CastleLight Energy
Est. 2006

# Indonesia's Coal Fleet Retrofits for the 21st Century

**Presentation By Keith Moore – CEO**

INTERNATIONAL CENTRE FOR SUSTAINABLE CARBON

**"Strategies for Targeted Emission's from The Indonesian Coal-Fired Fleet"**
**Jakarta, Indonesia**
**July 11 & 12 2023**

# Indonesia’s Electric Generating Capacity

- Estimated Total Capacity: 63 GW*
- 104 Coal-Fired Plants: 46 GW* (62% of total)
- > 50% require retrofits for Emissions Pollution Control

# Indonesia's Electric Generating Capacity

| | |
|---|---|
| Coal-fired Electric Generating Plants | >100 MW |
| • - 15 plants w/ ESP + $SO_2$ WFGD: | ~ 6.75 GW |
| • - 46 plants w/ ESP: | ~ 19.80 GW |

Plants seeking pollutant emissions control and higher efficiency

| | |
|---|---|
| • - 21 Wall-Fired w/ ESP: | ~ 11.00 GW |
| • - 15 Tangential-Fired w/ ESP: | ~ 5.10 GW |
| • - 8 Cyclone-Fired w/ ESP: | ~ 850 MW |

# PLN Coal-Fleet System Performance*

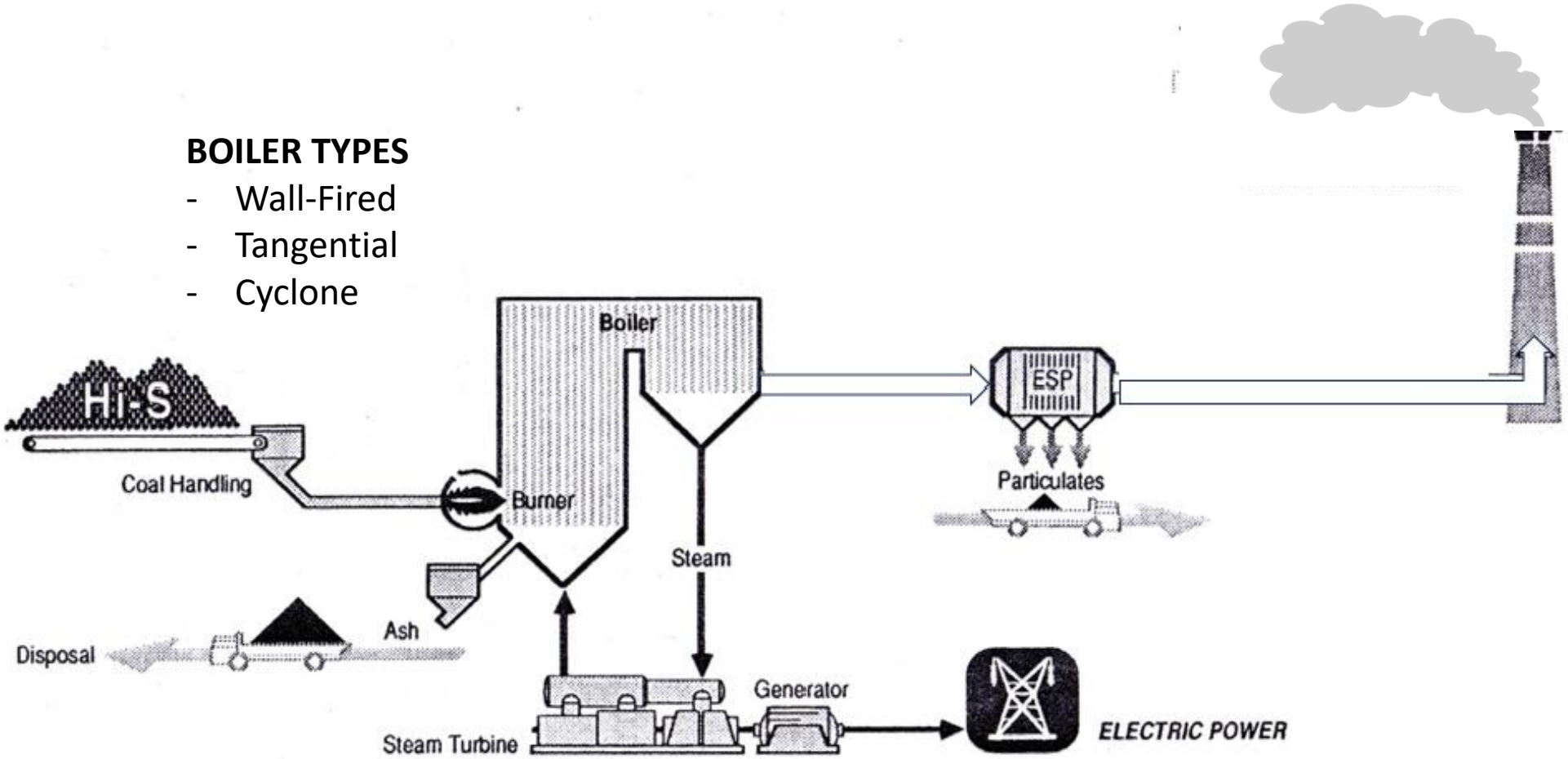
| | | |
|---|---|---|
| • Electrical Production: | (GW hrs. / yr.) | 114.7 |
| • Annual Coal Consumption: | ($10^6$ Tons / yr.) | 129 |
| • Thermal Efficiency Average: | (MW Out / Energy In) | 24.54% |
| • Heat Rate Average: | (3412 / % Efficiency) | 13,900 |
| • Capacity Factor: | (Delivered MW / Full Load MW) | 50.9% |
| • Load Factor: | (Generated MW / Rated MW) | 84.1% |

*Handbook of Energy & Economic Statistics of Indonesia - 2022

# Indonesia's Coal-Fired Plants 'Today'

**BOILER TYPES**

- Wall-Fired
- Tangential
- Cyclone



# Indonesia "Suralaya" Coal Analysis

## Removing water (coal drying) increases Fuel Energy Values

| Indonesia Coal Analysis - Suralaya (Tekmira) | |
|---|---|
| **Parameter** | **As Received Basis (%)** |
| Total Coal Moisture (water) | 27.8 |
| Inherent Coal Moisture (water) | 12.9 (- 46%) |
| Ash Content | 7.02 |
| Volatile Matter | 39.46 |
| Fixed Carbon | 40.55 |
| Total Sulfur | 0.82 |
| Net Calorfic Value | 4,367.75 |
| Calorfic Value (Air Dried) | 5753.75 (+ 32%) |

# Indonesia's Emission Standards for Coal-Fired Plants*

## $SO_2$ - $NO_x$ - Particulates & Mercury

| Maximum pollutant concentrations from stack | | | |
|---|---|---|---|
| Existing Plants | mg/m | ppm | # / MMBtu |
| Particulate Matter (PM) | 100 | | |
| Sulfur Dioxide ($SO_2$) | 550 | 193 | 0.45 |
| Nitrogen Oxides ($NO_x$) | 550 | 270 | 0.45 |
| Mercury (Hg) | 0.03 | | |

* Ministry of Environment and Forestry Decree: P15/MENLHK/4/2019 (April 23, 2019)

# LNS-CAP Emissions Meet Indonesia's Regulations

## ESSO LNS-CAP Facility, Cold Lake, Alberta, Canada

| Maximum pollutant concentrations from stack | | | |
|---|---|---|---|
| **Existing Plants** | **mg/m** | **ppm** | **# / MMBtu** |
| Particulate Matter (PM) | 100 | | |
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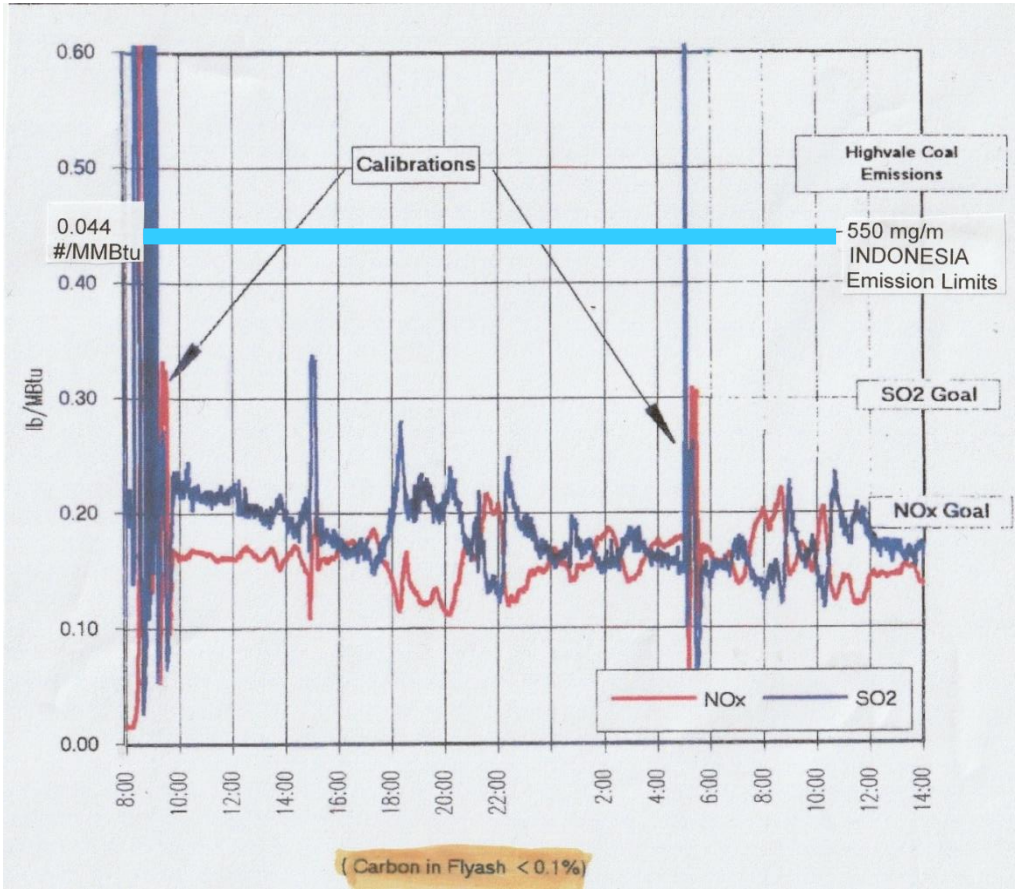
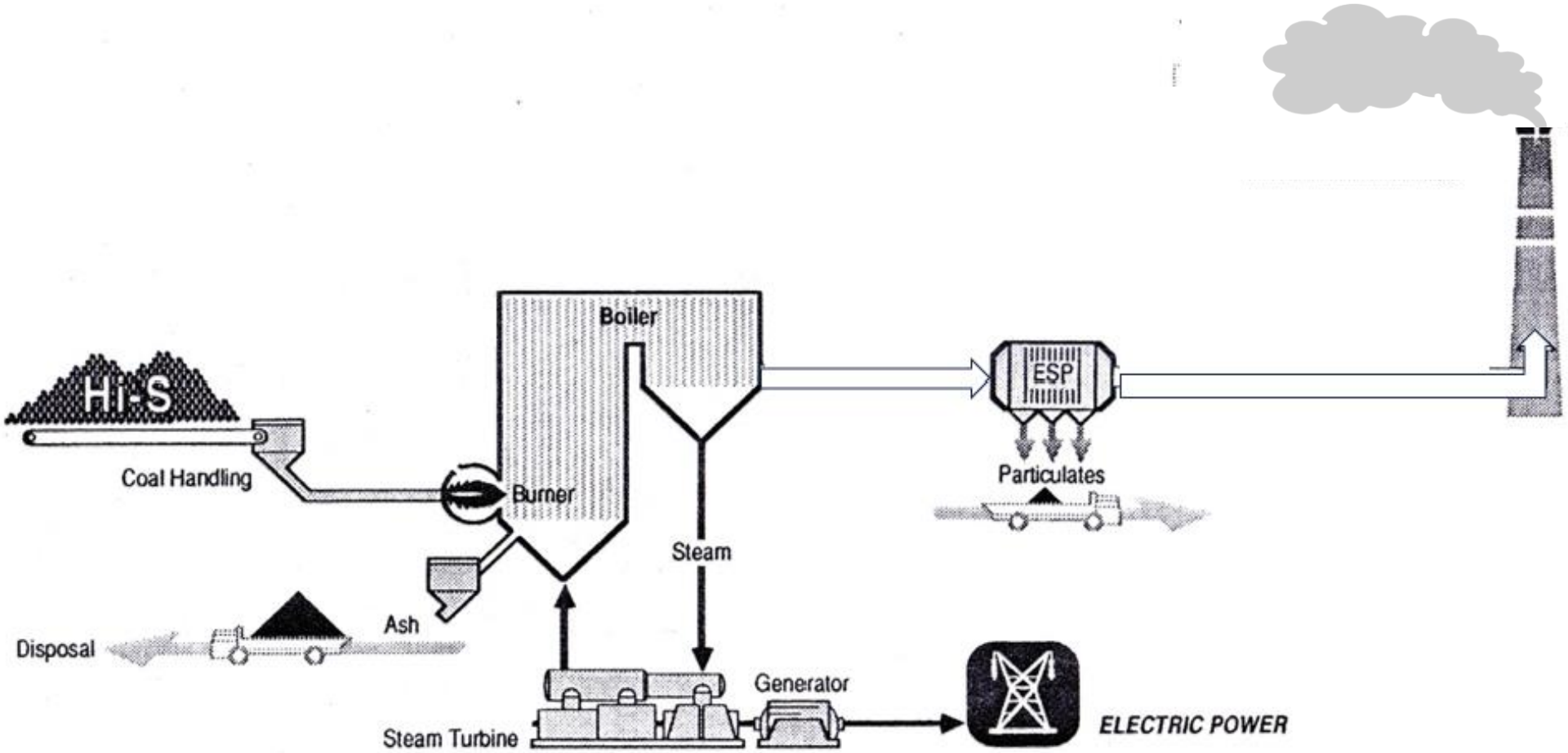



**Subbituminous "Highvale" Coal**

**$SO_2$ - 0.2 lb./MMBtu (250 mg/m) $NO_x$ - 0.15 lb./MMBtu (184 mg/m)**

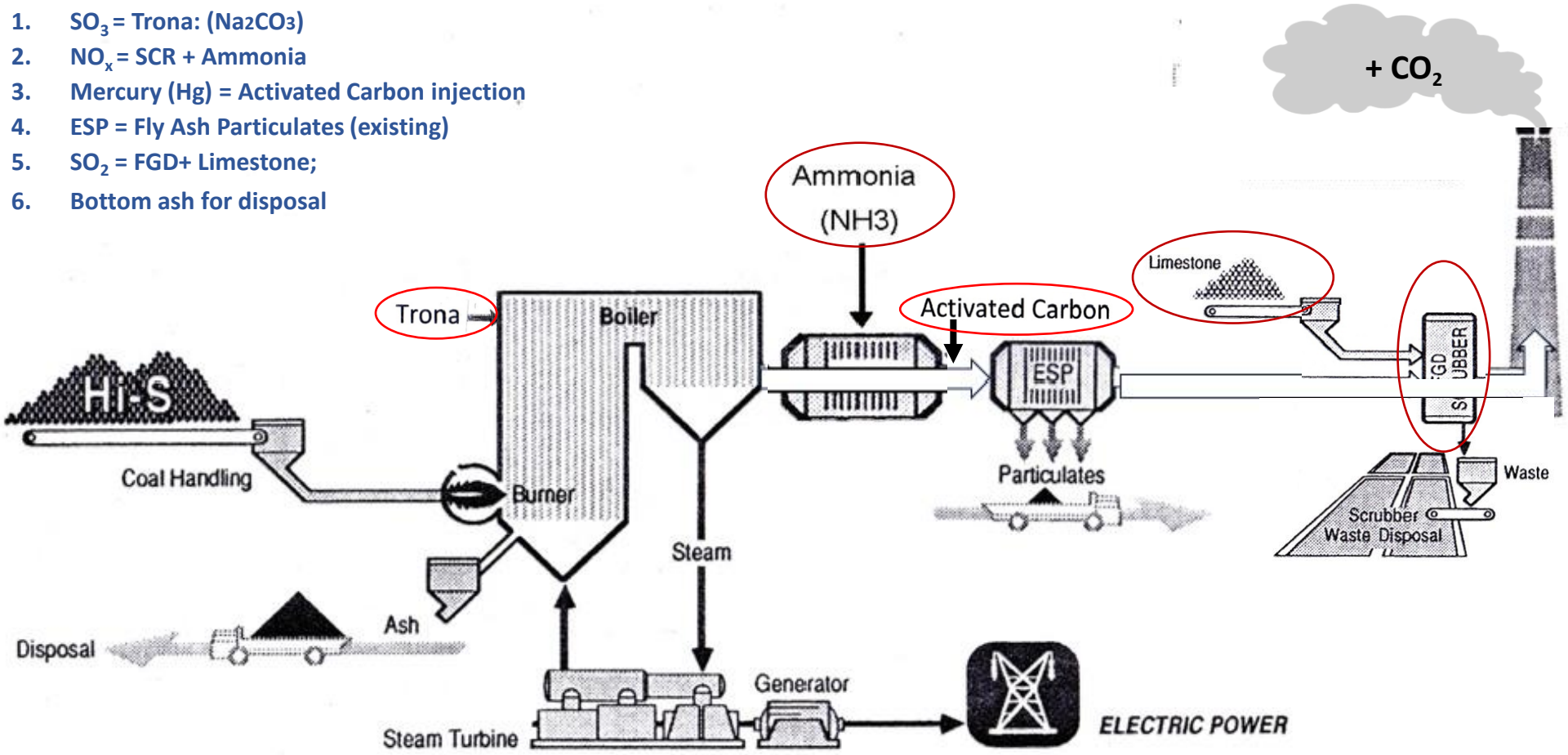
# Indonesia's Coal-Fired Plant 'Today'



# Indonesia's Coal-Fired Plant – Typical Conversion

## High $$$ + ~2 % Parasitic Loads + Increased $CO_2$ Emissions!

1. $SO_3$ = Trona: ($Na_2CO_3$)
2. $NO_x$ = SCR + Ammonia
3. Mercury (Hg) = Activated Carbon injection
4. ESP = Fly Ash Particulates (existing)
5. $SO_2$ = FGD+ Limestone;
6. Bottom ash for disposal



# CastleLight Energy Corp.

## Clean Combustion System (CCS)

### CCS Steam Generator Retrofit Program

- Review plant for modifications to improve Heat Rate efficiency.
- Develop detailed 3 view drawings of existing and CCS modified plant
- Add fast - safe coal beneficiation step (remove water from coal).
- Remove coal burners and install **CCS Hybrid of Coal Gasification**.
- Rework plant's rotating turbine and machinery for improved efficiency.
- Update plant's existing ESP for particulate and mercury control.

### CCS Features:

- Strong SO2 and NOx control with powdered limestone.
- High efficiency (slagging) combustion; carbon in fly ash (LOI < 1 %)
- Eliminates ash deposition on furnace walls.
- Plant operation, startup, and turn-down familiar to operators (same as before).

### CCS Technology:

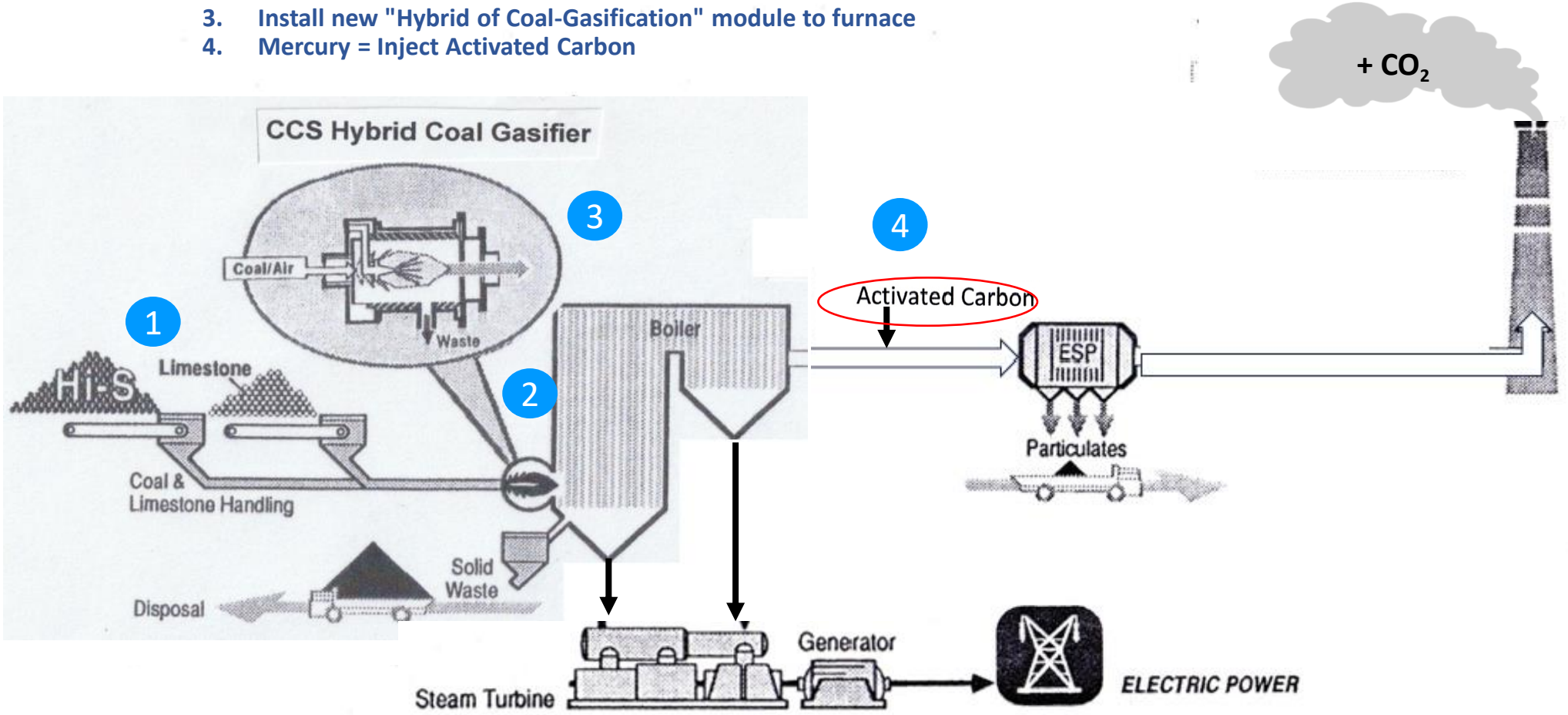
- Evolved from fundamental combustion research developed for the U.S Moon rocket program.

### U.S. Utility / U.S. DOE peer reviewed:

- > $60 million in R&D, Field Demonstrations & Commercial Programs.

# Indonesia's Coal-Fired Plant – CCS Conversion

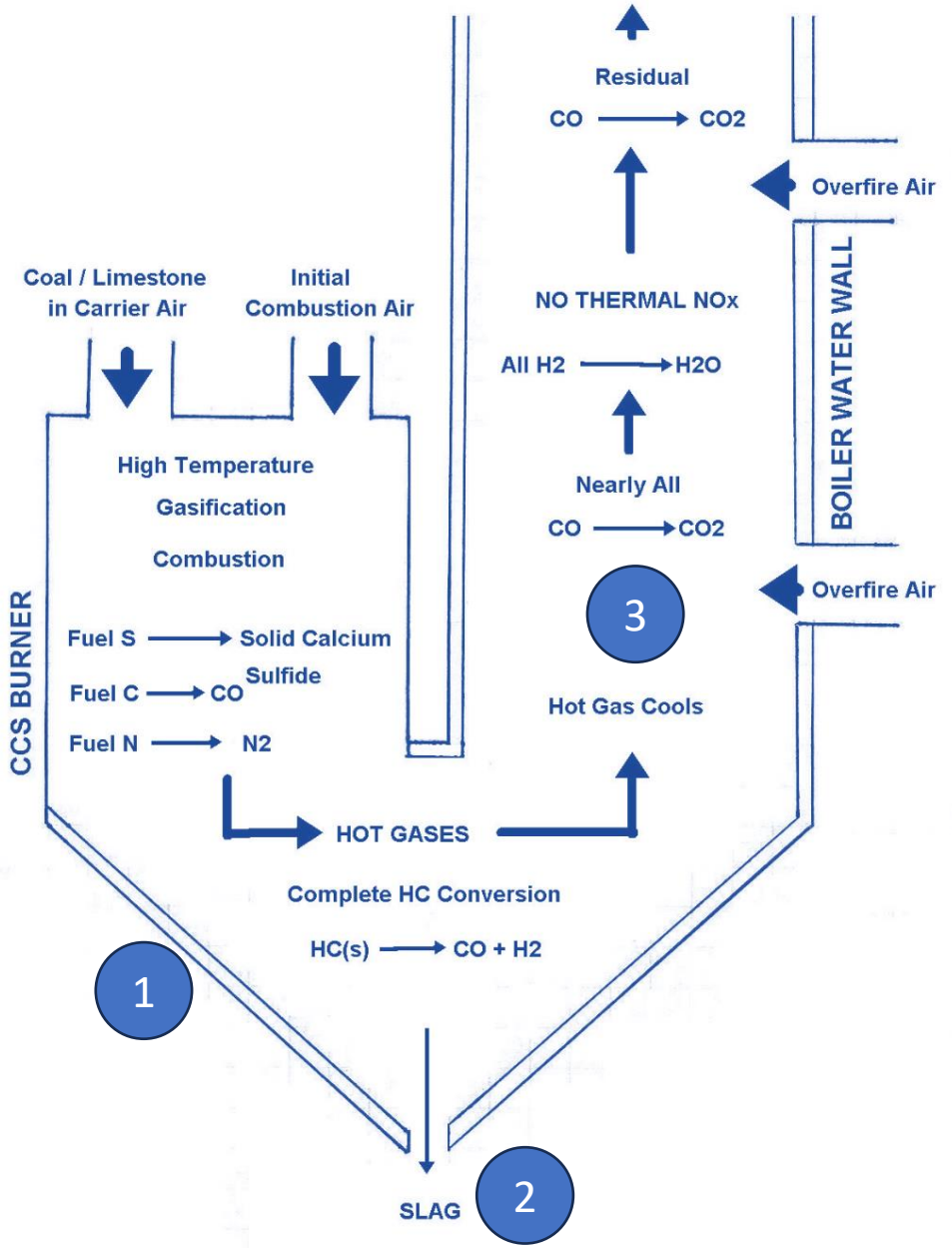
1. Pulverize coal with limestone – Remove water from coal
2. Remove Coal Burners
3. Install new "Hybrid of Coal-Gasification" module to furnace
4. Mercury = Inject Activated Carbon



# CCS Hybrid Coal Gasification Schematic

- Coal "Gasification" module added to furnace.
  - Replaces existing wind-box & coal burners.

1. Water cooled walls with high temp refractory
2. Liquid Slag / Bottom Ash drains to water quench tank for disposal
3. Existing Furnace with New Over Fire Air (OFA) Ports



# Retrofit Estimates for Coal-Fired Plant

## FGD+SCR+Baghouse VS. CCS + Baghouse

| Power Plant Emissions Control Cost - PRB Coal (80% CF) | | | | |
|---|---|---|---|---|
| Control Technology | Equipment CAPx ($/kW) | Fuel ($/MW-h) | O&M X ($/MW-h) | OpX ($/MW-hr) |
| FGD + SCR + Baghouse | 1327 | 17.4 | 4.6 | 22.0 |
| CCS + Baghouse | 425 | 13.2 | 2.0 | 15.2 |
| Delta Savings | 68% | 24% | 58% | 31% |

| Levelized Cost of Electricity for Existing Generation* | $/MW-h | | LCOE |
|---|---|---|---|
| Retrofit 400 MW Coal Plant w / CCS | $ | 27.7 | - |
| Nuclear | $ | 29.1 | 5% |
| Natural Gas Turbine Combined Cycle | $ | 34.4 | 24% |
| Hydroelectric | $ | 35.4 | 28% |
| Conventional Supercritical Coal | $ | 39.9 | 44% |
| Retrofit 400 MW Coal Plant w/ FGD+SCR+Baghouse | $ | 40.5 | 46% |
| Natural Gas Fired Combustion Turbine | $ | 88.2 | 218% |
| Intermittent Wind w/ Cost Imposed on CC Gas | $ | 107.4 | 287% |
| Intermittent PV Solar w/ Cost imposed on CC Gas | $ | 140.3 | 406% |

*** THE LEVELIZED COST OF ELECTRICITY FROM EXISTING GENERATION RESOURCES June 2019**

# CCS Coal Drying (Estimate) - **PLTU Suralaya Plant #1 to #7**

## RAW Suralaya* Coal:

| | | |
|---|---|---|
| • Coal HHV (J/g) (@ ~28% moisture): | 24,091 | |
| • Electricity Production (MW hrs. / yr.): | 19.55 x $10^6$ | |
| • Specific Wet Coal Consumption (Tons / MW hr.): | 0.525 | |
| • Coal Consumption (Tons / Yr.): | 10.14 x $10^6$ | |
| • Estimated CO2 emissions (Tons / yr.): | 188,540 | |

## CCS Dried Suralaya* Coal:

| | | |
|---|---|---|
| • Coal HHV (J/g) (@ ~9% moisture): | 30,448 | (+ 24.9%) |
| • Specific "Dry" Coal Consumption : (Tons / MW hr.): | 0.451 | (- 7.4 %) |
| • Estimated "Dry" Coal Consumption (Tons / Yr.): | 9.63 x $10^6$ | |
| • Estimated $CO_2$ Emissions (Tons / yr.): | 175,640 | |
| • Net $CO_2$ Reduction = 6.8 % | - 12,900 T/Yr. | |
| • Coal Consumption Reduced | - 437,000 T / yr. | |
| • Estimated Fuel Cost Savings (@ $20 / ton) | $87.4 x $10^6$ | |

# CCS Studies / Projects /Programs

## Wall-Fired / Tangential / Cyclone boilers ( > 2100 MW)

| Client / EPC | Plant Size | Boiler Type | Coal | Summary |
|---|---|---|---|---|
| **ESSO - Shell / Monenco** | **50 MMBtu - 3 T/hr.** | **Industrial Steamer** | **Western Subbituminous** | **$8 M Low NOx / SOx Pilot Demonstration - 1 yr. operation** |
| Southern Illinois Power Coop. / Bechtel | 33 MW | Cyclone - B&W | Illinois HS Bituminous | **$150 K Proposal - DOE Clean Coal Technology II (CCT II)** |
| **Southern Illinois Power Coop. / Bechtel & Riley Stoker** | **33 MW** | **Cyclone - B&W** | **Illinois HS Bituminous** | **$15 M AWARD - DOE Clean Coal Technology II (CCT II) (Project to 70% & Delayed - Not completed)** |
| Union Electric / Bechtel | 500 MW | Cyclone - B&W | Illinois HS Bituminous | $250 K Engineering Design & Cost Est. |
| Indianapolis Power & Light | 108 MW | CE - Tangential | Illinois HS Bituminous | **$25 M Proposal - DOE Clean Coal Power Initiative (CCPI)** |
| Central Illinois - AES | 125 MW | Wall-Fired - Riley Reheat | Illinois HS Bituminous | $100 K CCS Application Study |
| Progress Energy | 90 MW | Wall-Fired - B&W | W VA Bituminous | $100 K CCS Application Study |
| Central Illinois - AES | 260 MW | Wall-Fired - Riley Reheat | Illinois HS Bituminous | $150 K CCS Application & CFD Study |
| Houston Light & Power | 130 MW | CE - Wall Fired (Gas to Coal) | Western Subbituminous | $ 100 K CCS Conversion to coal confirmed |
| Niagara Mohawk P&L | 800 MW | Wall-Fired Foster Wheeler (Oil to Coal) | Bituminous | $ 100 K CCS Conversion to coal confirmed by FW |
| Wisconsin P&L | 90 MW | Wall-Fired - B&W | Bituminous | $100 K CCS Application Study |
| **Industrial Grain Processor / McBurney (CCS Installation by Client)** | **30 $MW_T$ (5 T/hr.)** | **Industrial Stoker** | **Illinois HS Bituminous** | **$3.5 M CONTRACT - CCS Design & Build Retrofit w/ Warrantee (MCR Full Load Operation)** |

# Rockwell International R&D Test Facility

25 x $10_6$ Btu/hr (1 ton/hr) (1990)

## Utility Consortium

**Provided Technical Guidance**

**and**

**Funded Retrofit Studies**

**for their**

**Coal-Fired Plants**

- Southern California Edison
- Houston Power & Light
- Wisconsin Public Service
- Niagara Mohawk Power
- TransAlta Utilities - Canada

# >>"Burns Coal as Clean as Natural Gas"<<

## Low $NO_x$ $SO_x$ Coal Application Pilot (LNS-CAP)

- ESSO Oil Recovery Site,
- Cold Lake, Alberta Canada
- 50 MMBtu/hr.
- 3T / hr. PRB Coal
- One Year Operation

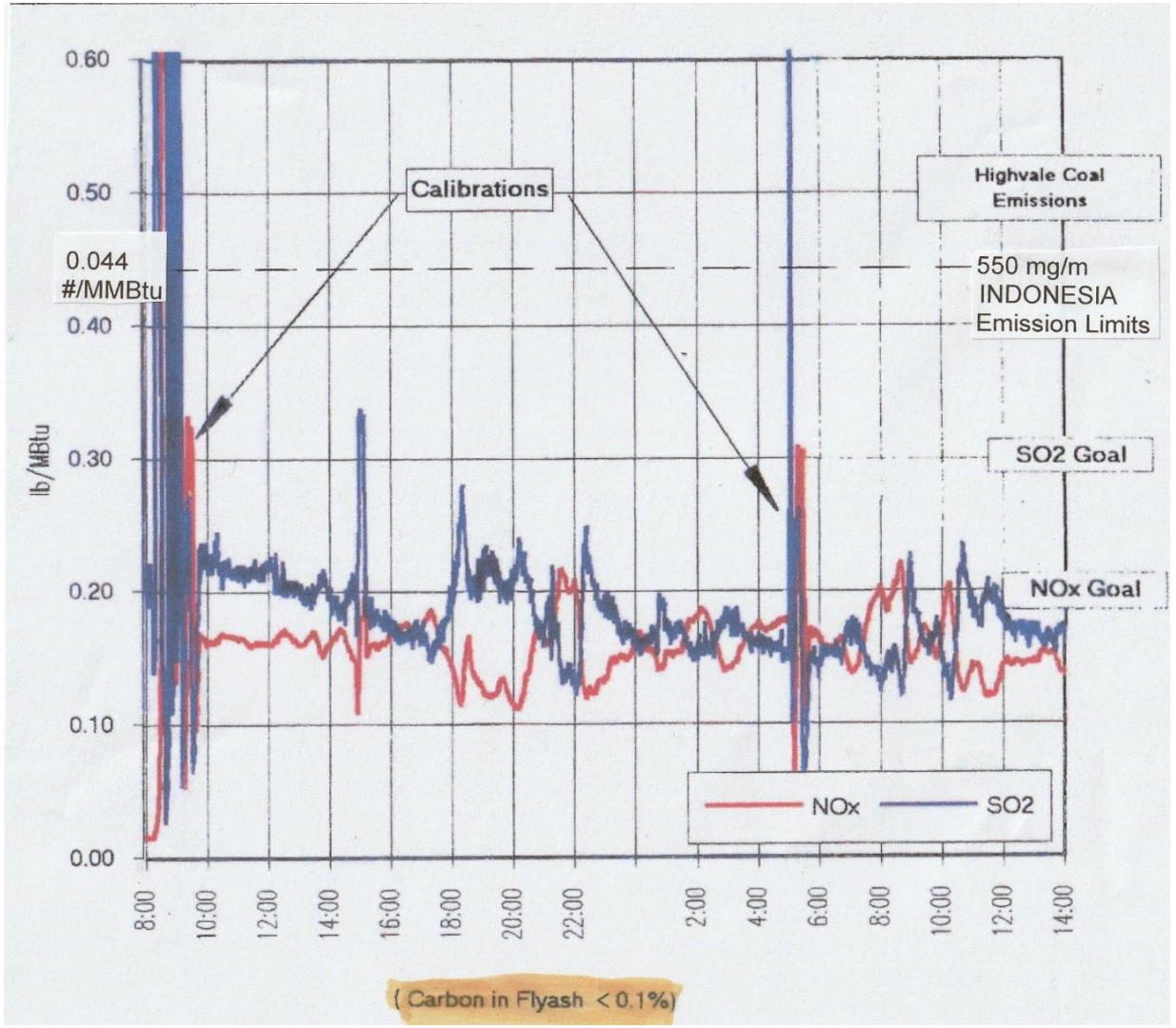
# LNS-CAP

## CCS Gasification Chamber Inspection

# LNS-CAP Demonstrated Emissions

ESSO LNS-CAP Facility, Cold Lake, Alberta, Canada – Subbituminous "Highvale" Coal

$SO_2$ - 0.2 lb./MMBtu (250 mg/m) $NO_x$ - 0.15 lb./MMBtu (184 mg/m)



# Coal-Fired Stoker Boiler

**CCS Retrofit Modifications**

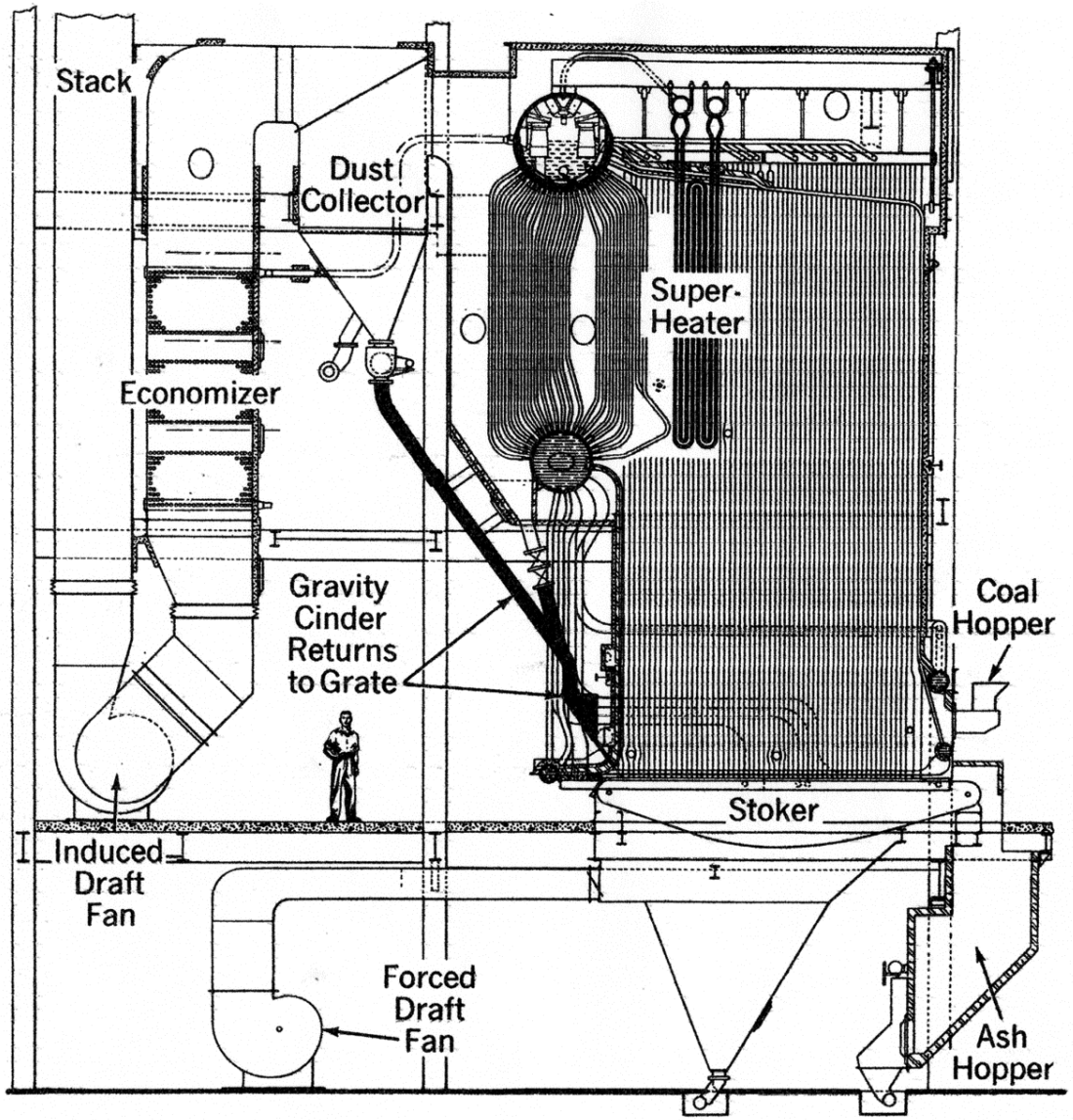
**Remove:**

- Stoker Feeder System
- Coal & Ash Hopper,
- Brick over stoker grate
- Control Panel

**Engineer, Design, & Supply all Hardware:**

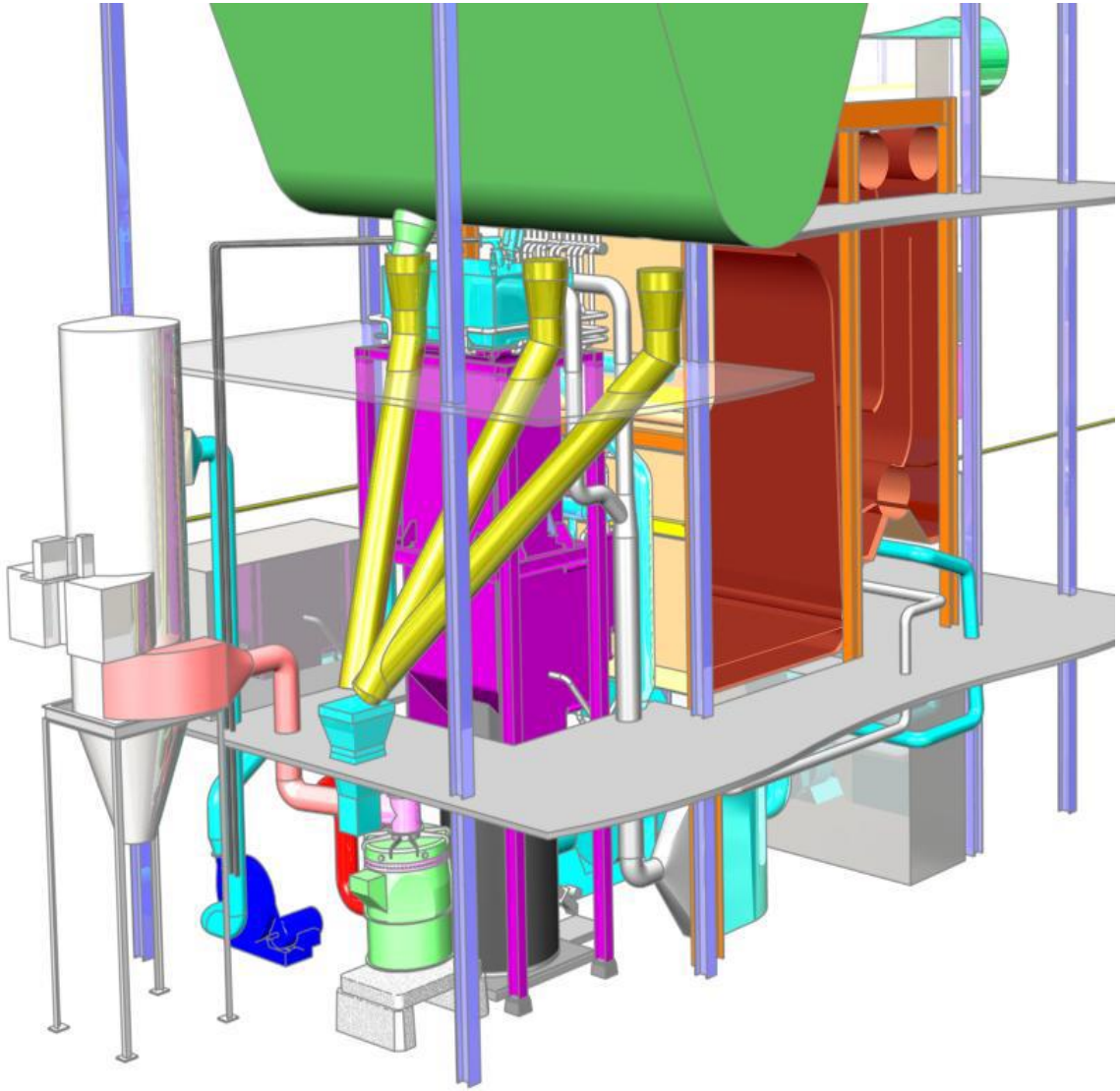
- CCS Burner,
- Gasification Chamber,
- Combustion Air Heat Exchanger
- All Boiler Instrumentation,
- Coal Mill, Coal-Air Separator, FD fan, Boiler & Combustion Management Sys, HMI & PLC New New Control Panel & MCC

**Operators (two / shift)**:
Was all manual; Now with HMI - from cold start to automatic full load operation in 5 hrs.



# CCS-Stoker® Boiler Retrofit

- 30 MW (Thermal)
- 125 MMBtu/hr.
- 5 T/hr. Coal
- Detailed 3D Model of Plant



# CCS Gasification Chamber Installation

# CCS Gasification Chamber Installation

- Shop fabricated assembly
- Membrane - water wall, studded and refractory lined.
- Connected to the boiler drums for natural circulation water cooling.
- The CCS Burner assembly is the blue box inside building

# CCS-Stoker® Equipment & Operation

- CCS “Indirect Firing” Scheme
- Refurbished 453 CE/ Raymond mill
- Uses hot combustion flue gas (< 10% $O_2$)
- Fixed sweep gas flow, variable coal flow
- Exit gas temperature: 150 F
- Dry powdered coal directed to pulse-jet bag house

Pulverizer

# CCS Coal-Air Separator

- Pulse-jet baghouse separates pulverized coal from mills wet sweep gas.
- Pulse-jet uses plants inert flue gas – for safety.
- Hopper maintains ~30 min. coal supply w/ level switches to manage coal feed to mill.
- PC then metered to CCS burners by rotary feeders.

# CCS-Stoker® Operation Observations

- No Ash Deposits on Furnace Walls @ 6 months
- No Plugging or Fouling of Back Pass Section

Furnace Walls

Furnace Ceiling & OFA Ports

# CCS-Stoker® Full Load

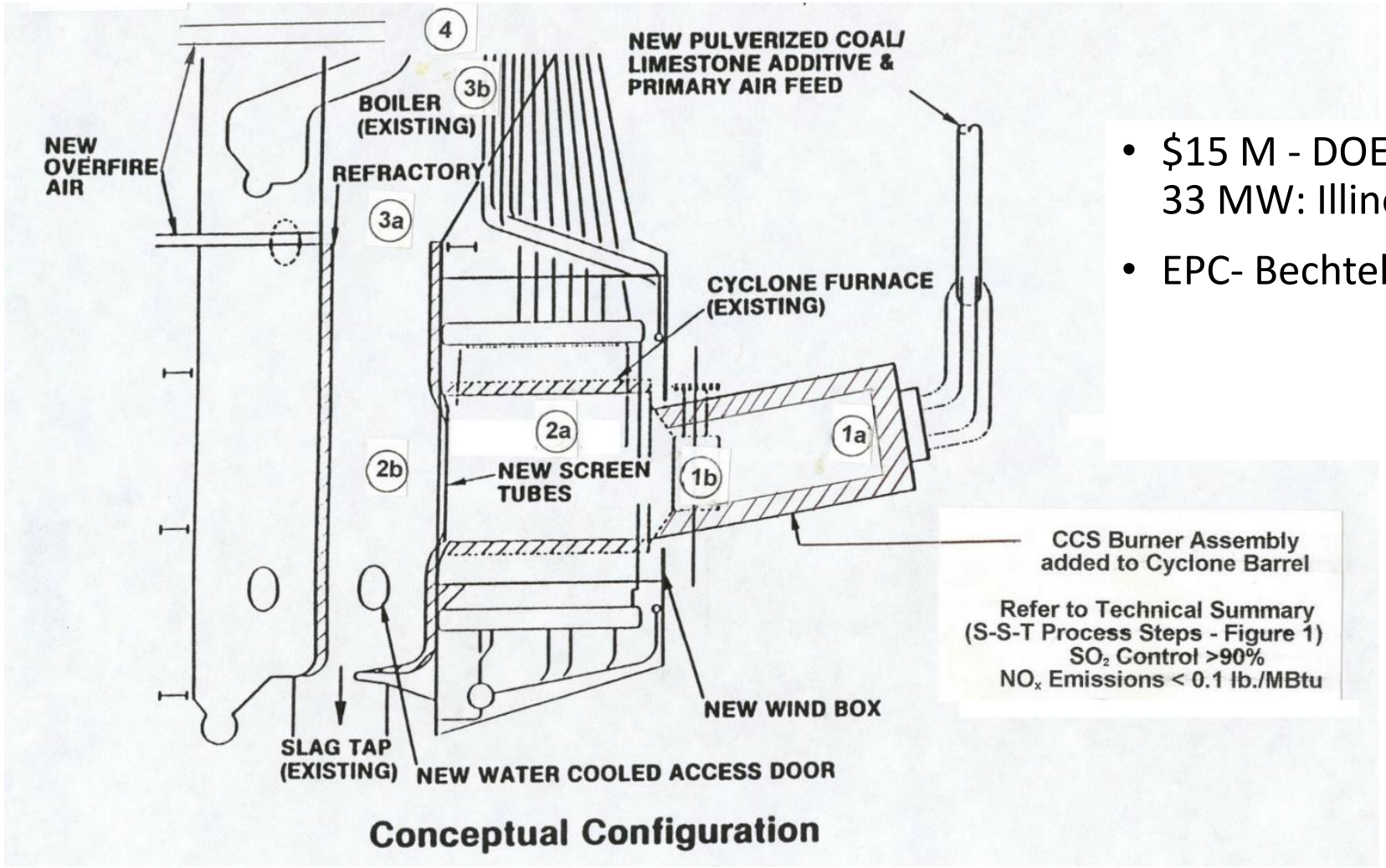
MCR Operation – 95,000 lb./hr. Steam

# CCS-Stoker® Retrofit Performance

## Full Load Operation (2.5 % Sulfur Illinois Bituminous Coal )

| Stoker Boiler Performance | Stoker Base Line Test | CCS Full Load | Change from Base Line % |
|---|---|---|---|
| **$SO_2$ Stack Emissions** lb./MMBtu / ($mg/m^3$) / ppm | 1.8 / (2250) / 790 | 0.72* / (900 ) / 315 | - 67 % |
| **NOx Stack Emissions** lb./MMBtu / ($mg/m^3$) / ppm | 0.5 / (630) / 680 | 0.14 / (180) / 88 | - 72 % |
| **Boiler Efficiency** | 77 % | 87 % | + 12.8 % |
| **$CO_2$ Emissions - Ton/yr.** | 94,019 | 73,720 | - 20,300 T/y |
| **$CO_2$ Emissions Reduction** | | | (- 21.6 %) |

# CCS-Cyclone Boiler Retrofit

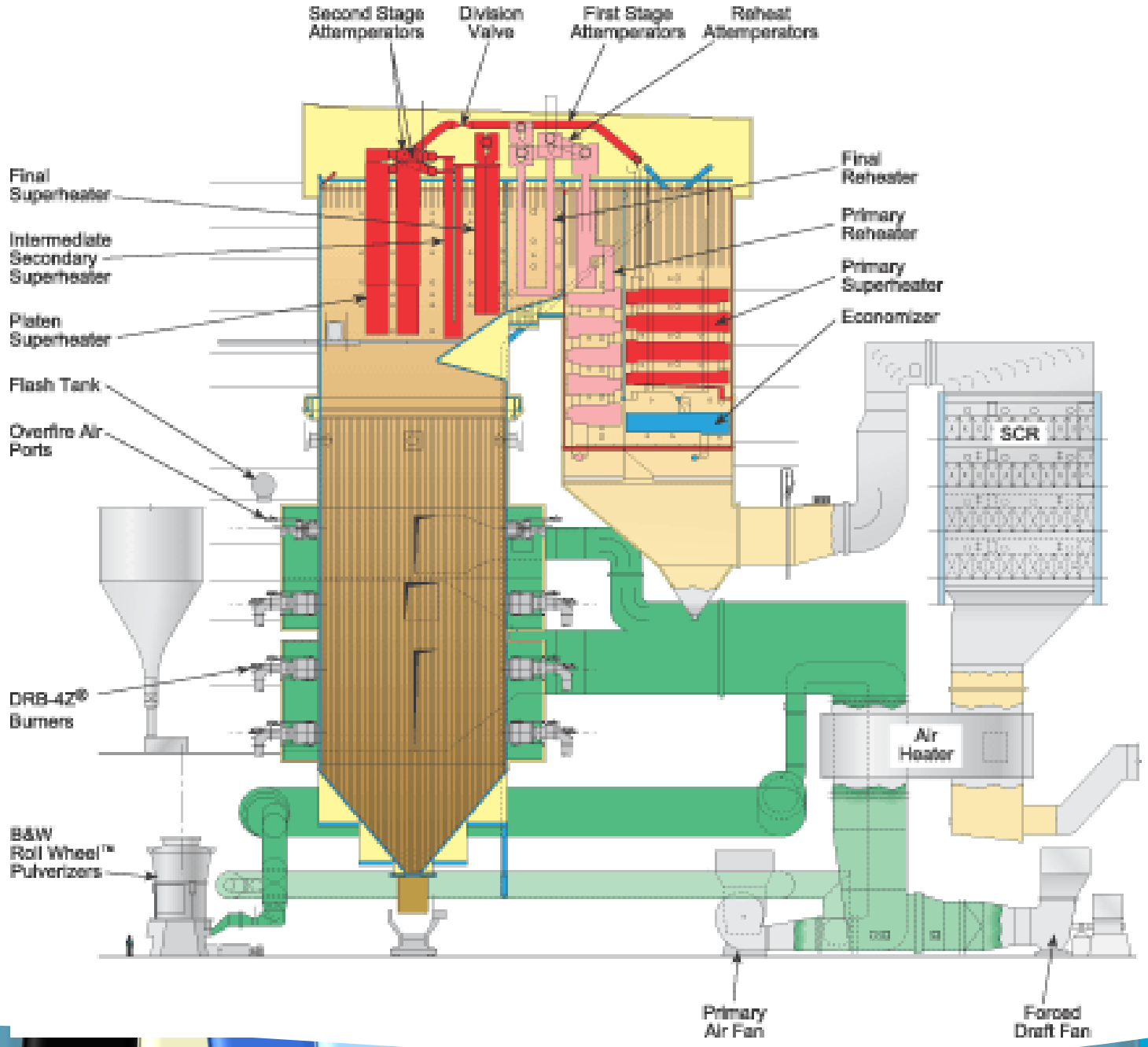



- $15 M - DOE Clean Coal Technology II (CCT II) – 33 MW: Illinois HS Coal
- EPC- Bechtel / Mfg. - Riley Stoker

# Typical 400 MW PC Fired Boiler

Opposed Wall Fired

- 6 Mills
- 24 Coal Burners

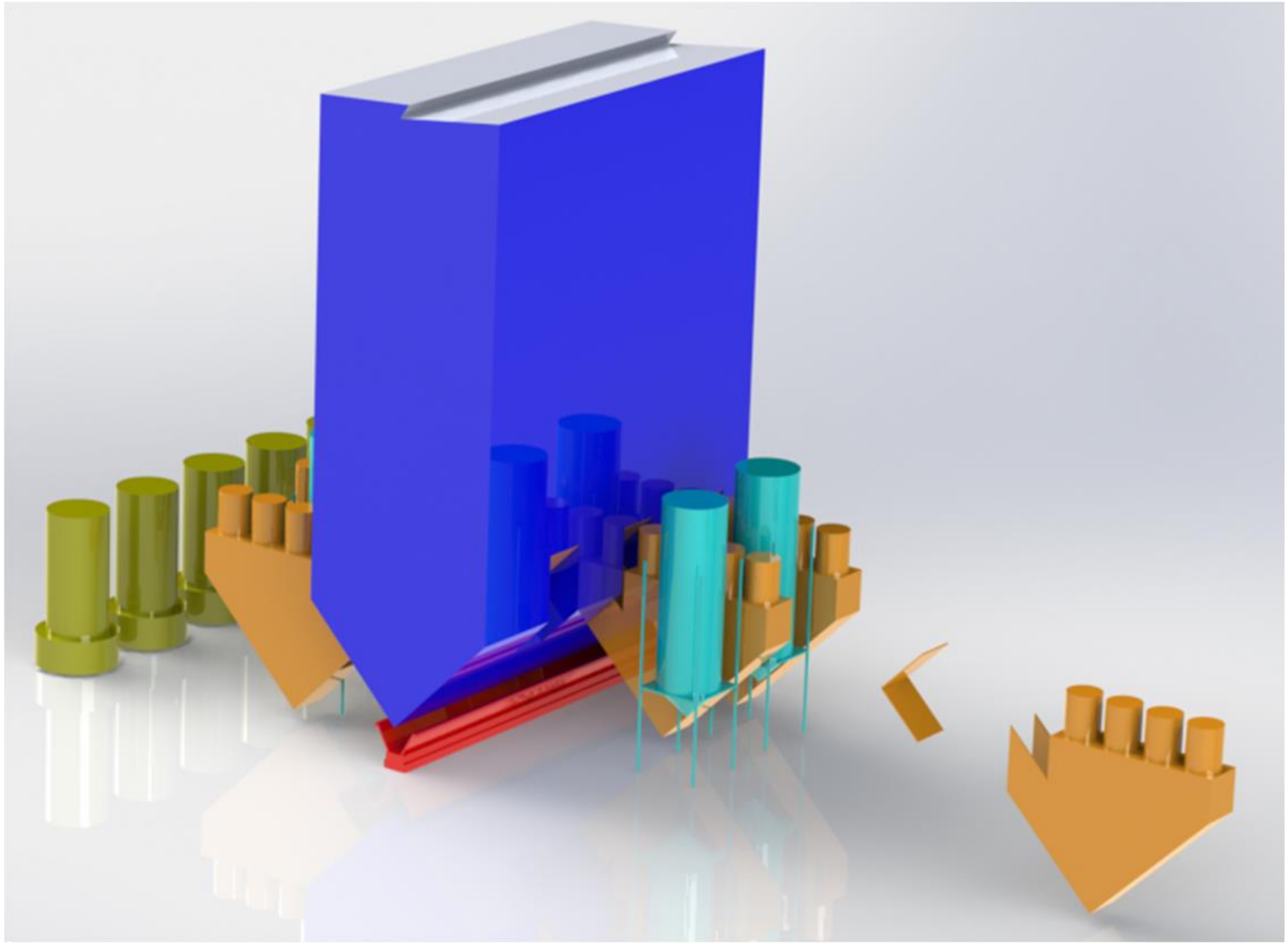


# CCS Wall-Fired Retrofit Boiler

- Remove: Coal Burners
- Brick over burner ports

Add New:

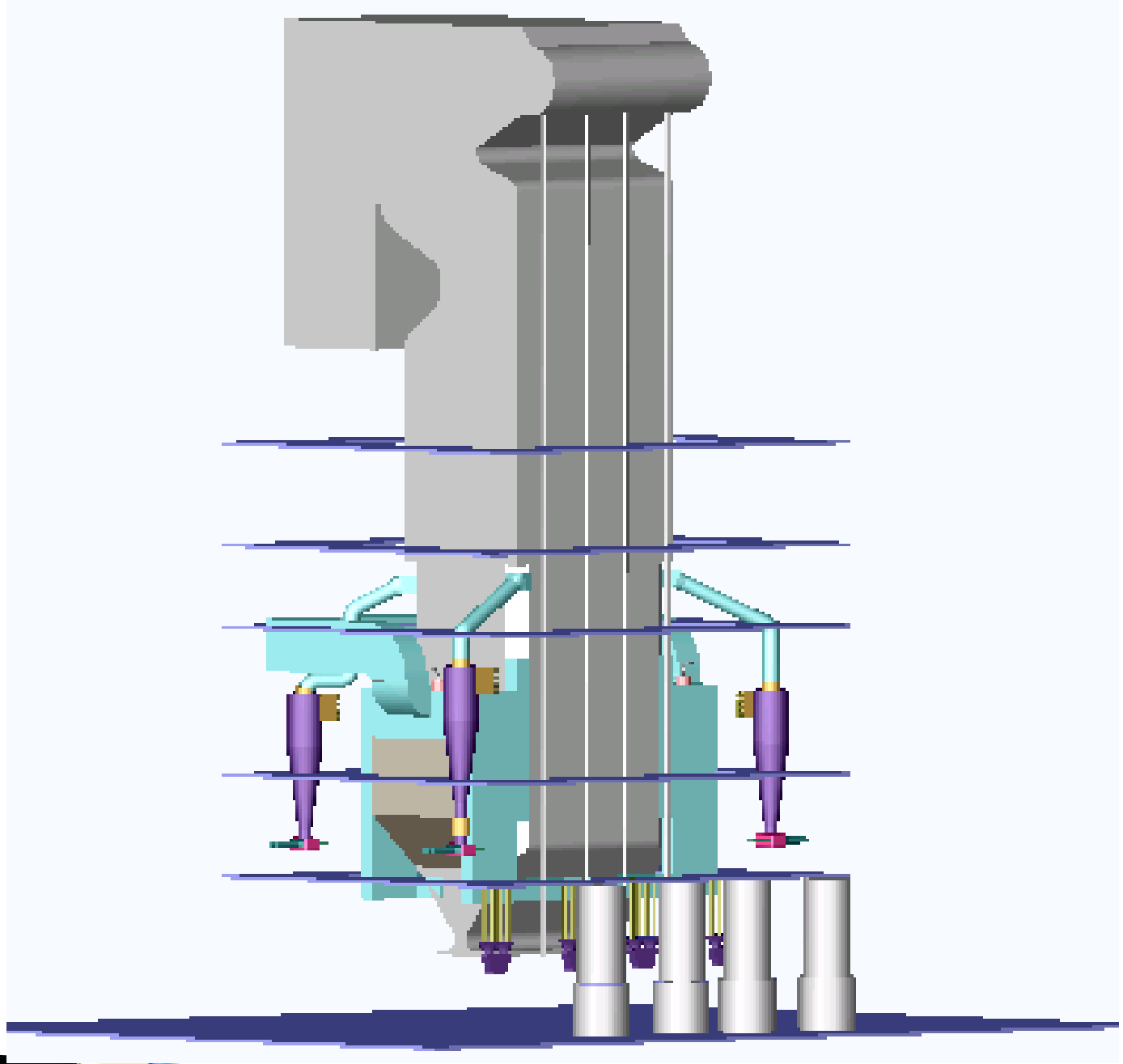
- 24 CCS Burners
- 6 Gasification Chamber's
- 6 Coal / Sweep Gas Seperators



# CCS-Tangential™ Boiler Retrofit

**Indianapolis Power & Light**
Unit 6

108 MW TANGENTIAL BOILER
WITH CCS RETROFIT



# CCS Retrofit Efficiency / Heat Rate

- Remove water from coal ; from 30% to ~ 8%
  (Increases fuel BTU values & reduce in furnace “Latent heat of water loss”)
- High temperature combustion: = higher steam temperatures:
  (each + 50 F = + 1% efficiency)
- High carbon conversion with low excess air:
  Very low (~ 1%) LOI (Low $NO_x$ burners = ~ 7% LOI)
- No $SO^3$ in flue gas (reduce furnace exhaust gas temperatures)
- Very clean furnace walls (minimum / no soot blowing required)
- Eliminate FGD and SCR emission control systems (~ 2% parasitic loss)
- Rework plant’s rotating turbine and machinery for improved efficiency.

# CCS Retrofit Summary

## Update coal-fired power plants for 21st Century

- From Fundamental Combustion Theory to Commercial Operation.
- Improve plant Heat Rate to near HLEC performance.
- Meets stringent environmental $SO_2$ & $NO_x$ pollution regulations.
- Affordable retrofit cost for competitive capacity factor & dispatch
- All equipment fits within plant site & boiler footprint.
- Ash products have value (sell bottom ash & fly ash)
- No Hazardous or Toxic Chemicals Required

**CCS is ADVANCED COAL GASIFICATION TECHNOLOGY!**

# Keith A. Moore  CEO - CastleLight Energy

**Business Development &Technology Management**
Mr. Moore focuses on strategies to mitigate / control pollution emissions from coal-fired electric generating plants to meet U.S. EPA's stringent air quality regulations.

Mr. Moore has 30 years of technical, business development and management of advanced environmental control technologies;

**Dry Flue Gas Desulfurization Systems**
(Dry FGD scrubber), including
development and commercialization

**The Clean Combustion System** (CCS)
a field-demonstrated hybrid of coal-gasification and combustion for control of $SO_2$ and $NO_x$ emissions with improved efficiency,

**Coal Beneficiation Processes**
Remove water, ash and recover oil values from coal,
He holds patents for Sulfur Capture and Coal Beneficiation

**B.S., Electrical Engineering**, Virginia Polytechnic Institute
General Contractor - "B" License, State of California
Pilot – Commercial / Instrument, IGI; SEL, Glider

**Keith A. Moore**
**CastleLight Energy Corp.**
277 Sunset Dr.
Oxnard, CA 93035
E-Mail: keith@castle-light.com
Phone: 805-551-0983
Visit: www.Castle-Light.com