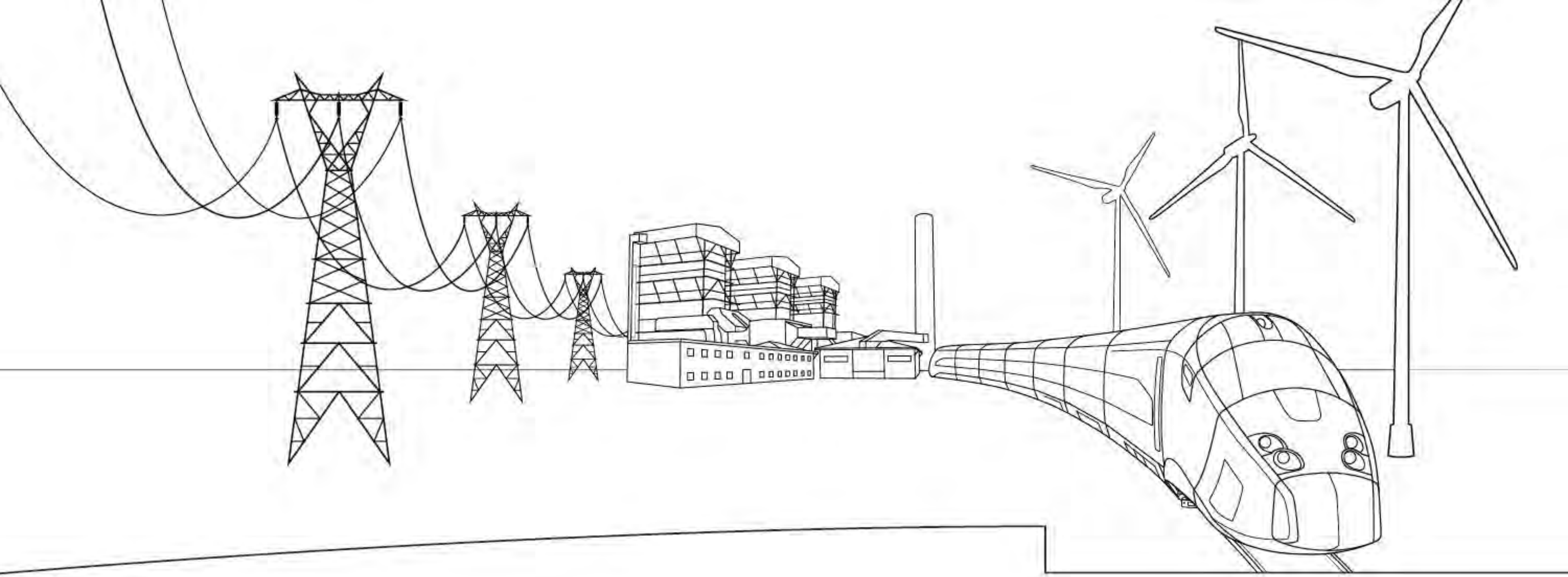

Zero Liquid Discharge Solutions for Power and Industrial Facilities

Phil Rader

CIBO Energy Session
Washington, DC

December 2, 2014

ALSTOM
Shaping the future

- **Introduction**
- Regulatory Drivers
- Technology Options
- Direct Evaporation ZLD
- Case Studies
- Summary

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Alstom ECS/CCS

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Alstom Environmental Control Systems
North American HQ – Knoxville, TN

- Introduction
- **Regulatory Drivers**
- Technology Options
- Direct Evaporation ZLD
- NID Technology
- Summary

Regulatory Drivers

Background

- Congress passed CWA in 1972 to "restore and maintain the chemical, physical, biological integrity of the Nation's waters."
- CWA authorizes EPA to establish Effluent Liquid Guidelines (ELG) for sources
- EPA identified steam electric power plants as a category in 1974 at placed limits on thermal and pollutant discharges
- Rules last updated in 1982

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Effluent Limitation Guidelines for Power Plants

- EPA proposes to revise guidelines that may impact 7 waste streams:
  - FGD waste water
  - Fly ash transport water
  - Bottom ash transport water
  - Combustion residual leachate
  - Nonchemical metal cleaning waste
  - Waste water from mercury cleaning systems
  - Gasification waste water
- Final ruling was to be ready by May 2014; delayed, now expected in September 2015
- Compliance 3 years after effective date of final ruling; additional time granted for ZLD solutions

Effluent Limitation Guidelines for Power Plants

- EPA proposed rules in April 2013

Constituent	30 day average	Max 1 day limit
Nitrate/Nitrite	0.13 mg/l	0.17 mg/l
Mercury	119 ng/l	242 ng/l
Selenium	10 µg/l	16 µg/l
Arsenic	6 µg/l	8 µg/l

  - Flow limits for high flow plants (>1000 gpm)
  - Meet discharge levels prior to comingling with other streams (prevents “dilution solution”)
  - Allows delay in implementation for plants that commit to ZLD solutions

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WFGD Waste Water Treatment Methods

- Dilution
- Surface impoundments
  - Gravity separation of suspended solids
  - Commingle with other waste water streams
  - Clarified water discharged; settled solids landfilled
- Chemical precipitation
  - Precipitate heavy metals
  - Coagulation/flocculation followed by thickening/filtration
  - Treated water discharged; precipitated solids landfilled
- Biological treatment
  - Used to treat Se, other metals, and DBA
  - Treated water discharged
- Vapor-compression evaporation

Waste Water is Discharged into Surface Water

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Methods to Eliminate WFGD Waste Water Discharge

- Closed-loop operation
  - Potential corrosion, performance, and operational issues
- Evaporation ponds
  - Limited to southwestern US
- Ash conditioning/fixation
  - Capacity depends on sulfur/ash in coal
  - Lime addition for stabilization
- Underground injection
- Direct evaporation

Zero Liquid Discharge

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Direct Evaporation Advantages

- True ZLD – no purge stream to permit, monitor, and report
- Wide applicability as retrofit solution
- Cost-effective
- Simplicity
  - Fewer unit operations than most conventional WWT
  - No secondary solid waste stream
- Proven technology
  - Spray dryers in service in power plants since mid-1970s
  - Duke Cliffside 6 evaporating WFGD waste water since December 2012

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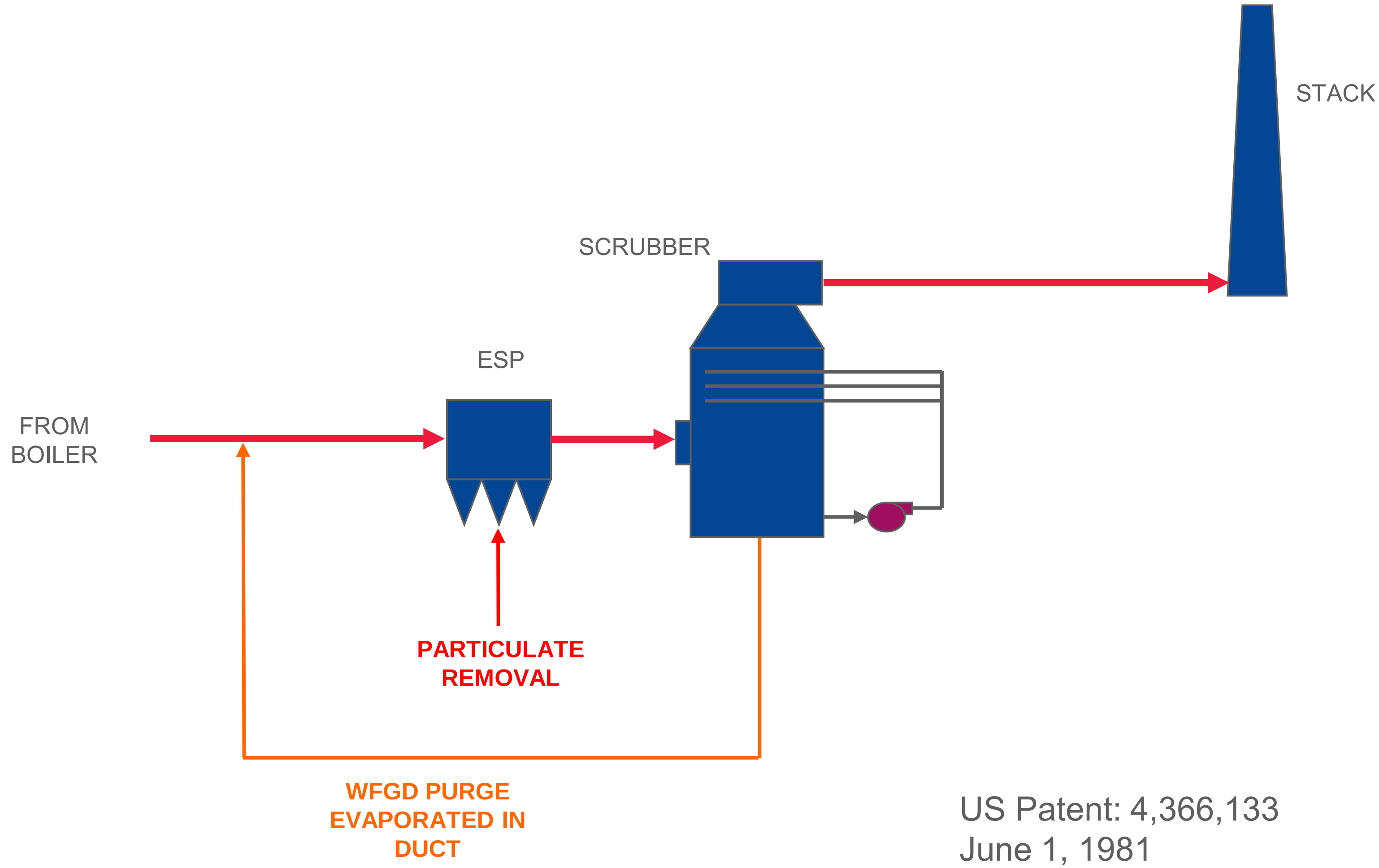
Direct Evaporation Circa 1981



US Patent: 4,366,133
June 1, 1981

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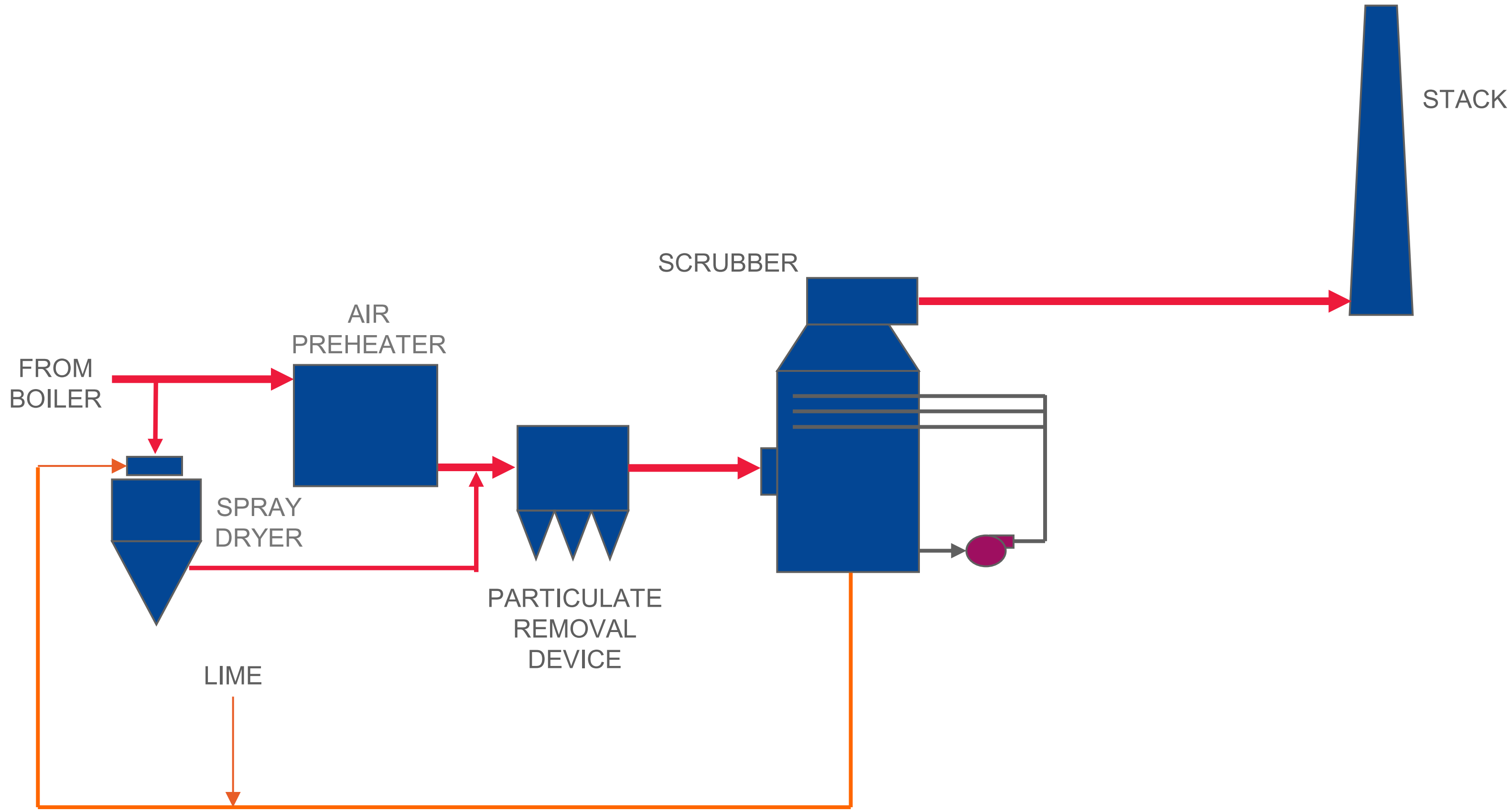
Slipstream SDE



WFGD PURGE EVAPORATED IN SDE

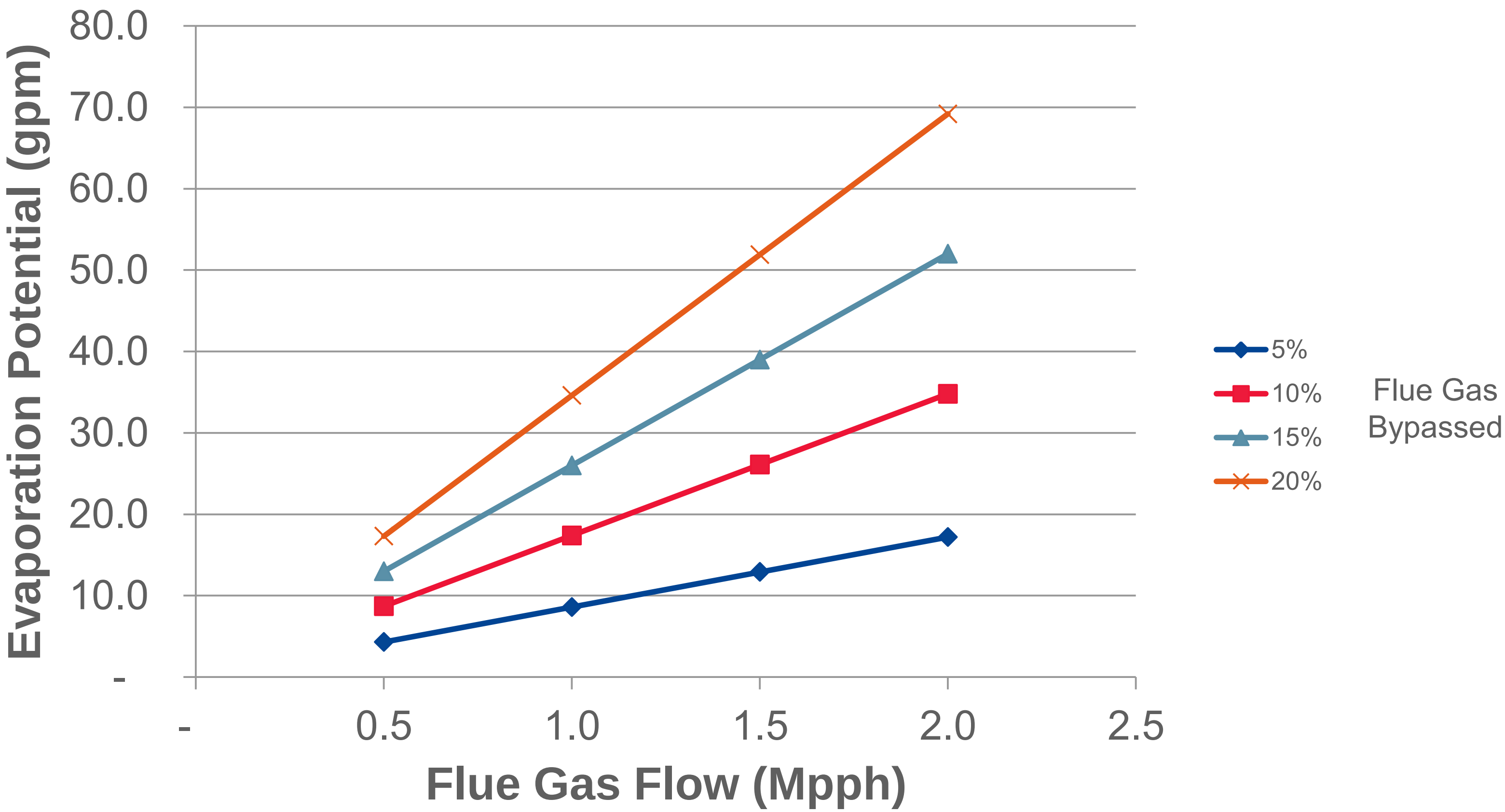
US Patent Application 14/146,424 January 2014

Slipstream DFGD for WFGD Purge Evaporation

- 5 to 10% APH bypass for most applications
- Hot gas reduces equipment cost
- Lime addition to purge stream
  - Corrosion mitigation
  - Co-benefits for SO_3 and HCl control expected
  - Improves bag life
  - Reduced scaling potential
  - Low lime consumption
  - Optimization potential
- Dissolved and suspended solids dried and collected by existing particulate control system

True Zero Liquid Discharge

Waste Water Evaporation Potential



Slipstream SDA offers significant evaporation capacity

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Alstom Spray Dryer Absorber Technology

Rotary Atomizer

Dual Fluid Nozzles

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Rotary vs. Dual Fluid Nozzle Atomization

Rotary Atomizer

- Single rotary atomizer
- Larger diameter, shorter vessel
- Lower power consumption
- Higher pressure drop
- Good turndown

Dual Fluid Nozzles

- 4-8 dual fluid nozzle lances
- Smaller diameter, taller vessel
- Higher power consumption
- Lower pressure drop
- Good turndown

Two proven technology options

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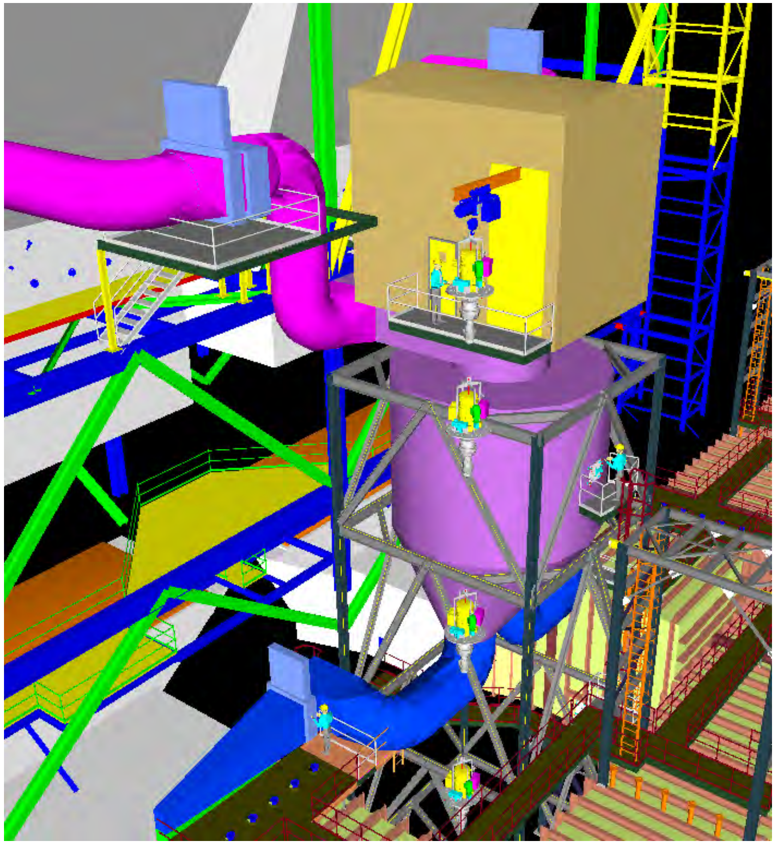
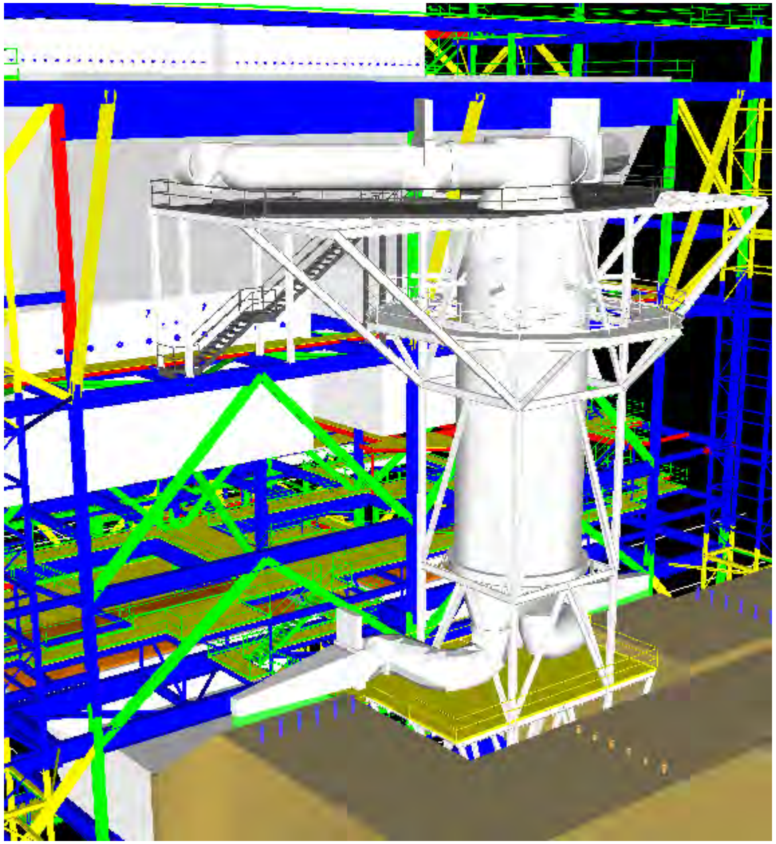
SDE Alternatives



Rotary Atomizer



Dual-Fluid Nozzles

Duke Energy Cliffside 6 AQCS

Project Scope	Spray dryer, fabric filter, spray tower, lime/limestone preparation and feed systems, by-product dewatering system, ductwork, fans, erection and commissioning advisors
Location	Cliffside, NC
Capacity	825 MW
Start-Up	May 2012
Fuel	Eastern Bituminous
SO2 Removal	99% with 3.2 lb/mmBtu fuel/with DBA
	99% with 2.8 lb/mmBtu fuel/no acid
No. Absorbers	Two spray dryers; one spray tower
By-product	Commercial gypsum
Gas Flow	2,800,000 ACFM
Reagent	Lime, limestone

Duke Energy
Cliffside Unit 6
Cliffside, NC

Over 100,000,000 Gallons of Waste Water Evaporated to Date

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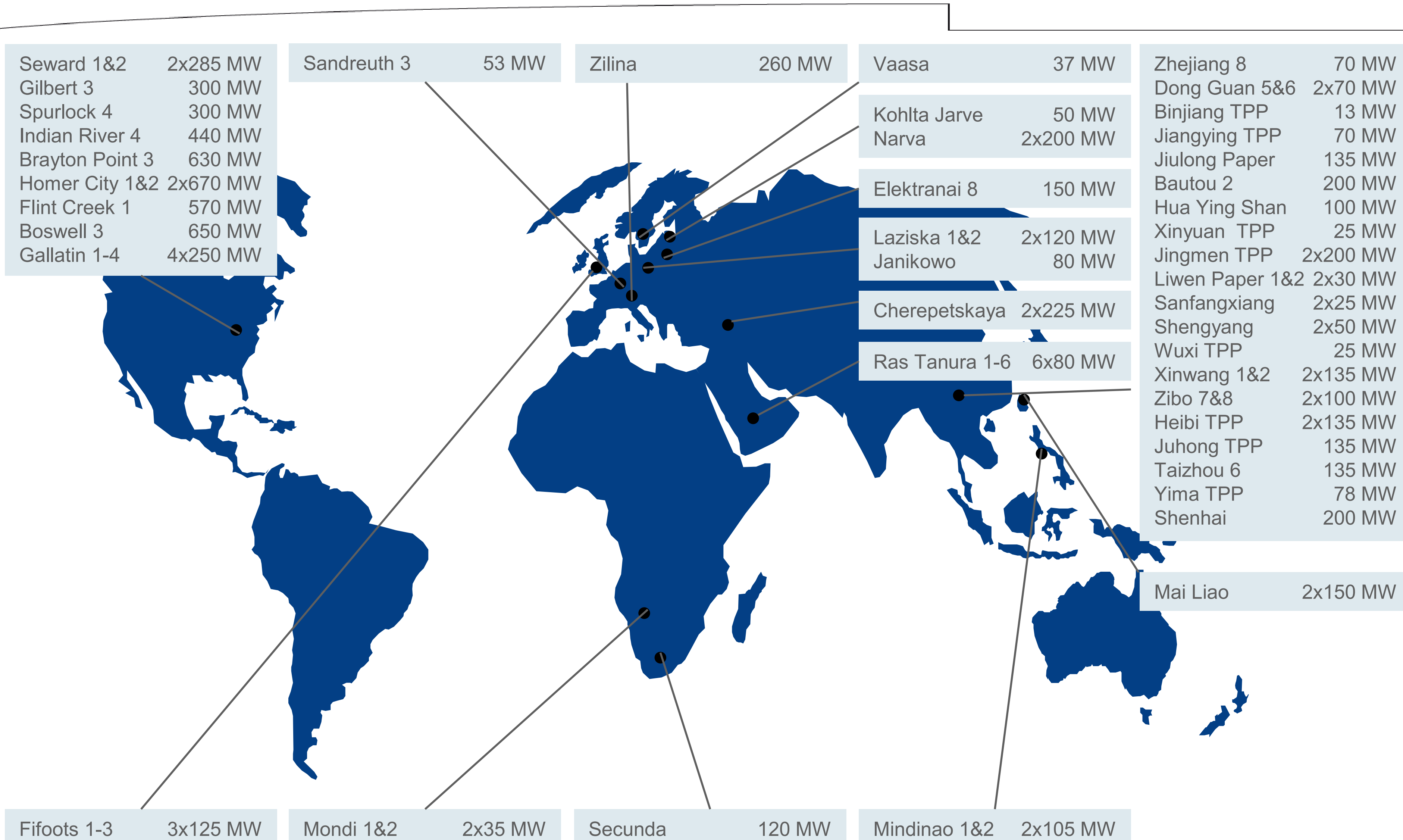
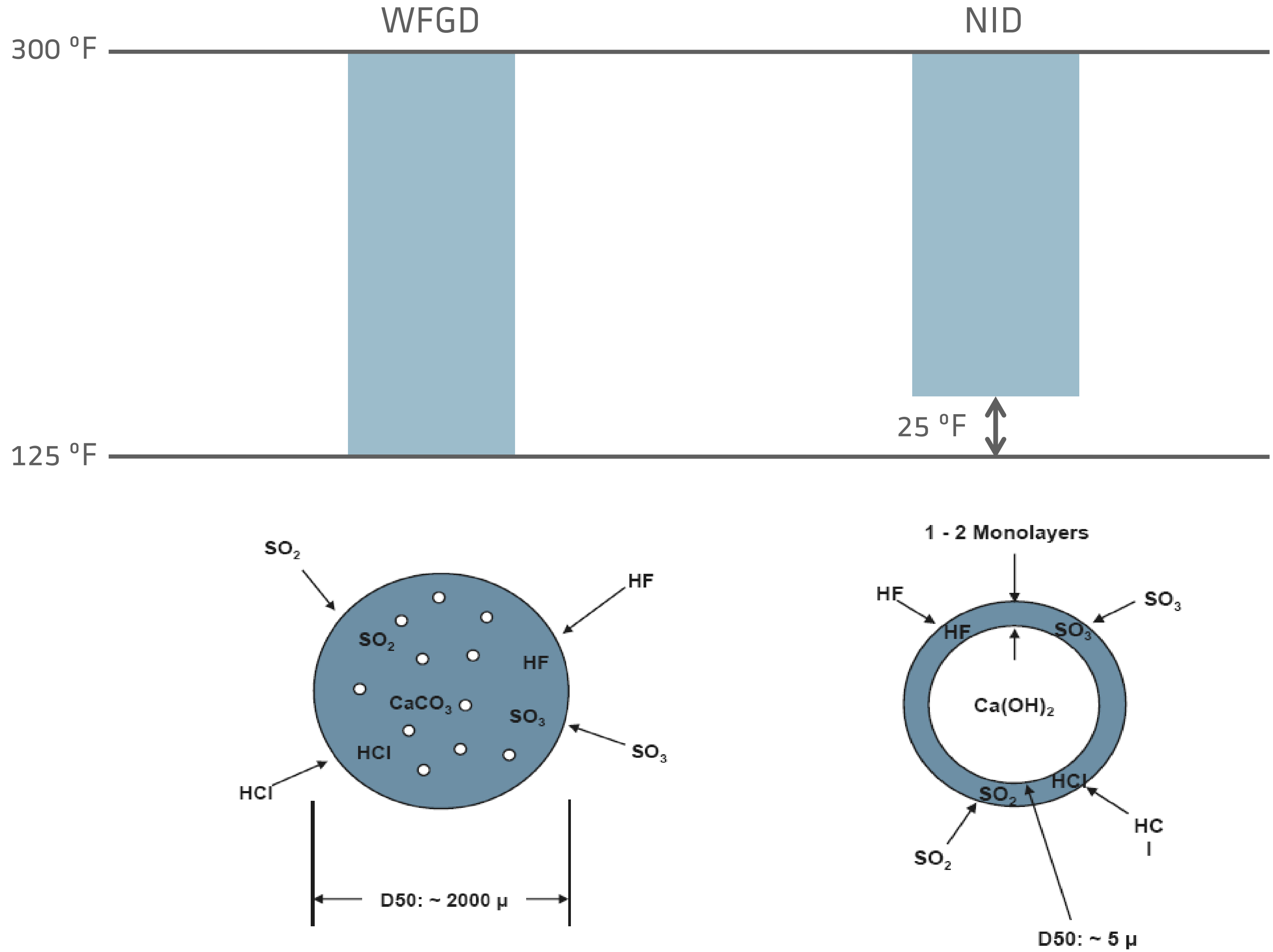
NID Overview

- Multi-pollutant control: High efficiency removal of SO_2, SO_3, PM, HCl, HF, and Hg
  - SO_2 removal: ≤ 98%
  - SO_3 emissions: < 1 ppm
  - PM (filterable): < 0.010 lb/MBtu
  - HCl: <0.002 lb/Mbtu
  - Hg: <1.2 lb/TBtu
- Lime-based dry FGD technology
  - Integrated hydrator/mixer – no slurry handling
  - Zero liquid discharge
  - Low water consumption; ability to use low quality water: CTB, WFGD purge
- Simple, compact design
  - Small footprint offers retrofit advantage
  - Low capital cost
  - Low BOP/construction cost
  - Low O&M cost
- Modular design
  - High reliability
  - Excellent turndown without gas recirculation
  - No scale up issues
- Fuel flexibility up to 2.5% sulphur coal or higher

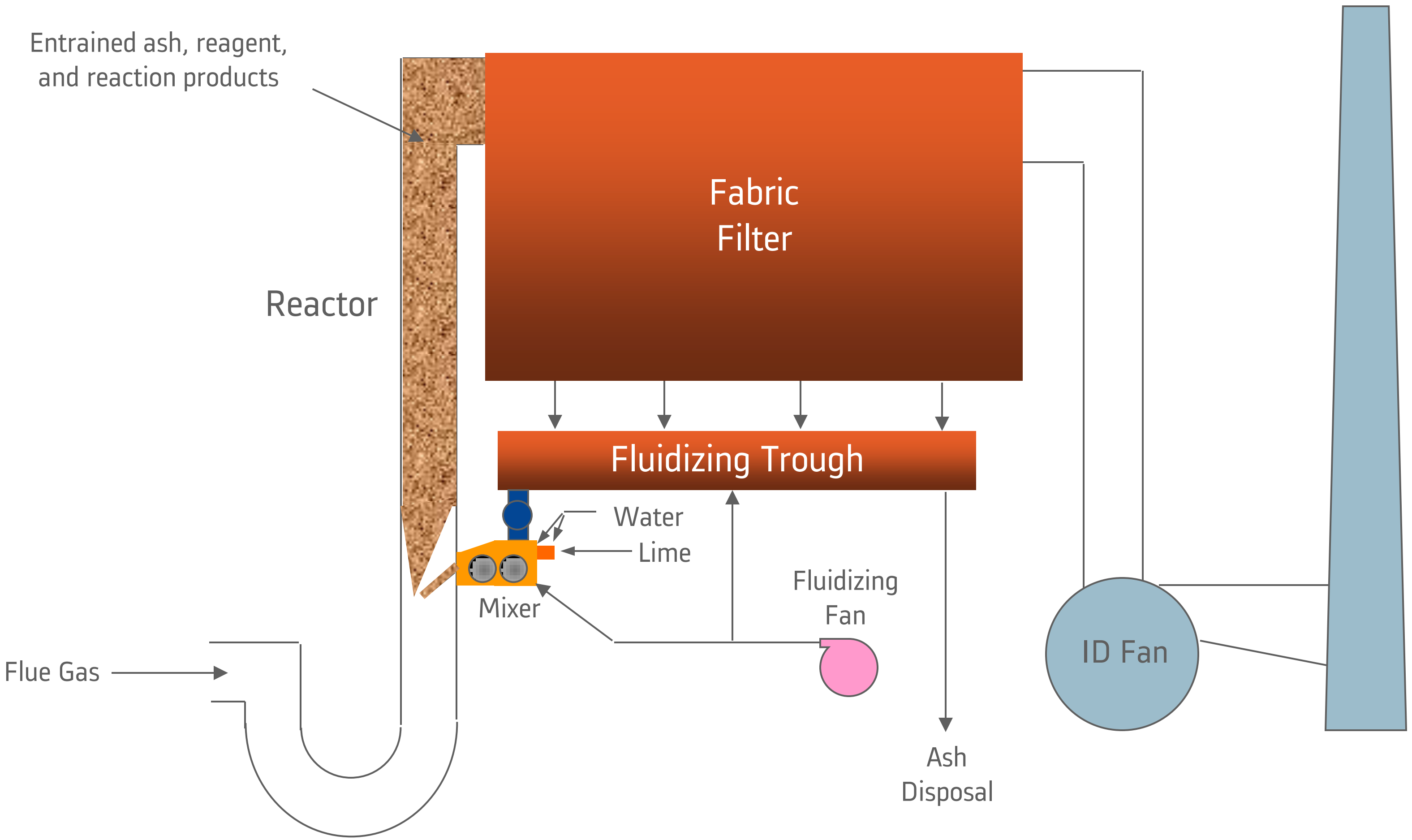
World-Wide NID Installations



FGD Technology Comparison

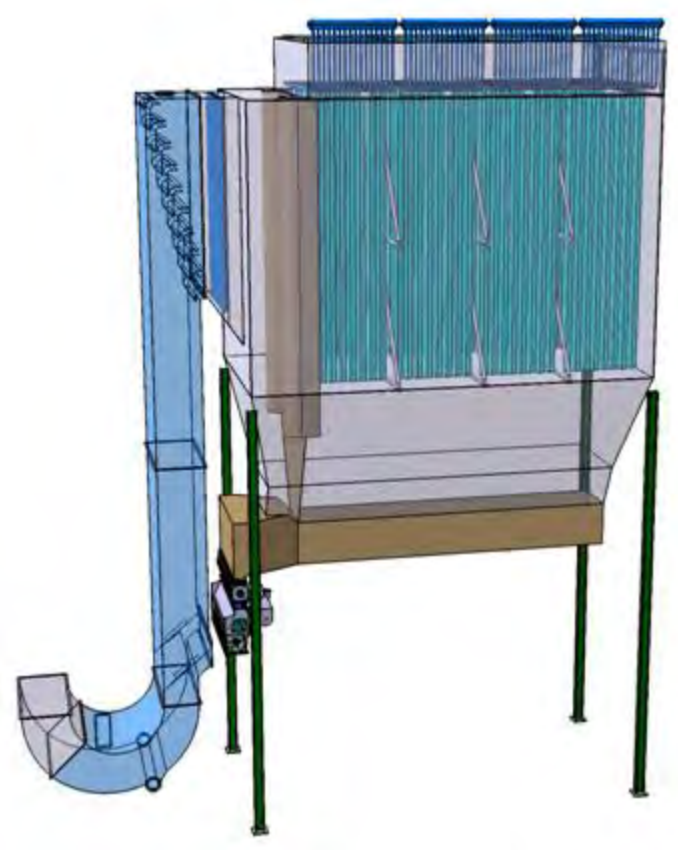


NID Flow Schematic



NID-C Concept

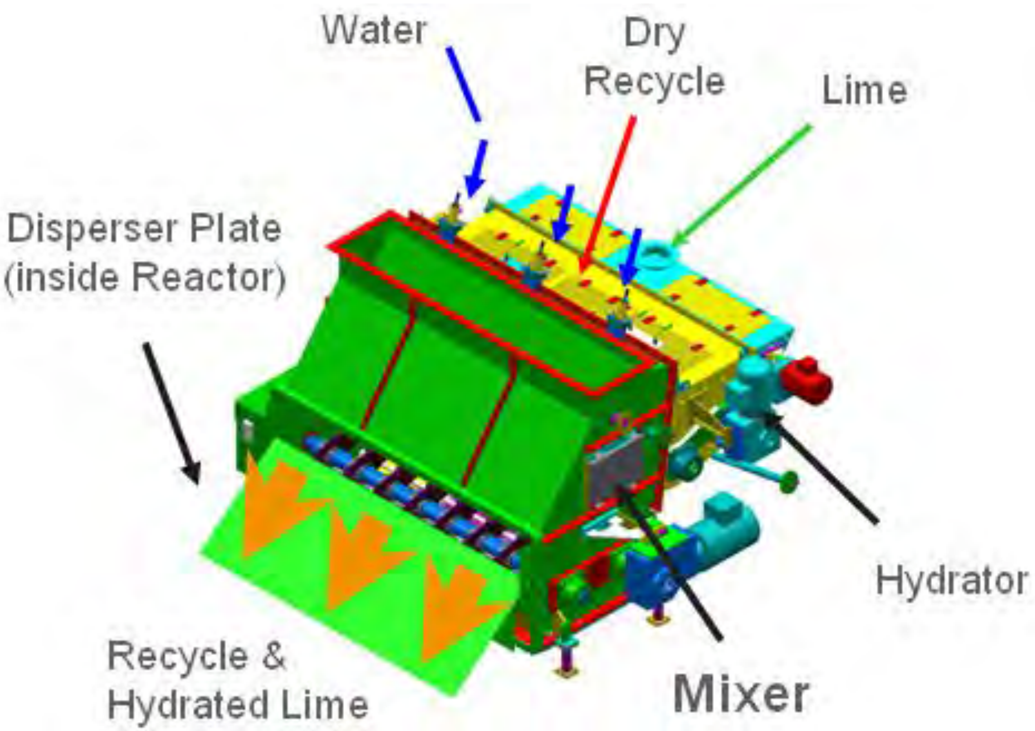
- Multiple, independently isolatable modules
- Dampers
  - Upstream of reactor
  - Downstream of FF compartment
- Nominal gas flow of 50,000-300,000 acfm per module
- Can be designed to achieve emissions guarantees at full load with one module out of service



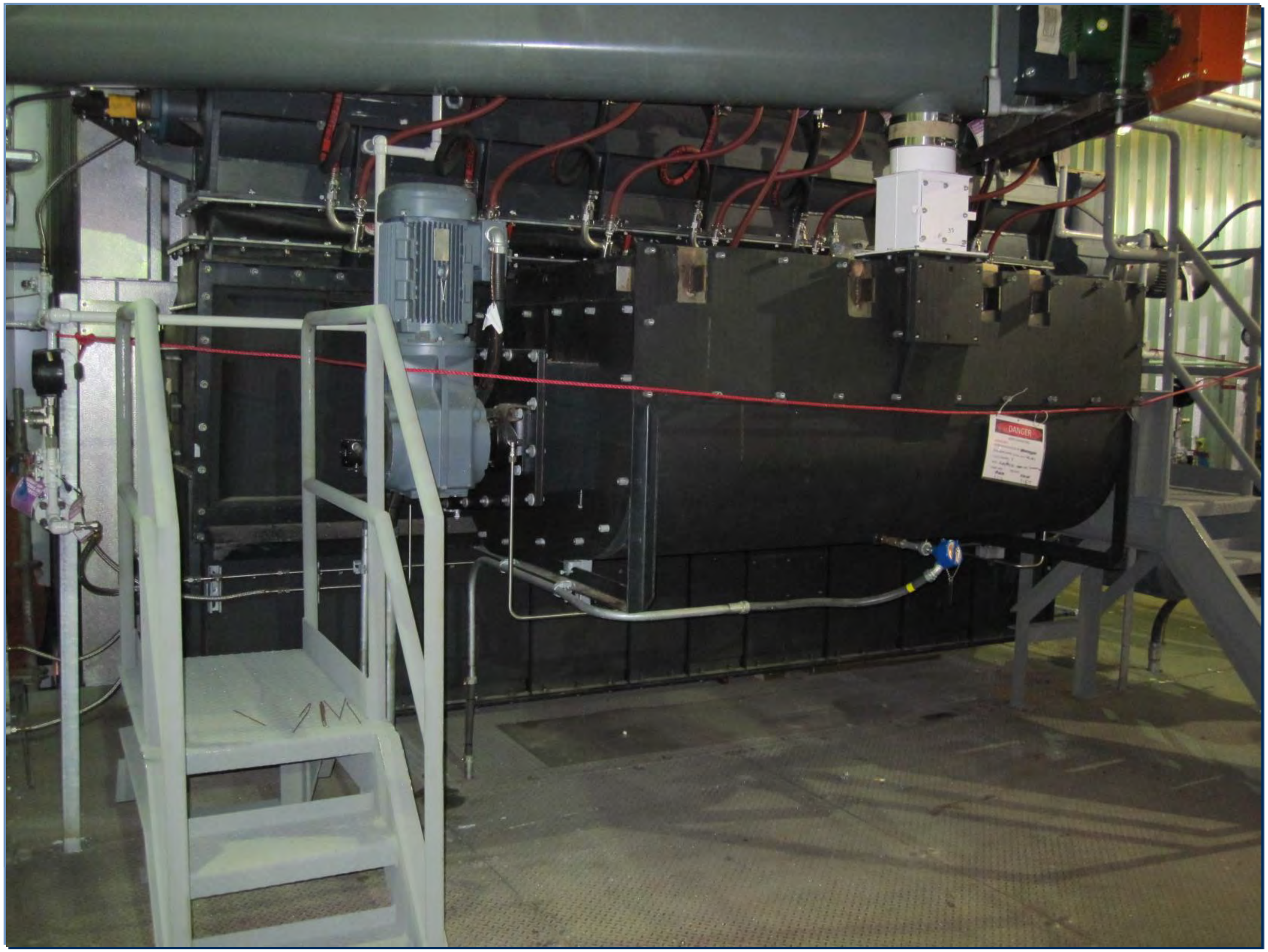
Allows for Turn-Down up to 50% without Recirculation

NID Arrangement

Mixer/Hydrator



Mixer/Hydrator



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Constructability Advantages

- Shop fabrication drastically cheaper than field fabrication
- NID allows high degree of shop fabrication even with truck shipment
  - J-duct reactors
  - Inlet ducts
  - Day silos
  - Mixers
  - Hydrators
- Barge access allows further pre-assembly
  - Fabric filter compartments
  - Inlet/outlet plenums

Modularization Lowers Construction Costs

FGD Technology Comparison

- ● Advantage
- ● Neutral
- ● Disdvantage

Technology Comparison	NID	WFGD
Capital cost	Advantage	Disdvantage
Reagent cost	Disdvantage	Advantage
Power cost (exc. fans)	Advantage	Disdvantage
Pressure drop	Disdvantage	Advantage
Byproduct disposal cost	Disdvantage	Advantage ?
Water consumption	Advantage	Disdvantage
Footprint	Neutral ?	Neutral ?
Installed base	Disdvantage	Advantage
Fuel flexibility	Neutral	Neutral
SO_2 removal	Neutral	Neutral
SO_3 removal	Advantage	Disdvantage
Hg removal	Advantage	Advantage

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Summary

- Increasingly stringent ELGs will likely impact operational practices at power and industrial facilities
- Advantages of direct evaporation include:
  - Zero liquid discharge
  - Simplicity
  - Cost effective
  - Proven technology
- Alstom NID technology offers comprehensive air emissions solution

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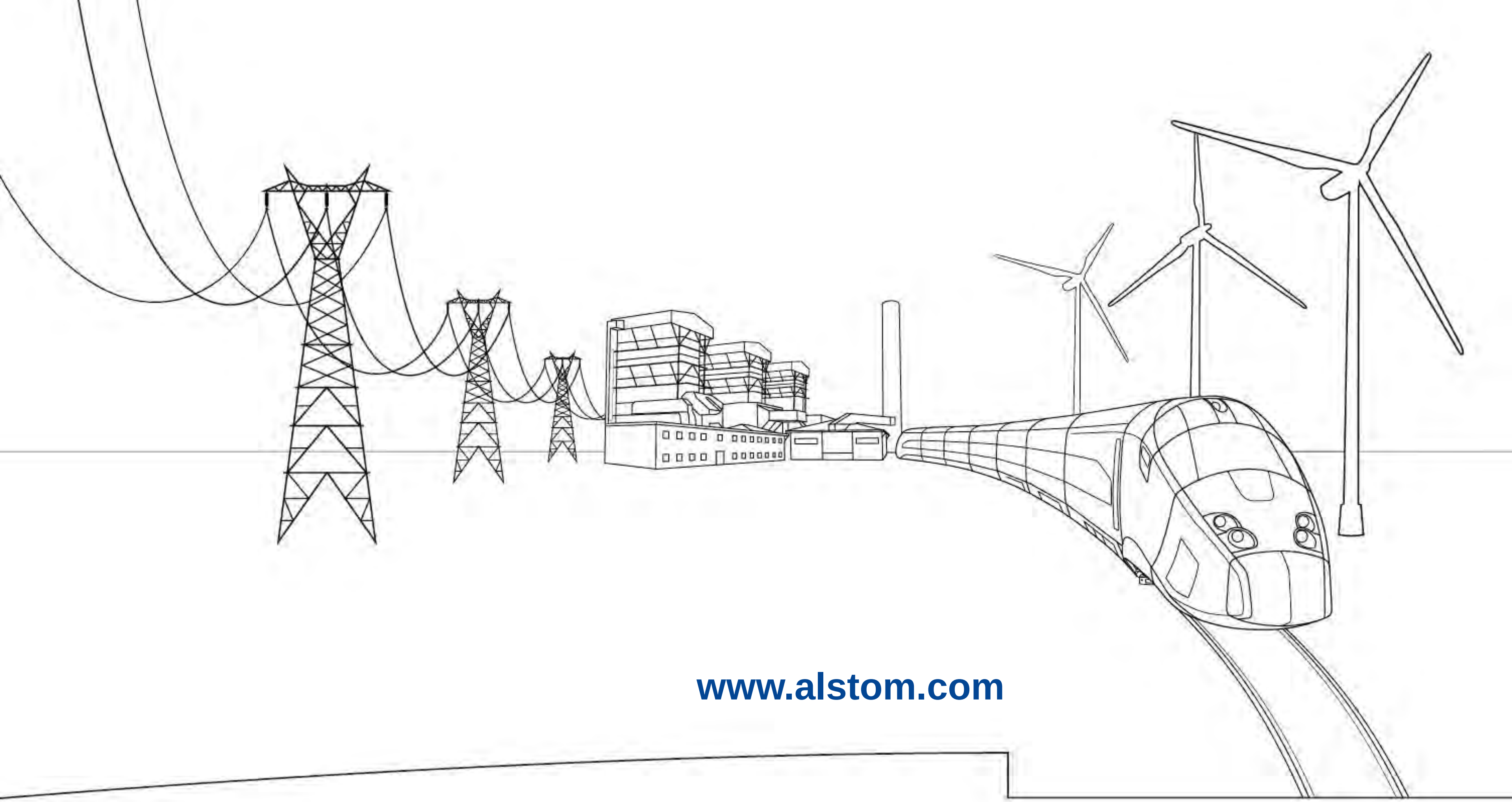

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