DeSOx Solutions for Indian Thermal Power Plants – Overview

Agenda

- Key Regulatory Drivers for DeSOx Solutions in Indian Power Plants
- DeSOx Technology Coverage of Isgec – Product/Technology Portfolio
- Introduction to the following Technologies:
  - Wet FGD
  - Semi Dry FGD
  - Dry Sorbent Injection (DSI)
- Conclusion – Technology Comparison and Suitability
- Isgec Experience on Various Technologies

Key Regulatory Drivers: Indian Power Plants

Pollutant	Unit*	TPPs installed before December 31, 2003	TPPs installed after 2003 to December 31, 2016	TPPs to be installed from January 1, 2017
SOx	mg/Nm^3	600 (<500 MW) 200 (>=500 MW)	600 (<500 MW) 200 (>=500 MW)	100

The above mentioned norms were introduced in Dec 2015 before which the SO_2 emission was governed by Chimney Height

***Corresponding to 6% O_2 Dry Volume**

DeSOx Technology Coverage of Isgec – Product/Technology Portfolio

Wet FGD

- Under Collaboration and Technology Transfer Agreement with BPE for Units > 100 MW

Semi Dry FGD

- Under Licensing Agreement with Sumitomo SHI FW for Units> 50 MW

Dry Sorbent Injection (DSI)

- Under case-to-case basis Licensing agreement with United Conveyor Corporation (UCC Environmental), USA.

Wet Flue Gas Desulphurisation (FGD) Technology

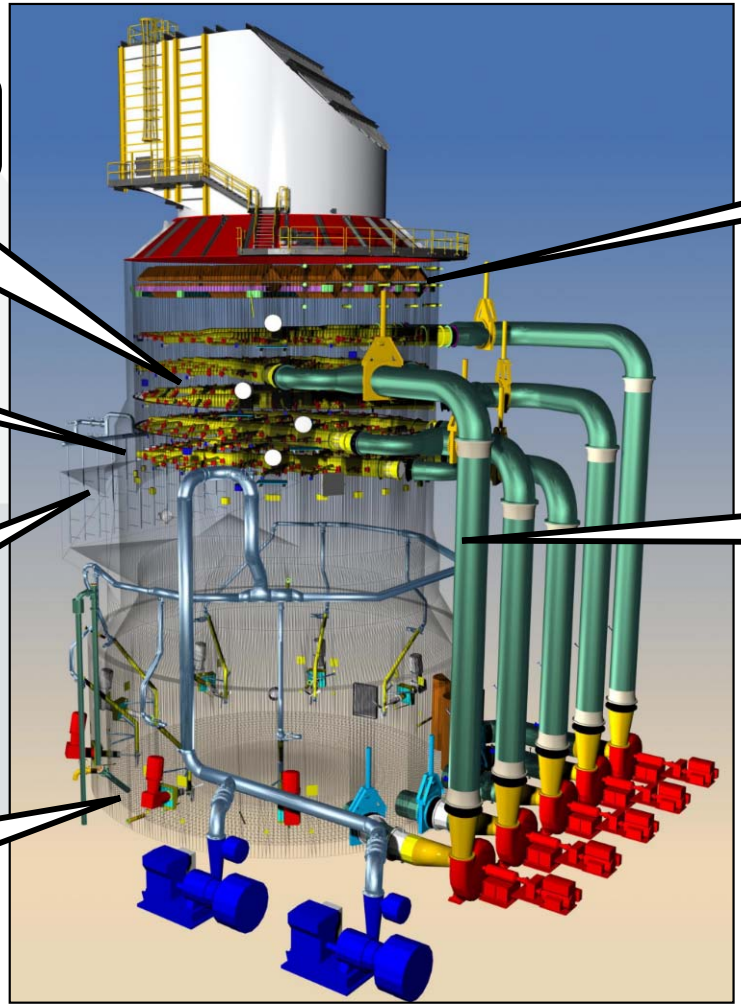
Wet Flue Gas Desulphurisation (FGD) Technology

- Single Loop Open Spray Tower Design
- Efficient use of reagents
- High chlorine designs
- Bidirectional nozzles installed
- Wider-angle spray cone ensures efficient spray pattern in spray zone
- Increase gas - liquid collisions
- Dual direction allows for complete coverage
- Over 12 GWs in operation
- Industry leading removal efficiency
- Greater than 99%

Wet Flue Gas Desulphurisation (FGD) Technology

- >20 units: ~12,000 MW
- Open spray tower
- Dual spray nozzles and wall rings technology
- High (>99%) SO2 removal producing wallboard grade gypsum
- High Reliability: >99%

Wet Flue Gas Desulphurisation (FGD) Technology



Bi-Directional Spray Nozzles

2-Stage Internal Mist Eliminator

Wall Ring

Absorber Design Greater Than 500 MW

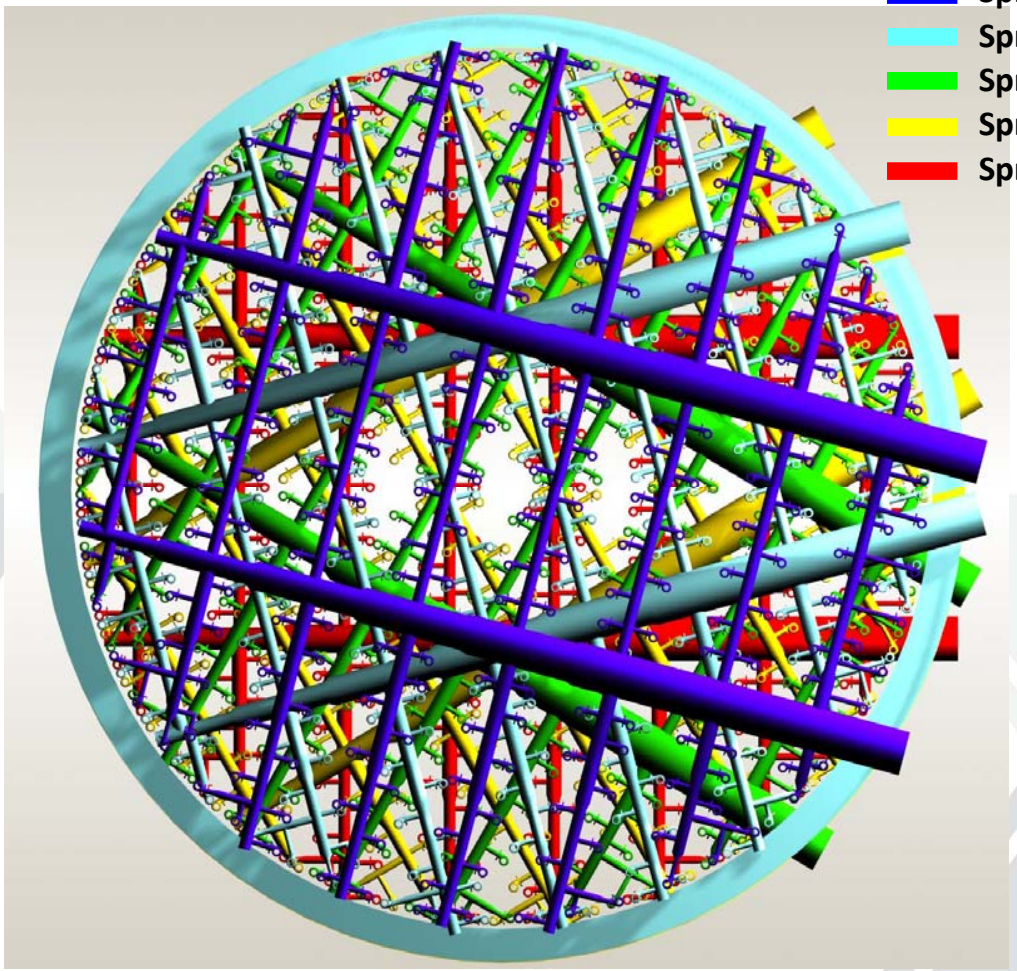
Absorber Inlet and Inlet Awning

Experience with Designing Systems to Treat Flue Gas from Multiple Units

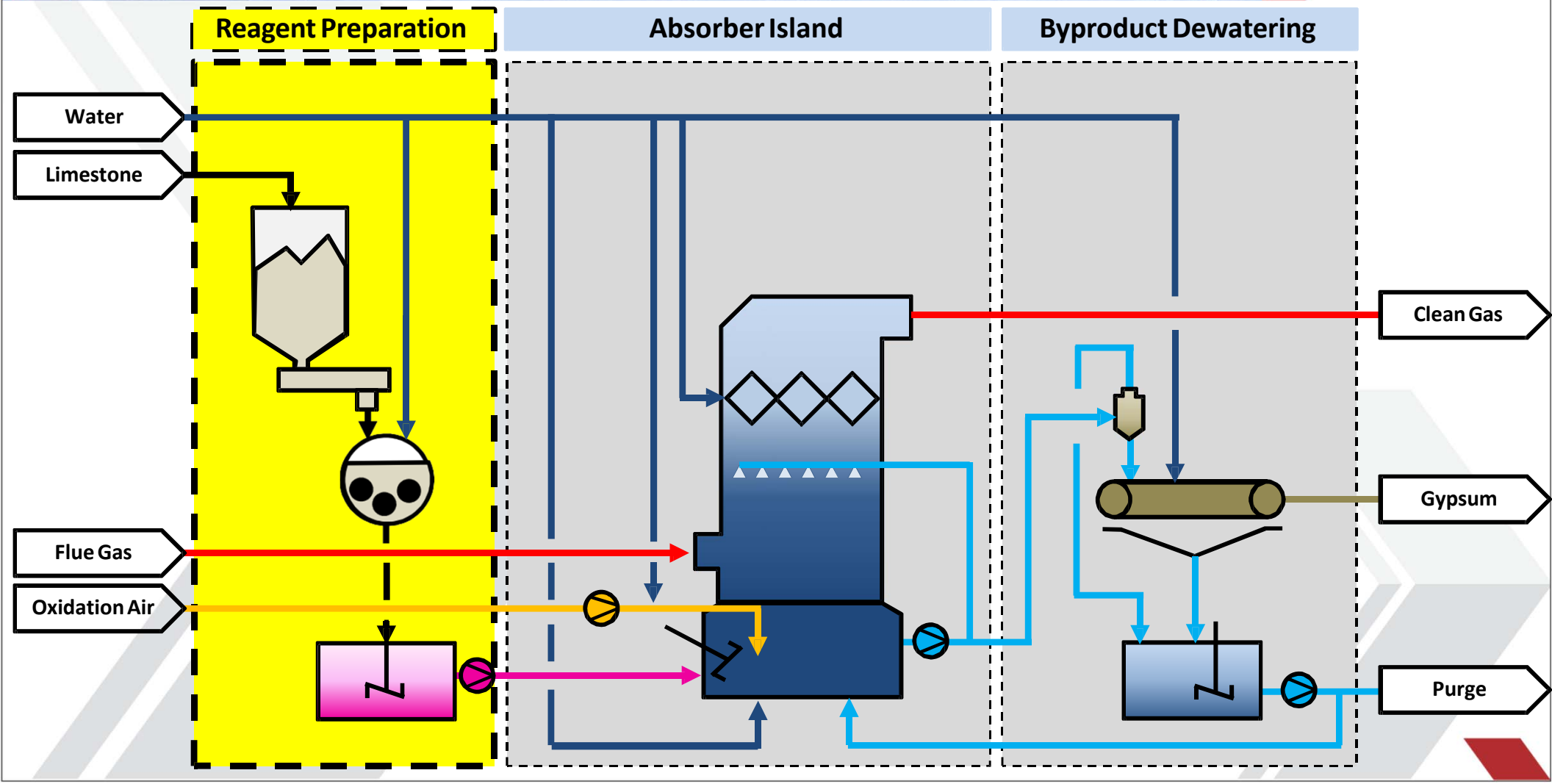
Reaction Tank forced oxidation with agitator

Wet Flue Gas Desulphurisation (FGD) Technology

Spray nozzles and piping arranged to minimize vertical alignment of nozzles and maximize spray pattern coverage



Wet Flue Gas Desulphurisation (FGD) Technology



Semi Dry Flue Gas Desulphurisation (FGD) Technology

(Circulating Fluidised Bed Scrubbers)

Semi Dry Flue Gas Desulphurisation (FGD) – CFBS Technology

Chemistry

$SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O$

$SO_2 + ½O_2 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O$

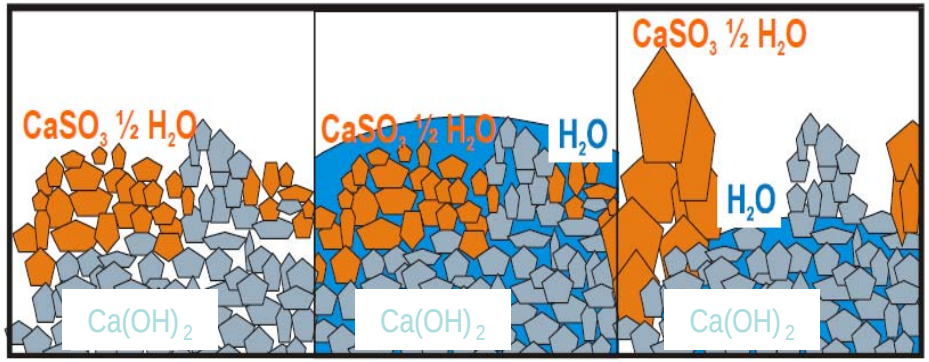
$SO_3 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O$

$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$

$2HF + Ca(OH)_2 \rightarrow CaF_2 + 2H_2O$

$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$

Formation of reaction products layer



Reaction after first pass	Water added to surface during fluidization	Sulfite crystal forms, exposing fresh surfaces

The reactions above take place in the dry desulphurization process in between the temperature range of 75 C – 145 C

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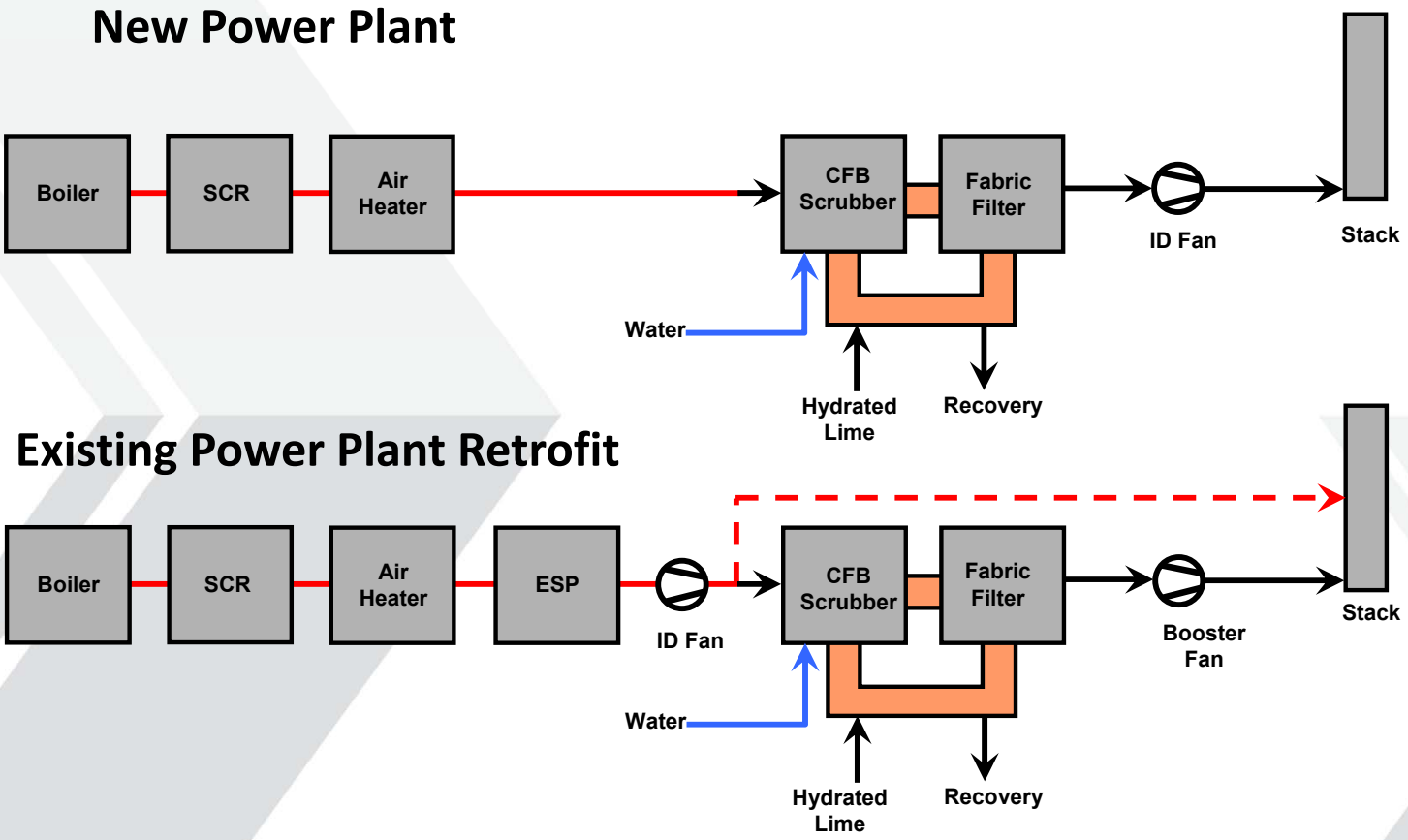
Main Power Plant Scrubber Arrangements



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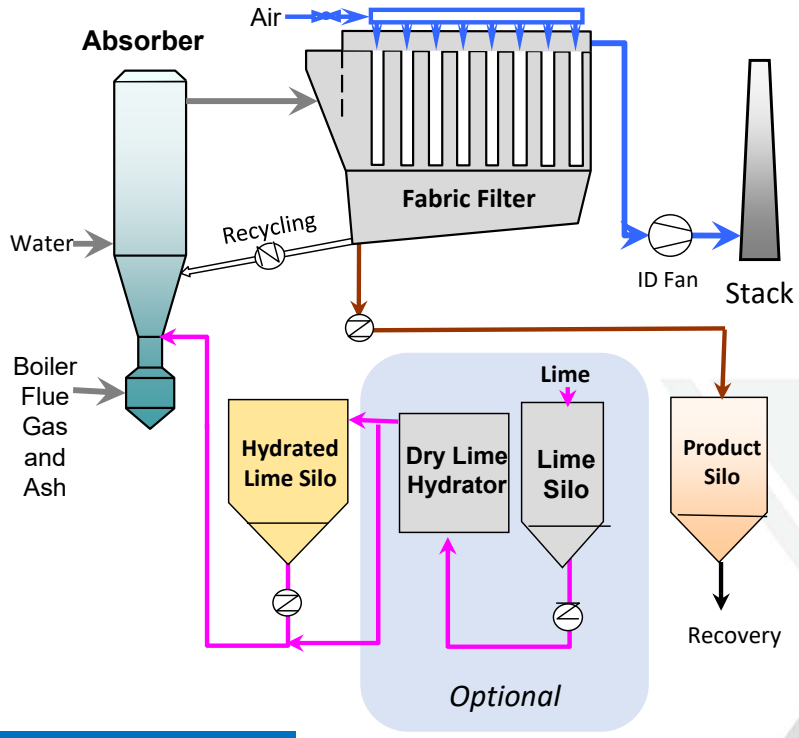
Circulating Fluidized Bed Scrubbing Technology

How does it work?

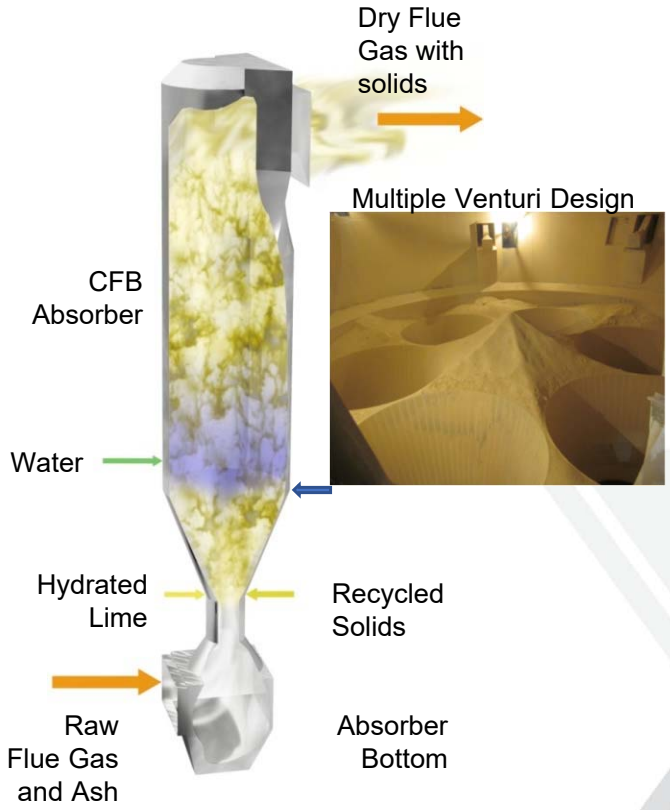
- Flue gas with fly ash enters the bottom of the absorber, flowing upward through venturi to accelerate the gas causing turbulent flow.
- Recycled solids, reagents and water mix with the turbulent flue gas providing gas cooling, reactivation of ash and capture of pollutants.
- The gas and solids enter the baghouse where solids are captured and recycled back to the absorber to capture more pollutants. Over 60% of the solids are recycled over and over to the absorber.
- Reactive absorbents like sodium carbonates, hydrated lime, 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 (project economics dictate need for onsite hydrator)



Flexible, reliable multi-pollutant capture with minimal water consumption

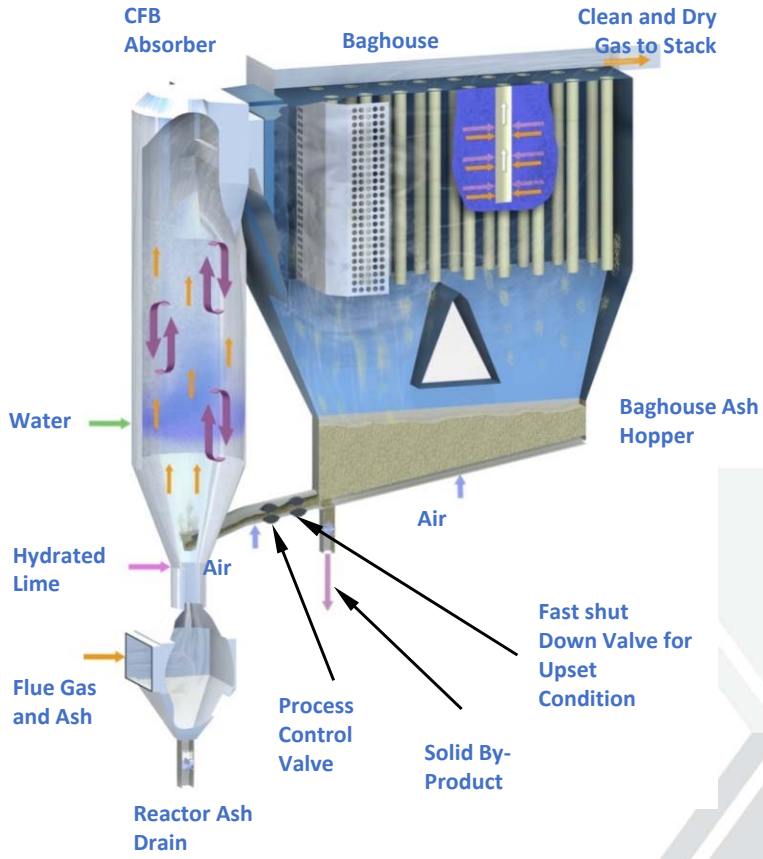
Design Features of our CFB Scrubber Absorber

- Optimized conditions for multi-pollutant capture
  - Turbulant flow efficently mixes fly ash, reagent and water
  - Residence time for gases 4-6 seconds and up to 60 seconds for solids in the absorber
  - Absorber operating temperature is chosen 15- 20 degrees above the dew point
- Wide performance and load range
  - Reagent injection not limited by gas temperature dew point so high pollutant capture can be achieved
  - Solids and water injected above venturi to ensure high turbulant mixing at low loads
- Low Maintenance
  - No mechanical lime spray
  - Solid circulation keeps reactor surfaces clean
  - Absorber bottom allows easy solids removal for maintenance
  - Water spray nozzles can be replaced online
- Multiple venturis allow single absorber designs up to 700 Mwe

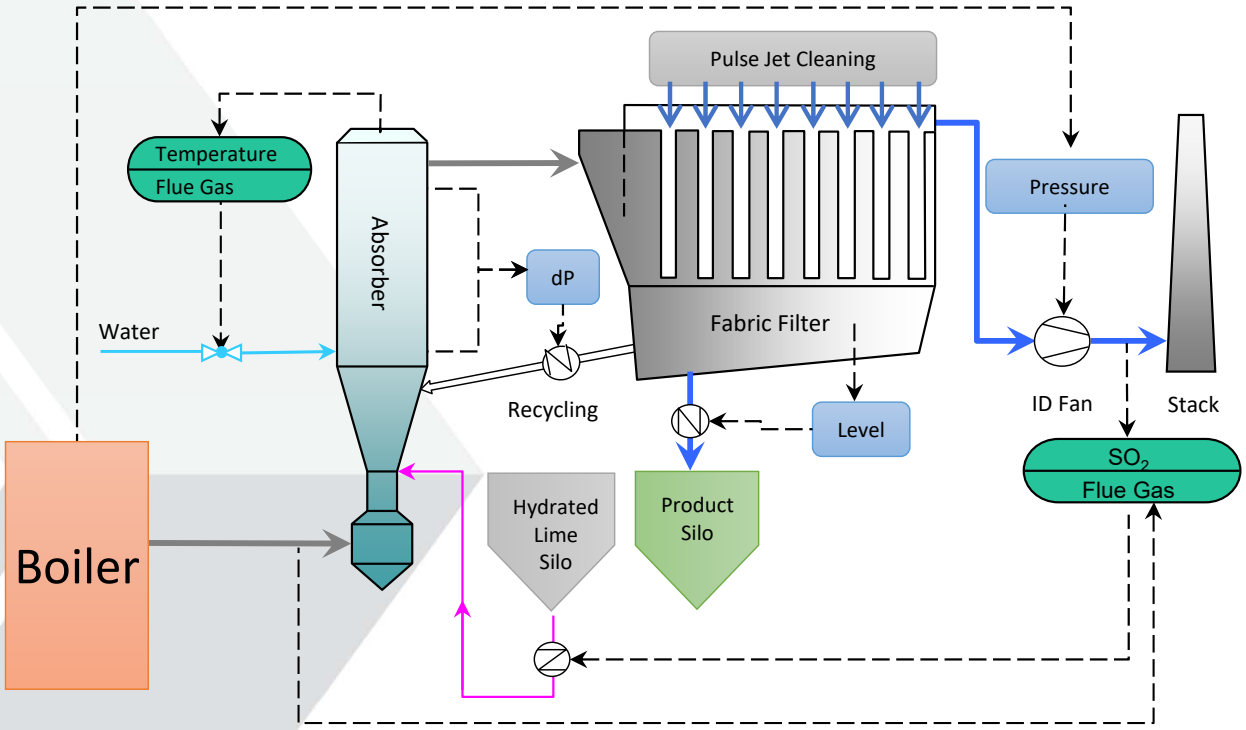


Baghouse and Solid Circulation Design Features

- High Utilization of Sorbents
  - Circulating solids can keep reagents in system up to 20-30 minutes
- 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 upset
- Baghouse does more than capture PM
  - 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
  - Stable dry by-product can be used for land restoration, road base or landfilled



Scrubber Control Provides Widest Capture Range with Minimal Lime and Water- Fuel and Load Flexibility



- Independent water control *maintains* dry flue gas at optimum temperature
- Independent sorbent control maintains stack emissions with changing fuels(recycling rate is controlled independently from FGT)
- Level detection in hopper is by vibrating probe type

Our CFBS Achieves High Capture of Multiple Pollutants

Performance Range of our Scrubber References

Pollutant	Stack Emission Level 6% O2, Dry		Capture	Notes
	mg/Nm3*	ppmv		
PM	2 – 20	-	99-99.9%	With Fabric Filter
	20 - 50	-	99-99.9%	With ESP
SO_2	10 – 200	3.5 – 75.1	85 - 99%	
SO_3	10 - 50	3 - 15	90- 99%	Hydrated lime reacts with SO3 within CFBS much quicker than SO2 and it's captured 'first'.
HCl	1 – 10	0.7 – 6.6	95 - 99%	
HF	0.1 – 1	0.1 – 1.2	95 - 99%	
Total Hg (all forms)	0.003 – 0.050	0.36 – 6 ppbv	60 – 80%	Low halogen PRB coal
	0.001 – 0.035	0.12 – 4.2 ppbv	80 – 90%	With lignite coke injection
	0.001 – 0.030	0.12 – 3.6 ppbv	90 – 99%	With activated carbon injection
Total Dioxines, Furanes (all forms)	0.009 – 0.08 x 10-6	0.7 – 6.0 ppbv	95 – 98%	With activated carbon injection

* Normal Conditions = 20°C, 101.325 kPA, 24.94 Nm^3/mol

World's Largest CFB Scrubber at Dry Fork PC Power Plant in USA

Cleaning the flue gas of 420 - 520 MWe PC boiler

- Plant Location: Gillette, Wyoming, USA
- Customer: Basin Electric Power Cooperative
- Plant Start-Up: 2011
- Plant Output: 420 MWe (520 MWe@SL)
- Fuel: PRB sub-bituminous coal
- Flue Gas Flow: 3,060,000 m3/hr
- Inlet Sulfur 350-2200 m3/hr
- Inlet Temperature 146 C, outlet 80 C
- Layout: 1 Absorber(13.4m Dia), 1 Fabric Filter

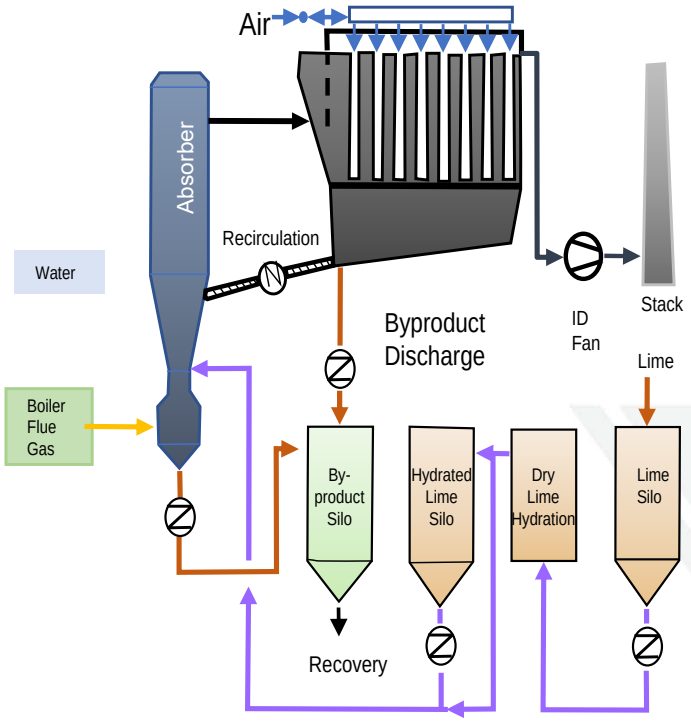
Stack Emission	SO2	SO3	HCl	Hg	PM
mg/dNm3 @ 6% O2	70	2	6	0.0025	15
ppmdv	25	0.6	3		
% capture	97	96	67	90	99.9

Operating successfully for 10 years

The Value Points of our CFB Scrubber

Proven References up to 520 MWe

- High Multi-Pollutant Capture Capability
  - Up to 99% capture of SO2, SO3, HCl, HF, Hg, Furans and Capture of very fine particulates – under 2 µm
- Low Capital Cost
  - Up to 40% less than wet FGD
  - Avoids expensive wet stack liner retrofits
  - Avoids expensive upgrades to old ESPs
- Low Water Use
  - 40- 50% less than wet FGD
  - Can use low quality water streams
- High Reliability and Low Maintenance
  - No slurry preparation, handling, dewatering, liquid waste streams
  - No mechanical atomizers or spray heads
  - No paddle mixers
- Compact footprint, ability to fit in tight spaces
- High Operational Flexibility
  - Capture not limited by flue gas due point temp
  - Can be integrated with CFB boilers using boiler ash as reagent
- SFW has a Long and Broad Experience
  - 77 units operating globally since 1989
  - Wide Fuel experience: Coal, Lignite, MSW, Oil
- All components can be sourced and made in India



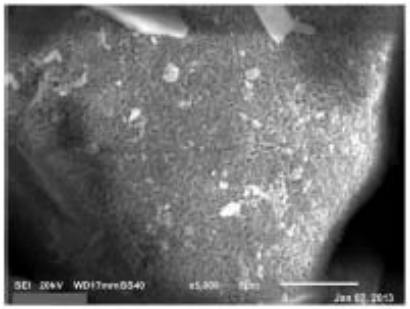
Dry Sorbent Injection (DSI) Technology

Dry Sorbent Injection (DSI) Technology

SO_2 Removal – Sorbent Choice

Trona

- Use when:
  - Moderate to high SO_2 removal needed (approx. 50% to 90%)
  - Not available in all areas



Sodium Bicarbonate

- Use when:
  - Moderate to High removals needed (50 to > 90%)
  - Want to minimize loading to ESP and/or ash removal systems

Hydrated Lime

- Use when:
  - Have fabric filter or large ESP
  - Low to moderate removals (30 to 70%)

SO_2 and Sorbent Reactions

Trona

Calcination: $2(Na_2CO_3\ NaHCO_3\ 2H_2O) \rightarrow 3Na_2CO_3 + CO_2 + 5H_2O$

SO_2 Reaction: $Na_2CO_3 + SO_2 + 1/2\ O_2 \rightarrow Na_2SO_4 + CO_2$

Sodium Bicarbonate

Calcination: $2NAHCO_3 \rightarrow NA_2CO_3 + CO_2 + H_2O$

SO_2 Reaction: $Na_2CO_3 + SO_2 + 1/2\ O_2 \rightarrow Na_2SO_4 + CO_2$

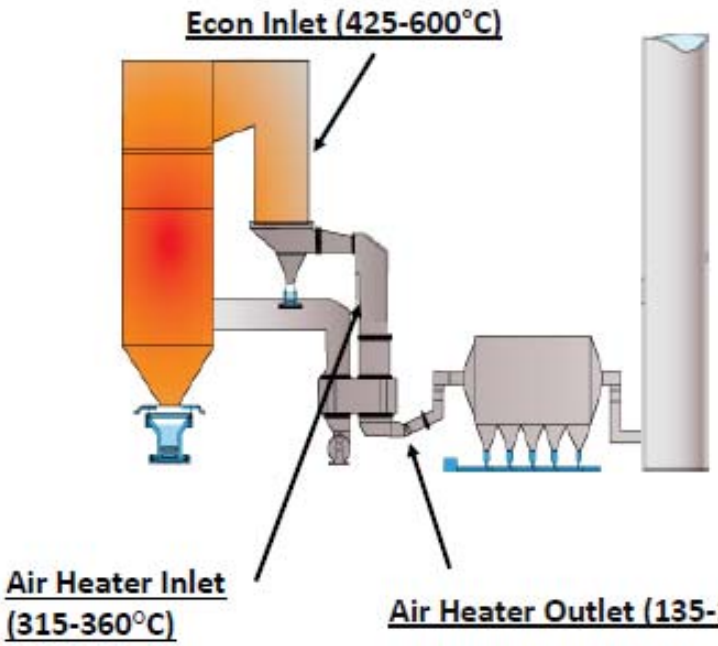
Hydrated Lime

$Ca(OH)_2 + SO_2 + ½\ O_2 \rightarrow CaSO_4 + H_2O$

Dry Sorbent Injection (DSI) Technology

Dry Sorbent Injection Locations

Temperature Effects

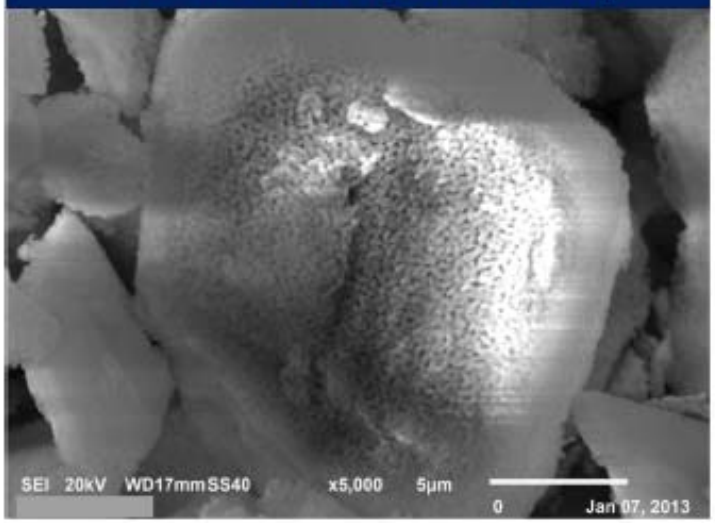


Optimum Temperature Ranges

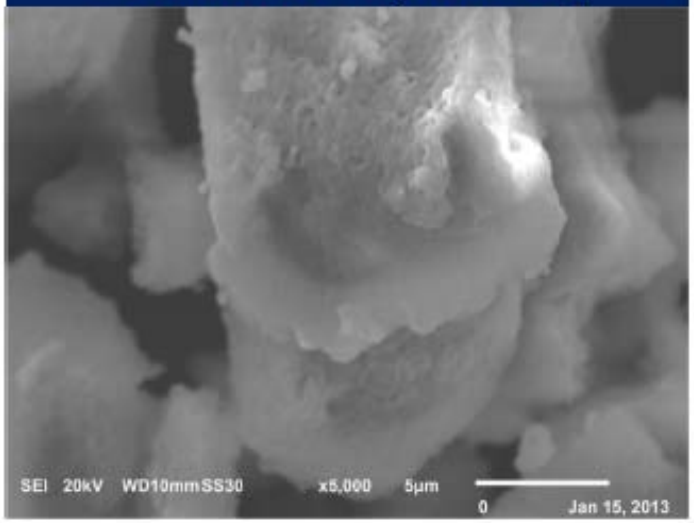
- Trona – 150 to 535°C
- SBC – 150 to 345°C
- Hydrated Lime – 65 to 600°C, with best performance at air preheater inlet

High Temperature Effects on SBC

SBC at 160 °C (AH Outlet)

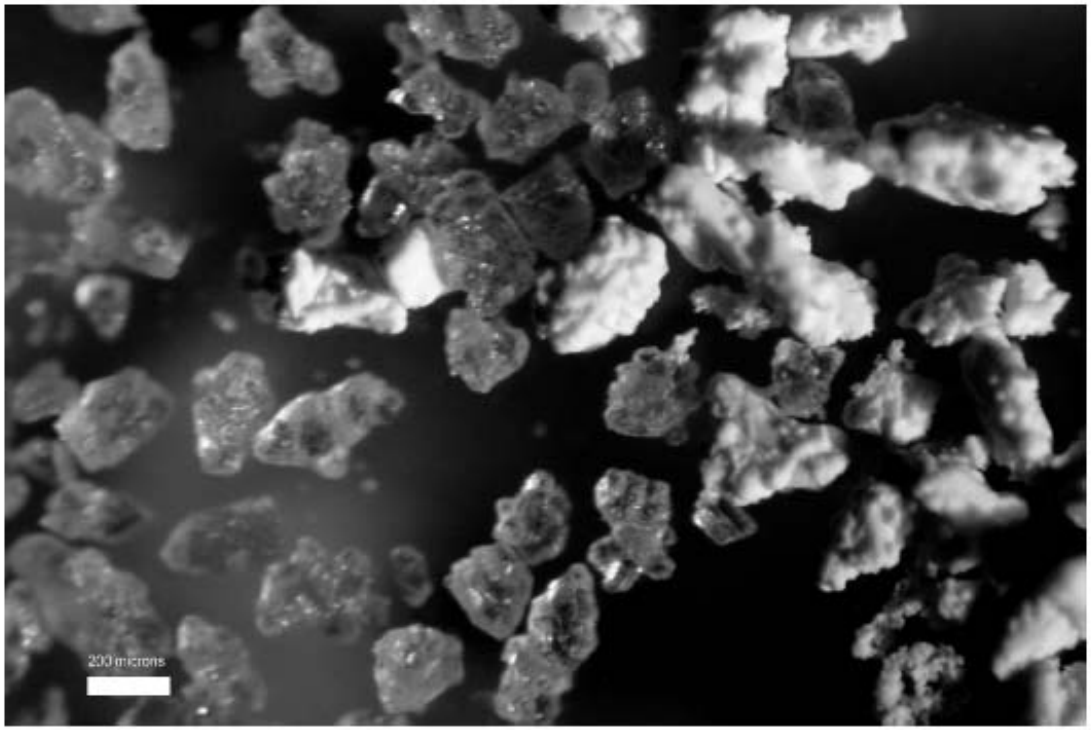


SBC at 400 °C (AH Inlet)



Particles lose porosity at above 345C

Low Temperature Effects on SBC



Porosity not well formed at less than 150C

Dry Sorbent Injection (DSI) Technology

Typical Large SO_2 Reduction System

Dry Sorbent Injection (DSI) Technology – Case Study (Reference Unit)

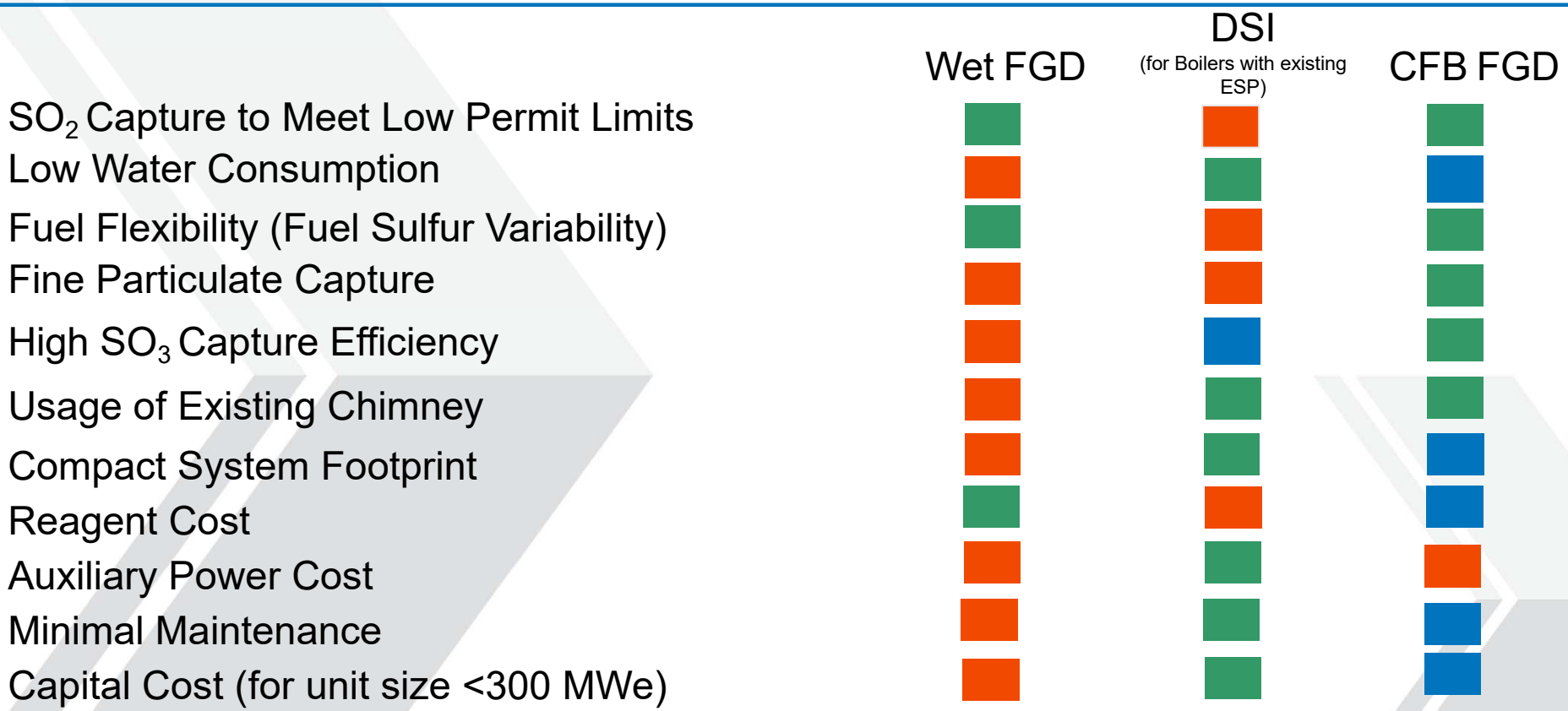
NRG Powerton Station

- Unit 5 – 800 GMW
- Unit 8 – 800 GMW
- 100% low sulfur PRB coal
- Load following units
- CE Twin Furnace Boilers
- Both units have SCR for NO_x reduction, cold-side ESPs, and ACI systems for Hg reduction
- Trona or SBC injection at AHI
- 28 TPH Injection capacity per unit, plus 50% redundancy
- Achieve up to 90% SO_2 removal
- Actual injection rates less than guarantees and significantly less than system capacity

Conclusion – Technology Comparison and Suitability

Dry Sorbent Injection (DSI) Technology

Wet FGD, Dry Sorbent Injection (DSI), Circulating Fluid Bed FGD



Isgec Experience on Various Technologies

Isgec Experience on Various Technologies

Sr. No.	Client Name	Project	Capacity (in MWe)
Wet FGD			
1.	NTPC Limited	Kudgi Super Thermal Power Project	3x800
2.	NTPC Limited	Gadarwara Super Thermal Power Project	2x800
3.	THDC India Ltd. Thru L&T MHI Power Boilers Pvt. Ltd.	Khurja TPP	2x660
4.	Odisha Power Generation Corporation	Ib Valley TPS, Stage – II	2x660
Dry Sorbent Injection (DSI)			
5.	MAHAGENCO	Khaperkheda TPS (Unit # 3 & 4)	2x210
6.	WBPDCL	Kolaghat TPS (Unit # 3,4,5 & 6)	4x210
Semi Dry FGD – CFBS Technology			
7.	Hindalco Industries Limited	Mahan Aluminium CPP	1x150

Thank You Sincerely!!!!

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