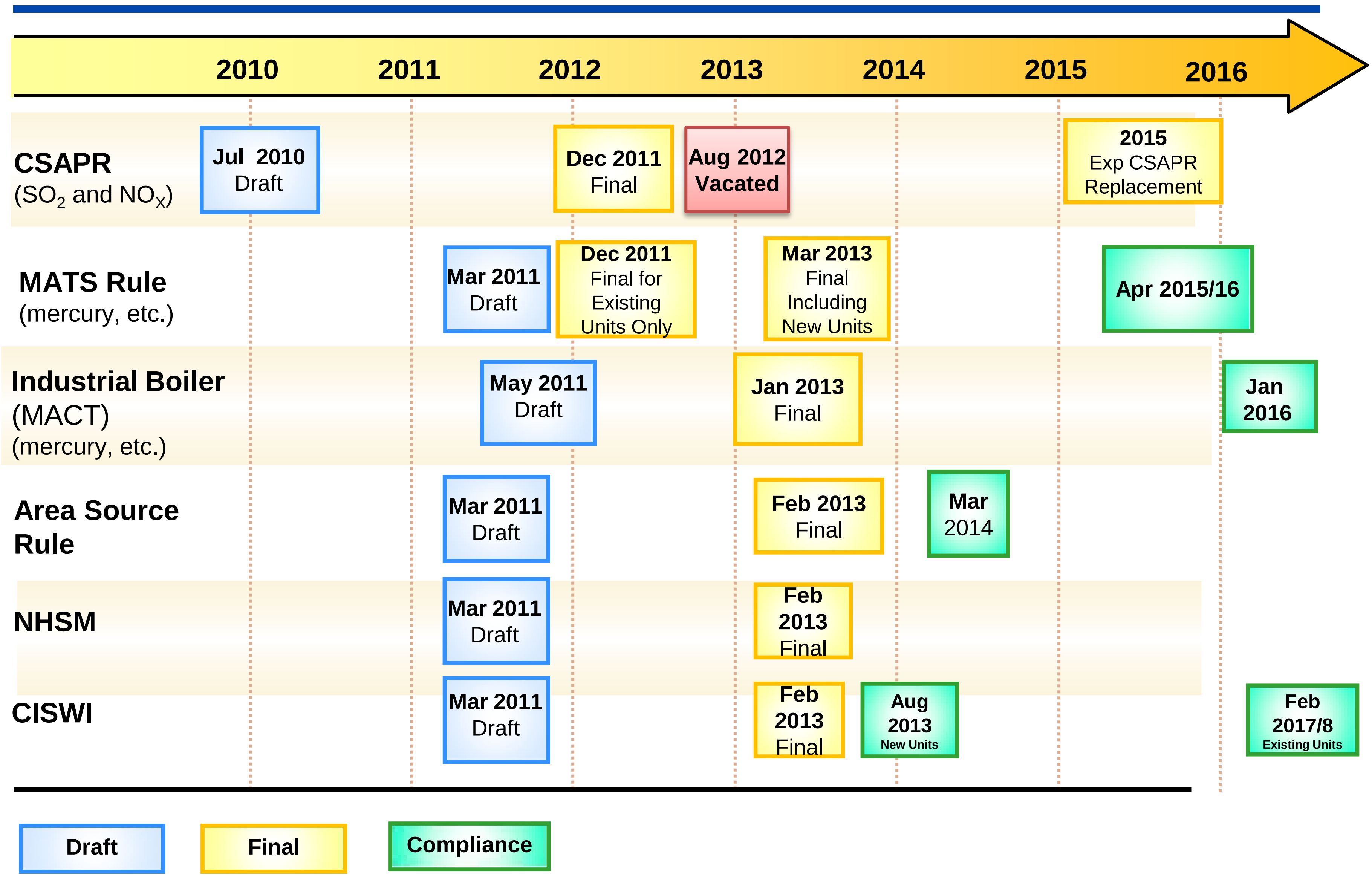
Rev 070813

EPA Rules Timeline



SOx and NOx Regulation
- The Cross State Air Pollution Rule (CSAPR)

- CAIR (clean air interstate rule) struck down
  - Effective during 2005-2008 allowing 31 eastern states to freely trade SOx and NOx allowance credits
  - Vacated by DC district court in 2008 due to disconnect with state national ambient air quality standards (NAAQS)
- CSAPR (cross state air pollution rule) struck down
  - EPA finalized CSAPR on December 16, 2011, which had similar overall NOx, SOx reductions as CAIR, but with restricted allowance trading to better control interstate pollution and help downwind states meet their NAAQS. Program was planned to take effect January 1, 2012.
  - On December 30, 2011, the US Court of Appeals for the D.C. Circuit issued a ruling to stay CSAPR pending a judicial review
  - On August 21, 2012, US Court of Appeals for the D.C. Circuit vacated the Cross-State Air Pollution Rule (CSAPR) and directed EPA to continue implementing the previously-vacated Clean Air Interstate Rule (CAIR)
    - Judges ruled that EPA violated the Clean Air Act by requiring states to reduce cross-state emissions by more than necessary and failed to first let each state implement the necessary emission reductions before implementing federal controls
    - EPA requested a rehearing from the full D.C. Circuit but the court denied it

Mercury and Air Toxics Standards Rule (MATS) - Formally Utility MACT

- On December 21, 2011 the EPA released the final version of the Mercury and Air Toxics Standards Rule (MATS)
  - Under section 112 of the CAA requiring a maximum achievable control technology (MACT) standard for hazardous air pollutants (HAPs)
  - Applies to all electric generating units 25 MWe or larger that burn coal or oil
  - The rule identifies two subcategories of coal-fired units, four subcategories of oil fired units and a subcategory for units that combust gasified coal or solid oil (IGCC)
  - For coal-fired units, numerical emission limits for measurable HAPs are established for mercury, PM (a surrogate for non-mercury metals), and HCl (a surrogate for all acid gases)
- MACT standard establishes emission limits based on:
  - For existing units: emission limit is based on average emission achieved by the best performing 12% of existing sources
  - For new units: emission limit is based on best controlled "similar" source
- On April 24, 2013, EPA relaxed the MATS emissions limits (Hg, HCl, PM) for new sources relative to their original proposed limits in response to strong industry opposition
  - 12 times higher for PM,
  - 15 times higher for Hg,
  - 25 times higher for HCl,
  - 2 times higher for alternative sulfur dioxide (SO2)

Mercury and Air Toxics Standards Rule (MATS) - Coal-Fired Unit Emission Limits

Category	Existing Unit		New or Reconstructed[2] Unit		Measurement Method (EPA or Otherwise)
	Unit designed for low rank virgin coal[1]	Not low rank virgin coal	Unit designed for low rank virgin coal[1]	Not low rank virgin coal	
Filterable Particulate Matter (PM)	0.03 lb/mbtu	0.03 lb/mbtu	0.09 lb/MWh	0.09 lb/MWh	Method 5 , PM CEMS
Total or individual non-Hg metals	Filterable PM (above) is considered a surrogate				Method 29
Hydrogen Chloride (HCl)	0.002 lb/mbtu	0.002 lb/mbtu	0.01* lb/MWh	0.01* lb/MWh	Methods 26, 26A or HCl/HF CEMS
Mercury	4.0 lb/Tbtu	1.2 lb/Tbtu	0.04 lb/GWh	0.003 lb/GWh	Method 30B or Hg CEMS
Sulfur Dioxide[3]	0.2 lb/mbtu	0.2 lb/mbtu	1.0 lb/MWh	1.0 lb/MWh	(SO2) SO2 CEMS

Note 1. EPA defines a unit burning low rank virgin coal as a unit burning non-agglomerating virgin coal having a calorific value (moisture, ash free basis) of less than 19,305 kJ/kg (8,300 Btu/lb) and that is constructed and operates at or near the mine that produces such coal , 2. Reconstructed units are defined as having undergone upgrade or refurbishment work totaling over 50% of the cost of a new unit. 3. If unit has a FGD and CEMS, then HCl limit can be met instead by SO2 surrogate limit of 0.2 lb/mbtu (Existing) or 0.4 lb/MWh (New unit). New sources must use CEMS or CPMS as the measurement methods for filterable PM compliance.

Mercury and Air Toxics Standards Rule (MATS) - Coal-Fired EGUs Compliance Timing

- New sources
  - Published in the Federal Register on April 24, 2013
  - PLUS 60 days or upon startup, whichever is later
- Existing Sources
  - Published in the Federal Register on February 16, 2012
  - PLUS 60 days (April 16, 2012)
  - PLUS three years (April 16, 2015)
- One-Year Extension can be granted by state permitting authority when:
  - unit will not be retired and extension necessary for the installation of controls on-site
  - unit will retire, but extension necessary for the construction of replacement power on-site
  - unit will retire, but extension necessary for:
    - the installation of controls off-site
    - construction of replacement power offsite
    - or construction of additional transmission AND serious risk to electric reliability exists
- One-Year Administrative Order
  - EPA issued a enforcement policy memo indicating a “5th year” will be available for “reliability critical” units

The Industrial Boiler MACT Rule - Outlook and Impact

- Targets major sources facilities and will Impact:
  - 14K boilers and process heaters at 1600 industrial facilities
  - Some universities, municipalities, and military installations
  - All types of boilers and heaters: coal, biomass, gas and liquid fueled
  - Major sources defined as producing over 10 tpy of any single HAP or 25 tpy for all HAPs
- Set emissions limits and MACT standard for boilers over 10 Mbtu/hr (1 MWe) heat input
  - Sets emission limit and MACT standard for 4 HAPs or surrogates: Hg, CO, HCl, PM
  - Annual compliance testing for all pollutants with annual unit tune-ups
  - CEMs for CO, PM (units over 250 Mbtu/hr (25 MWe)) with 30 day rolling average compliance
  - Natural gas and units under 10 Mbtu/hr require only work practice standard and annual tune-ups
- On Dec. 2, 2011, EPA proposed revised rule replacing dioxin limits with work practice, revising PM and CO limits, an exempting biomass plants from PM CEMS
- Later in December 2011, EPA stayed the rule due to unresolved public comments
- On Jan 9, 2012, DC District Court vacates EPA's stay making the rule effective on this day
- EPA responded by issuing a guidance document indicating it will not enforce rule
- EPA issued final rule on December 20, 2012 (published in Federal Register January 31, 2013) which reduces the stringency of many of the emission limits that will be imposed on industrial boilers and extends the deadline for compliance until early 2016
- The final rule also divides "boilers" into 19 subcategories and contains over 100 different emissions limits

Industrial Boiler MACT Emission Limits

Comparing June 2010 Proposal, February 2011 Final, December 2011 Reconsideration Proposal, and December 2012 Final Rule

	PM (lb/mmBtu)				HCl (lb/mmBtu)				Hg (lb/mmBtu)				CO (ppm @ 3%O_2) see note 2			
	2010 Prop.	2011 Final	2011 Recon.	2012 Final	2010 Prop.	2011 Final	2011 Recon.	2012 Final	2010 Prop.	2011 Final	2011 Recon.	2012 Final	2010 Prop.	2011 Final	2011 Recon.	2012 Final
New PC Coal	0.001	0.0011	0.0013	**0.011**	6.0e-5	0.0022	0.022	**0.022**	2.0e-6	3.5e-6	8.6e-7	8.0e-7	90	12	9 28	**130 320**
Ex. PC Coal	0.02	0.039	0.044	**0.04**	0.02	0.035	0.022	**0.022**	3.0e-6	4.6e-6	3.1e-6	**5.7e-6**	90	160	41 28	**130 320**
New Bio Stoker	0.008	0.0011	0.029	**0.030**	0.004	0.0022	0.022	**0.022**	2.0e-7	3.5e-6	8.6e-7	**8.0e-7**	560	160	590 410	**620 390**
New Bio BFB	0.008	0.0011	0.0098	**0.0098**	0.004	0.0022	0.022	**0.022**	2.0e-7	3.5e-6	8.6e-7	**8.0e-7**	40	260	230 180	**230 310**
New Bio Susp.	0.008	0.0011	0.051	**0.030**	0.004	0.0022	0.022	**0.022**	2.0e-7	3.5e-6	8.6e-7	**8.0e-7**	1,010	470	58 1,400	**2,400 2,000**
Ex. Bio Stoker	0.02	0.039	0.029	**0.037**	0.006	0.035	0.022	**0.022**	9e-7	4.6e-6	3.1e-6	**5.7e-6**	560	490	790 410	**1,500 720**
Ex. Bio BFB	0.02	0.039	0.11	**0.11**	0.006	0.035	0.022	**0.022**	9e-7	4.6e-6	3.1e-6	**5.7e-6**	250	430	370 180	**470 310**
Existing Bio Susp.	0.02	0.039	0.051	**0.051**	0.006	0.035	0.022	**0.022**	9e-7	4.6e-6	3.1e-6	**5.7e-6**	1,010	470	58 1,400	**2,400 2,000**
New Hvy Liquid	0.002	0.0013	0.013	**0.013**	0.0004	0.0032	0.0012	**0.00044**	3.0e-7	2.1e-7	4.9e-7	**4.8e-7**	1	3	10 18	**130**
Ex. Hvy Liquid	0.004	0.0075	0.062	**0.062**	0.0009	0.0003	0.0012	**0.011**	4.0e-6	3.5e-6	2.6e-5	2.0e-6	1	10	10 18	**130**

- Less stringent than the limit immediately preceding it
- More stringent than the limit immediately preceding it
- Same as the limit immediately preceding it
- Initial limits proposed in 2010 or the completely re-evaluated stack test and CEMs limits for CO proposed in 2011.

[1]The 2012 final limits in bold font are less stringent than the original 2010 proposal.

[2]The stack test limits are provided above the CO CEMS limits (10-day or 30-day average).

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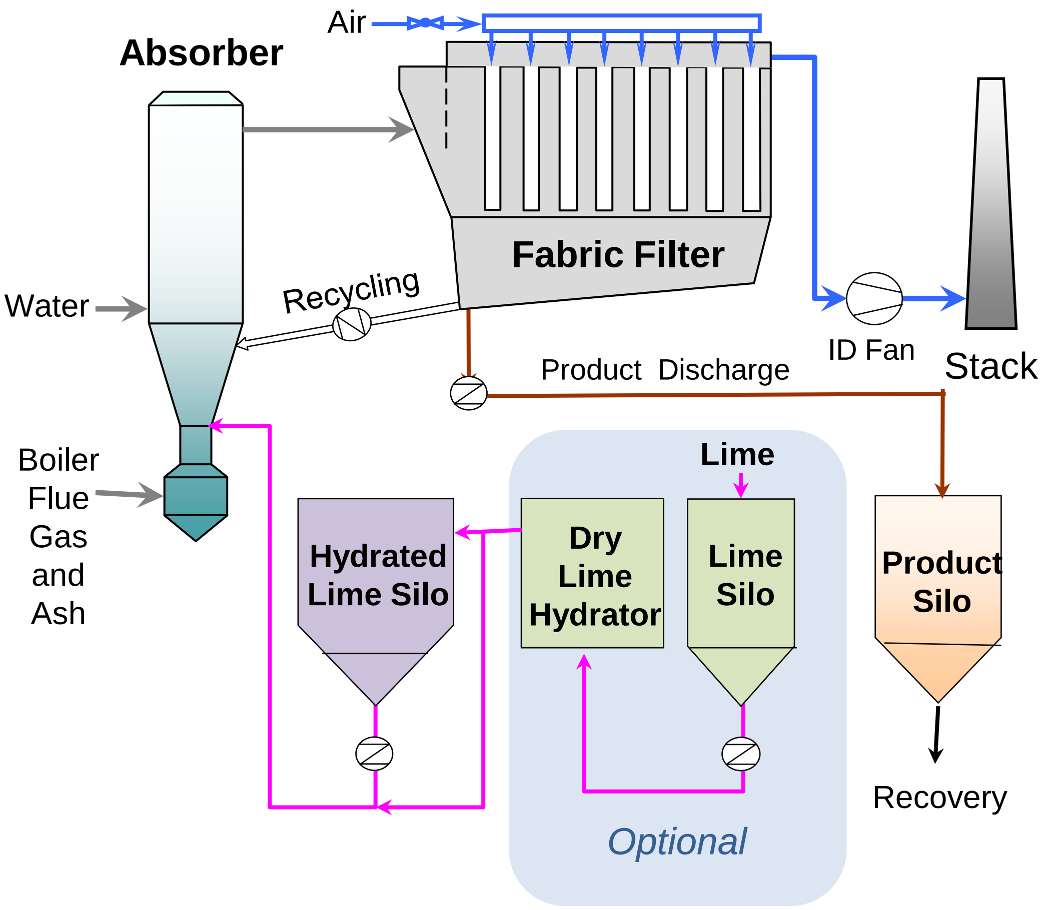
Circulating Fluidized Bed Scrubbing Technology

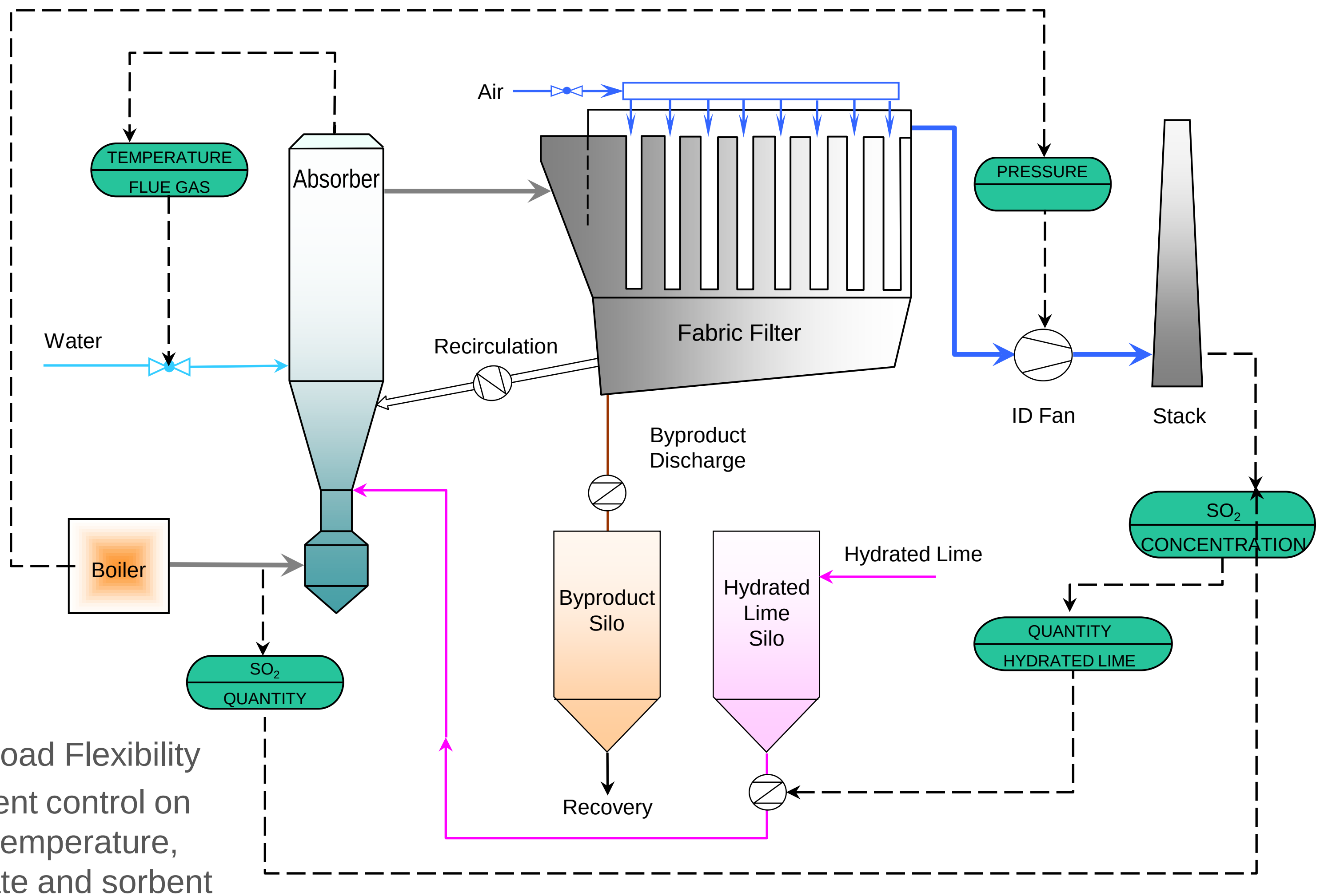


Flexible, reliable multi-pollutant capture with minimal water consumption

How does it work?

- Flue gas with or without ash enters the bottom of the absorber, flowing upward through venturi to accelerate the gas flow causing turbulence flow.
- Recycled solids, hydrated lime and water mix with the turbulent flue gas providing gas cooling, reactivation of ash and capture of pollutants.
- The gas and solids enter the baghouse where solids are captured and recycled back to the absorber to capture more pollutants
- Reactive absorbents like activated carbon or others can be added to target specific pollutants
- Optional dry lime hydrator produces hydrated lime on-site from lower cost quick lime

Independent Reagent and Water Control Provides Widest Capture Range and Minimal Water Need



Fuel and Load Flexibility

Independent control on flue gas temperature, recycling rate and sorbent injection.

FW CFB Scrubber Achieves High Capture of Multiple Pollutants

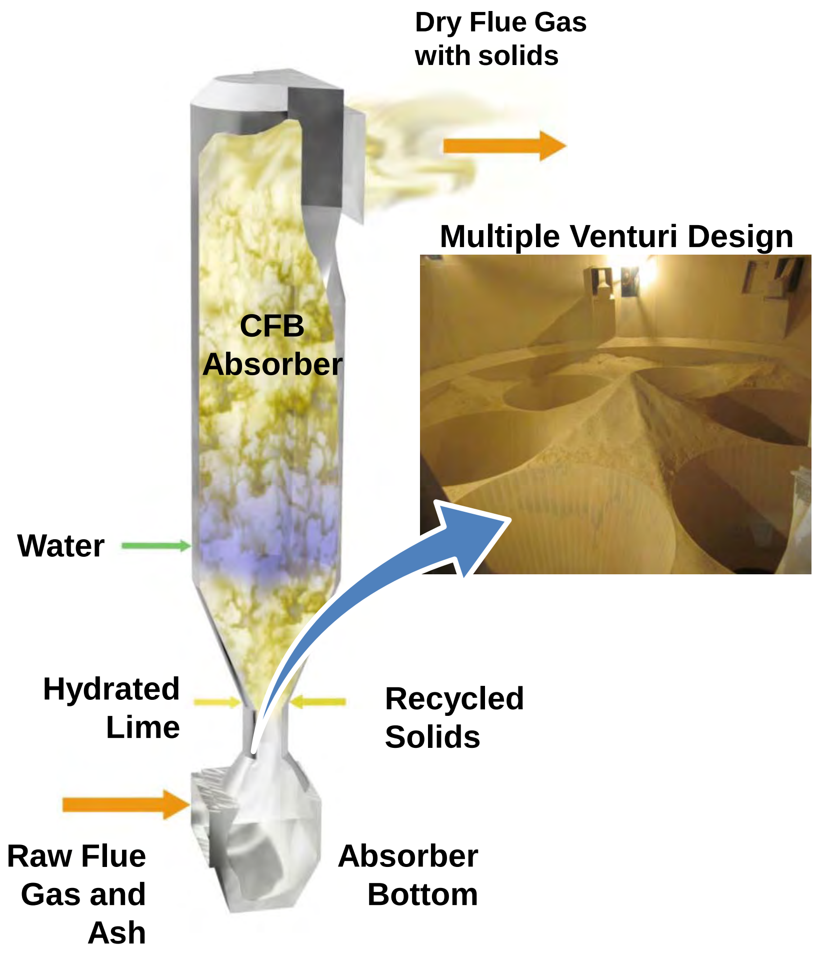
- Typical Performance for Foster Wheeler Circulating Fluidized Bed Scrubbers

Pollutant		Outlet Condition [2]	Removal Rate	Notes
SO_2 and SO_3	$[mg/m^3]$	10 – 50	Up to 99%	
HCl	$[mg/m^3]$	1 – 10	85 – 99%	
HF	$[mg/m^3]$	0,1 – 1	99%	
Hg [1]	$[\mu g/m^3]$	3 – 50	60 – 80%	Low halogen PRB coal
	$[\mu g/m^3]$	1 – 35	80 – 90%	With lignite coke injection
	$[\mu g/m^3]$	1 – 30	90 – 99%	With lignite coke/activated carbon injection
Dioxines, Furanes [1]	$[ng/m^3]$	0,009 – 0,08	95 – 98%	

1) Total of all compounds in all phases expressed as elements
2) Definition of standard: 20° C; 1,013.25 hPa
3) Outlet conditions range depending on flue gas inlet conditions

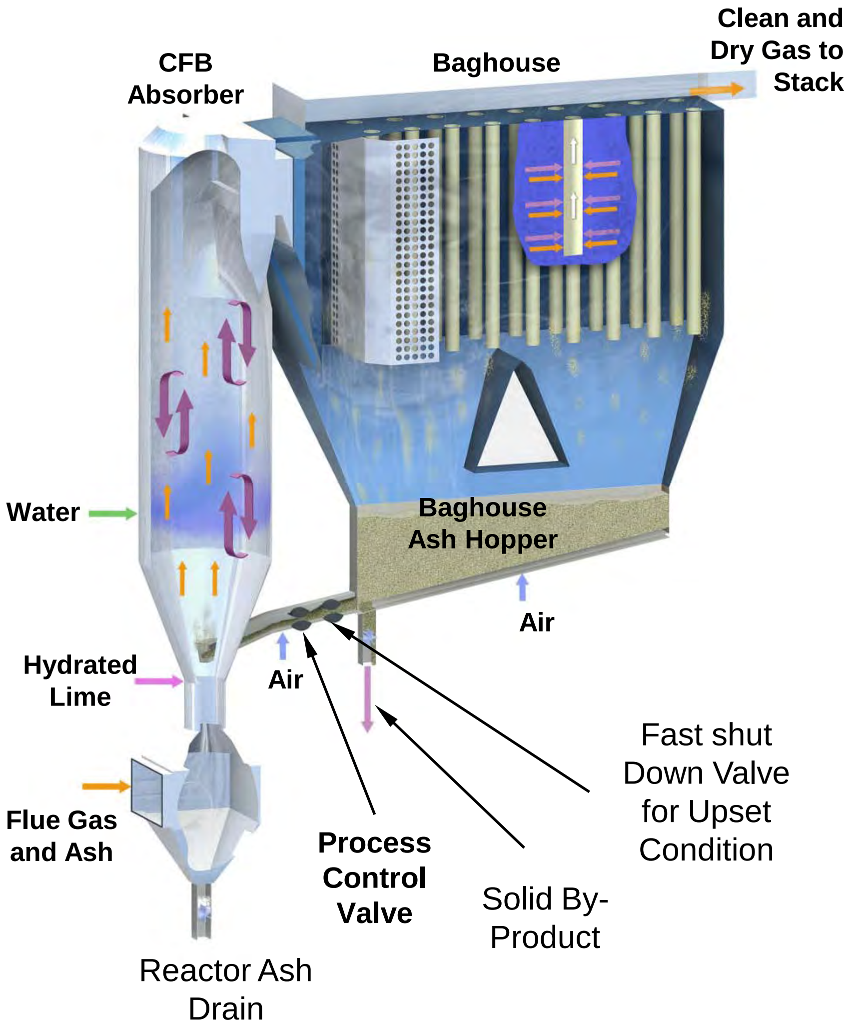
Design Features of CFB Absorber

- Turbulent CFB absorber provides optimized conditions for multi-pollutant capture
  - Flue gas is efficently mixed with hydrated lime and water for 4-6 seconds (NID is about 1 sec)
  - Wall turbulators Increase turbulence near wall
- Flexible process provides wide performance and load range
  - Hydrated lime injection not limited by gas temperature to achieve high pollutant capture
  - Solids and water injected above venturi to ensure high turbulant mixing at low loads
- Low Maintenance
  - Low maintenance water nozzles can be replaced while unit is online
  - Solid circulation keeps reactor surfaces clean
  - No mechanical spray heads to maintain
  - Absorber bottom allows easy solids removal for maintenance
- Multiple venturis allow single absorber designs up to 800 Mwe



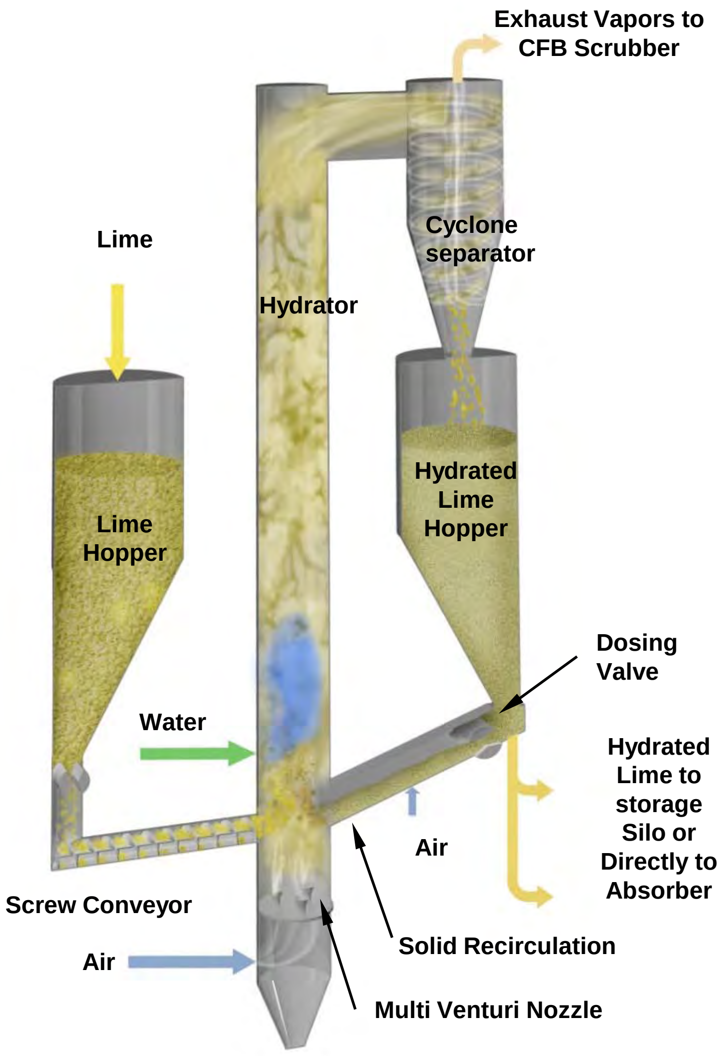
Baghouse and Solid Circulation Design Features

- High Utilization of Sorbents
  - Circulating solids can keep reagents in system up to 20-30 minutes for high utilization
- Fluidized ash storage in baghouse reduces installed cost and improves system reliability
- Highly reliable low maintenance air slide
  - No mechanical paddle mixer with their associated maintenance and reliability issues
  - Fast shutdown valve for automatic purging of absorber solids during boiler trip
- Advanced two stage baghouse
  - Drop-out chamber allows high dust loading while maintaining low pulse frequency and long bag life
  - Bag filter cake captures vapor phase metals, acid gases and ammonia slip
- Dry sorbent and product are easy to handle
  - No slurry preparation, handling, dewatering, liquid waste streams



FW Lime Hydrator Improves Sorbent Economics and Operational Flexibility

- Produces high quality hydrated lime from economical quick lime
  - High hydrated lime BET surface area improves capture efficiency and lime utilization
- Low maintenance and reliable hydrator
  - No mechanical mixers
  - No rotating parts (except screw conveyor)
  - No slurry handling
  - No exhaust fabric filter or point source emission
- Operational Flexibility
  - Hydrator turn down to 25%
  - Adjustable $Ca(OH)_2$ Reactivity Range
    - Higher moisture level when direct feeding to CFB absorber for higher reactivity
    - Lower moisture level for stable silo storage



CFB Scrubber Technology Advantages

Wet FGD, Spray Dryer FGD, Circulating Fluid Bed FGD

	Wet FGD	SDA FGD	CFB FGD
SO_2 Capture to Meet Low Permit Limits	Advantage	Disadvantage	Advantage
Low Water Consumption	Disadvantage	Advantage	Advantage
Fuel Flexibility (Fuel Sulfur Variability)	Advantage	Disadvantage	Advantage
Fine Particulate Capture	Disadvantage	Advantage	Advantage
High SO_3 Capture Efficiency	Disadvantage	Advantage	Advantage
Mercury Capture	Disadvantage	Neutral	Advantage
Compact System Footprint	Disadvantage	Neutral	Advantage
Minimal Maintenance Requirements	Disadvantage	Neutral	Advantage
Overall			Advantage

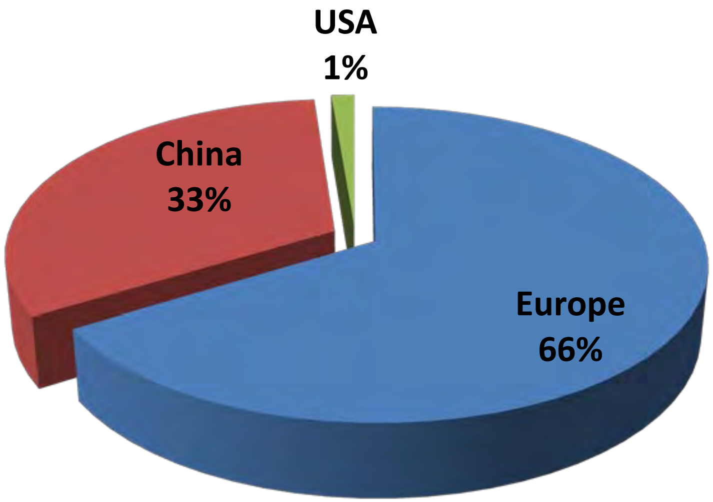
Advantage (green) **Neutral** (blue) **Disadvantage** (red)

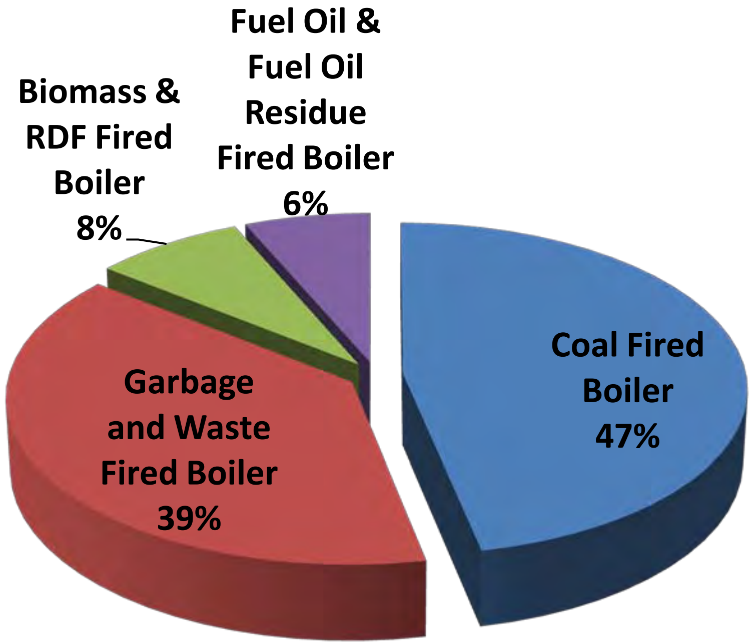
Source: Basin Electric/Sargent & Lundy Study

FW CFB Scrubber Technology is Proven in Multiple Applications Up to the Utility Scale

77 FW units installed worldwide

- About 25% with ESPs/ 75% with Bag House
- Single unit size up to 520 Mwe (sea level altitude)





Largest CFB Scrubber is at Dry Fork Station

- Plant Location: Gillette, Wyoming, USA
- Plant Elevation ft (m): 4,300 (1,300)
- Customer: Basin Electric Power Cooperative
- Plant Start-Up: June 26, 2011
- Plant Electrical Output: 420 MWe (520 MWe@SL)
- Fuel: PRB Coal
- Scrubber configuration: 1 Reactor, 1 Fabric Filters
- Fuel Sulfur Content: 0.5-7.5%daf
- SO2 Removal: Up to 97%
- SO3 Removal: Up to 96%

Plant MCR Load	Inlet	Outlet	Removal %
Flue gas flow, ACFM (Nm3/h)	1,792,000 (1,580,000)	1,550,000(1,690,000)	
SO2 lb/MMBtu (mg/Nm3)	0.30-1.79 (350-2,200)	0.06 (60-75)	80 - 97%
SO2 ppmv	130-770	20-25	77 - 97%
SO3 ppmv (mg/Nm3)	8-14 (25-42)	0.3-0.6 (1-2)	96%
HCl ppmv (mg/Nm3)	5-9 (8-15)	2-3 (4-6)	60 - 67%
Dust lb/MMBtu (mg/Nm3)	3-5 (4,000-6,000)	0.012 (12-17)	99.6 - 99.9%
Temperature °F (°C)	294 (146)	155-175 (70-80)	

Definition of standard: 68°F, 14.7psig

FW CFB Scrubber at Refinery in Germany

- Plant Location: Germany
- Customer: Undisclosed
- Plant Start-Up: 2012
- Plant Electrical Output: 2×175 MWth
- Fuel: Heavy Fuel Oil
- Scrubber configuration: 2 Reactor, 2 Fabric Filters
- Fuel Sulfur Content: 1-5%daf
- SO2 Removal: Up to 97%
- SO3 Removal: Up to 97%

Plant MCR Load	Inlet	Outlet	
Flue gas flow of each scrubber ACFM (Nm3/h)	225,000 (227,000)	215,000 (257,000)	
SO2 lb/MMBtu (mg/Nm3)	0.7-1.8 (1.9-7.3)	0.06 (200)	91 – 97%
SO2 ppmv	600-2,600	70	88 – 97%
SO3 ppmv (mg/Nm3)	14-270 (50-970)	0.1-1.4 (0.5-5)	99.3 – 99.5%
Particulate ppmv (mg/Nm3)	0.033 (65)	0.01 (20)	70%
Temperature °F (°C)	360 (180)	180-210 (80-100)	

Definition of standard: 68°F, 14.7psig

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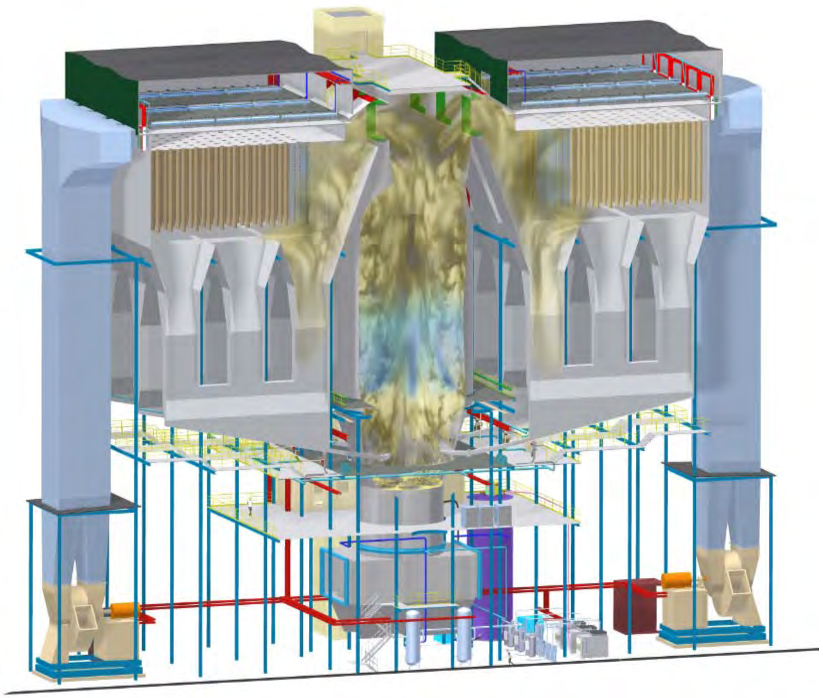
The Value Points of FW's CFB Scrubber

- High Multi-Pollutant Capture Capability
  - Over 99% Capture of SO_2, SO_3, HCl, HF
  - 70-95% Hg capture
- Low Installed Cost
  - 30- 50% less than wet FGD with better multi-pollutant performance
- Low Water Use
- High Reliability and Low Maintenance
- High Operational Flexibility
  - Flue gas temperature does not limit lime injection providing wide range of capture
  - Lower cost lime can be used with Hydrator
- Compact footprint
- Flexibility to use low-quality lime and water
- Proven Reference at 525 MWe.



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Thank You For Listening