Re-Engineering Coal-Fired Generating Plants for Low Pollutant Emissions and Extended Competitive Life

Meet EPA's Cross State Air Transport Rules (CSAPR) and Mercury and Air Toxic Standards (MATS) with low-cost Coal Beneficiation and Hybrid Coal-Gasification

By

CastleLight Energy Corp

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CastleLight Energy Corp.

- **CastleLight Energy Corp.**
  comprises the technical team from Rockwell International - from 1980's rocket engine modeling programs.
- **Developed the Clean Combustion System™** (CCS)
  - Control of SO_2 & NO_x with improved efficiency
- **Coal Beneficiation Processes**
  - Remove water, ash, & mercury from coal
  - Recover oil values from coal
- **Commercial Field Demonstrated Technology**
- **Provide Technology Management & Licensing**

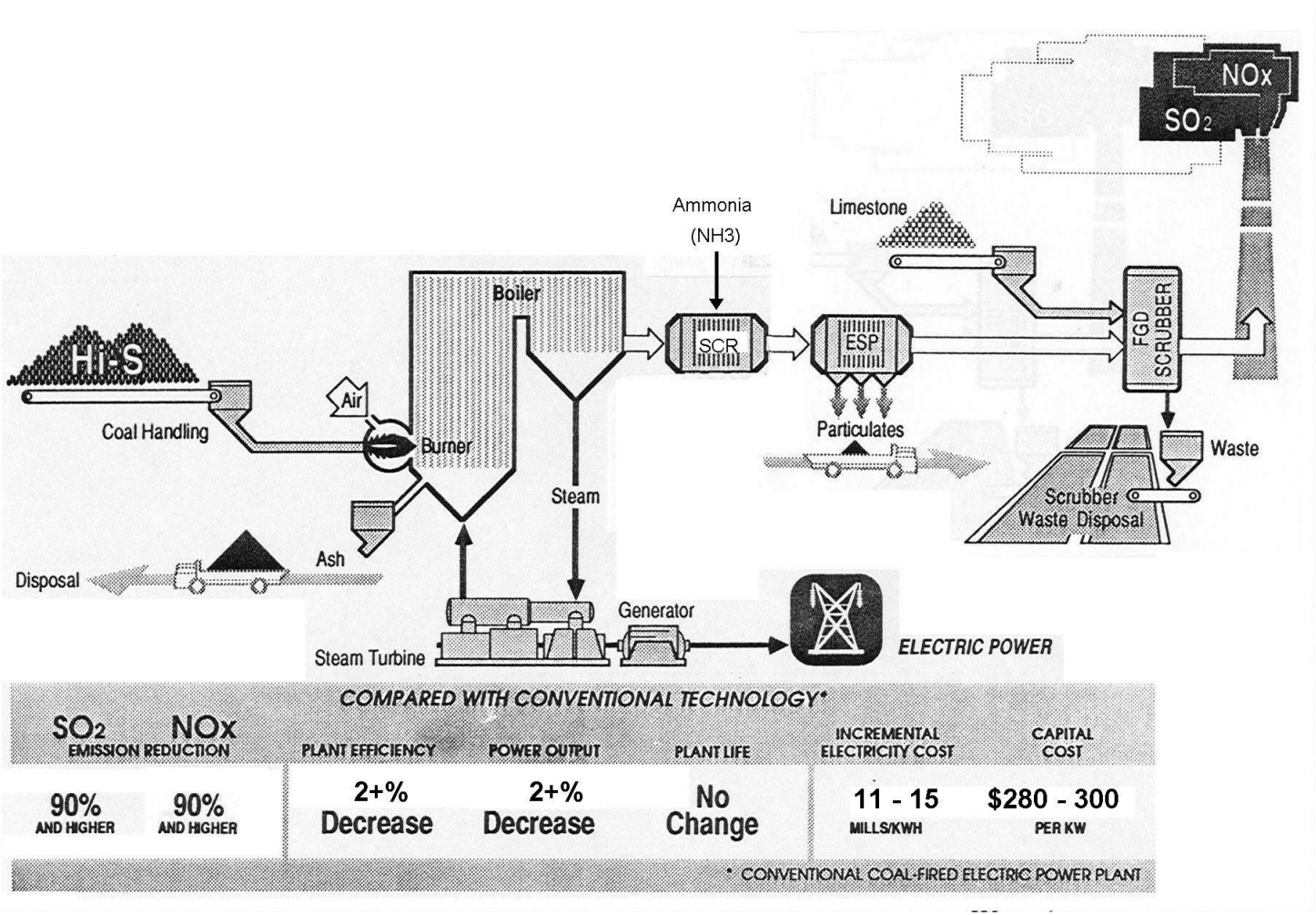
Observation

EPA 's Strict New Environmental Regulations

- Cross State Air Transport Rules (CSAPR)
  - Focus on SO_2 & NO_x (particularly in summer months)
- Mercury and Air Toxic Standards (MATS)
  - Focus on Particulates, SO_2 Mercury, HAPS
- Green House Gas Performance (GHG) - No CO_2 increase allowed
- **Impact:**
  - The older, smaller (<400MW) coal-fired generating plants may be abandoned due to cost of emissions compliance.
- **Solution / Approach:**
  - Re-Engineer plant with Clean Combustion System (CCS) for:
    - ❖ SO_2, NO_x, and mercury emissions compliance
    - ❖ Higher Efficiency (No CO_2 increase)
    - ❖ Construction Permit with waiver of PSD - No NSR
    - ❖ Lower Retrofit & Operating Cost = Competitive Dispatch

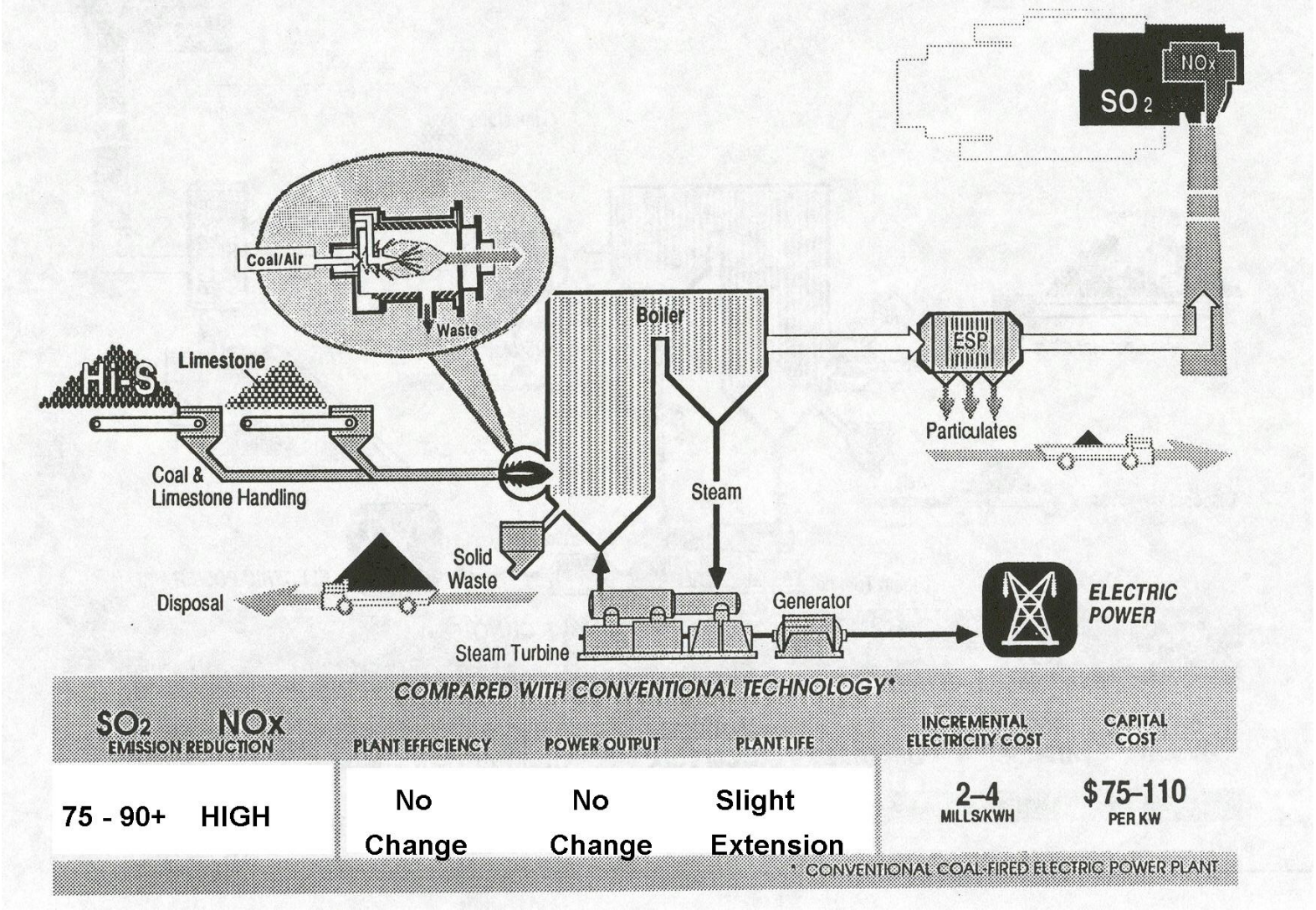
Conventional Emission Controls

SO_2 = FGD+ Limestone; NO_x = SCR + Ammonia; SO_3 = Trona, Hg = Activated Carbon



CCS Hybrid Coal-Gasification

SO_2 & NO_x Control Right in the Combustion Step



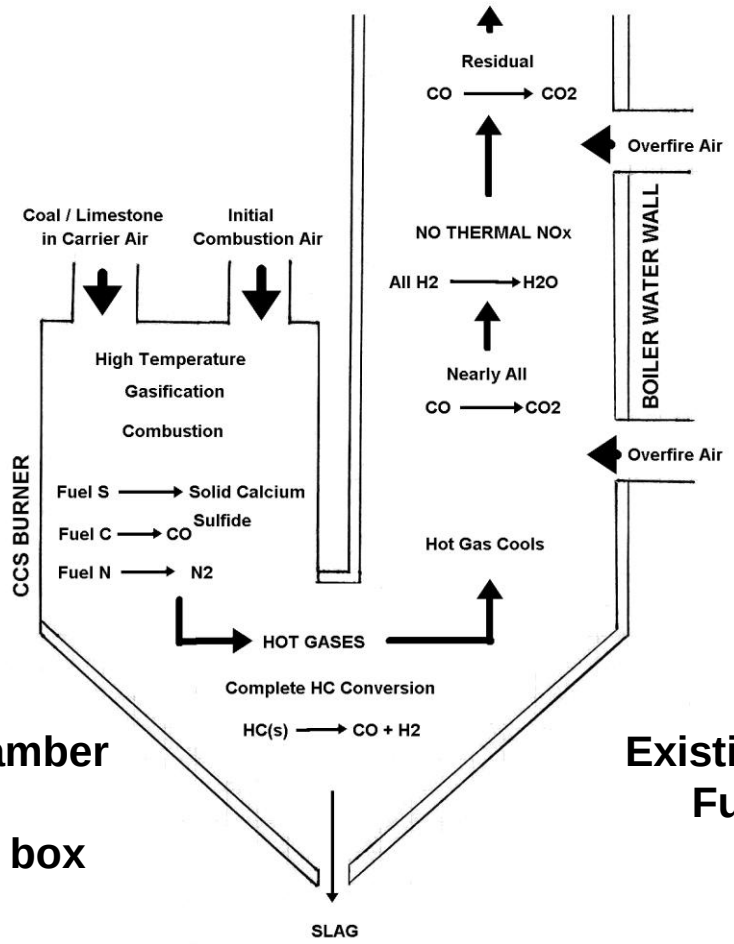
COMPARED WITH CONVENTIONAL TECHNOLOGY*

SO_2 EMISSION REDUCTION	NO_x EMISSION REDUCTION	PLANT EFFICIENCY	POWER OUTPUT	PLANT LIFE	INCREMENTAL ELECTRICITY COST	CAPITAL COST
75 - 90+	HIGH	No Change	No Change	Slight Extension	2–4 MILLS/KWH	$75–110 PER KW

* CONVENTIONAL COAL-FIRED ELECTRIC POWER PLANT

Hybrid Coal Gasification Schematic

The Clean Combustion System (CCS)



CCS Gasification Chamber replaces coal burners & wind box

Existing Boiler Furnace

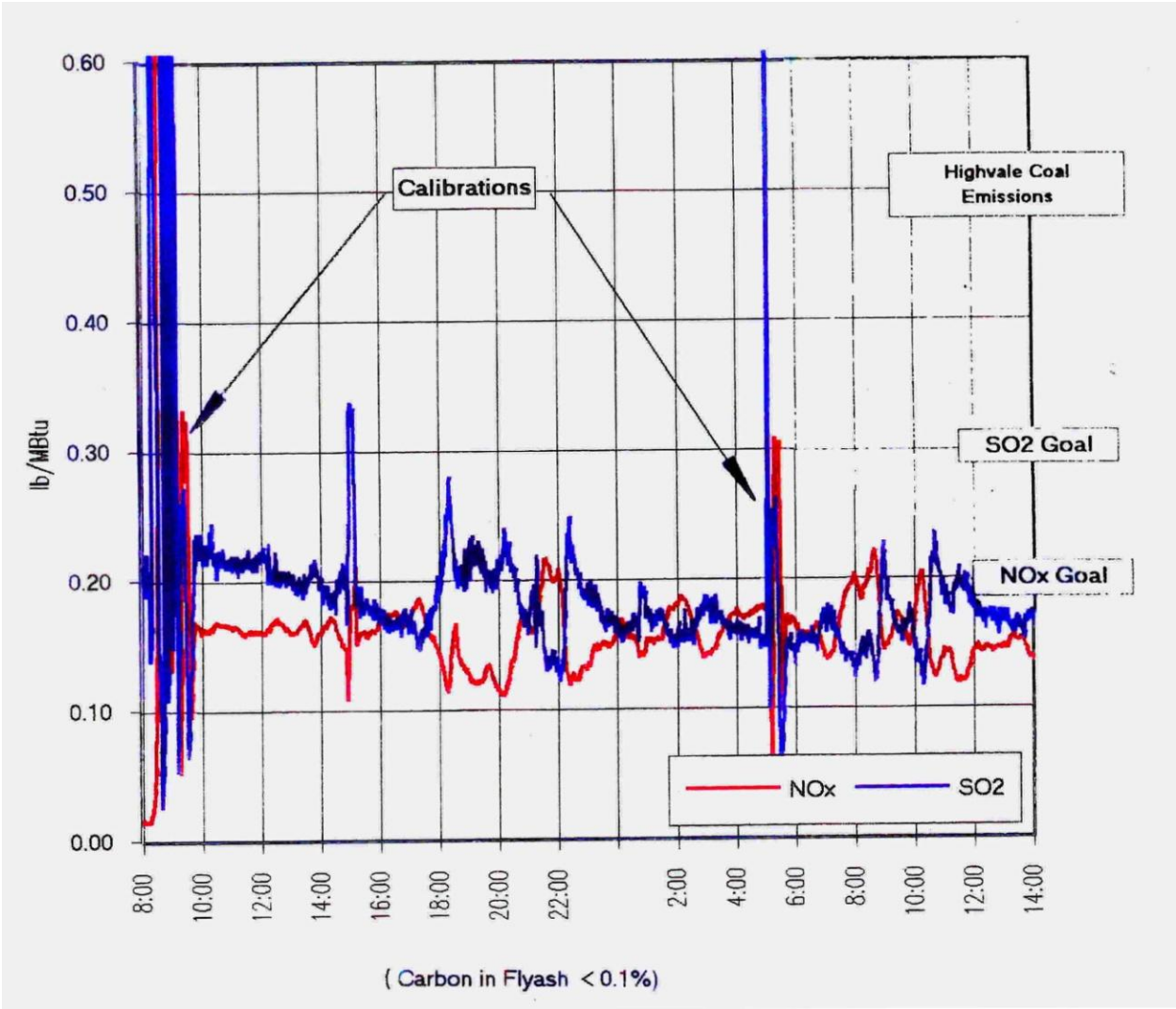
LNS-CAP Facility

ESSO Site, Cold Lake, Alberta Canada
50 mmBtu/hr – 3T/hr PRB Coal

Demonstrated Emissions

SO_2 - 0.2 lb./mmBtu & NO_x - 0.15 lb./mmBtu

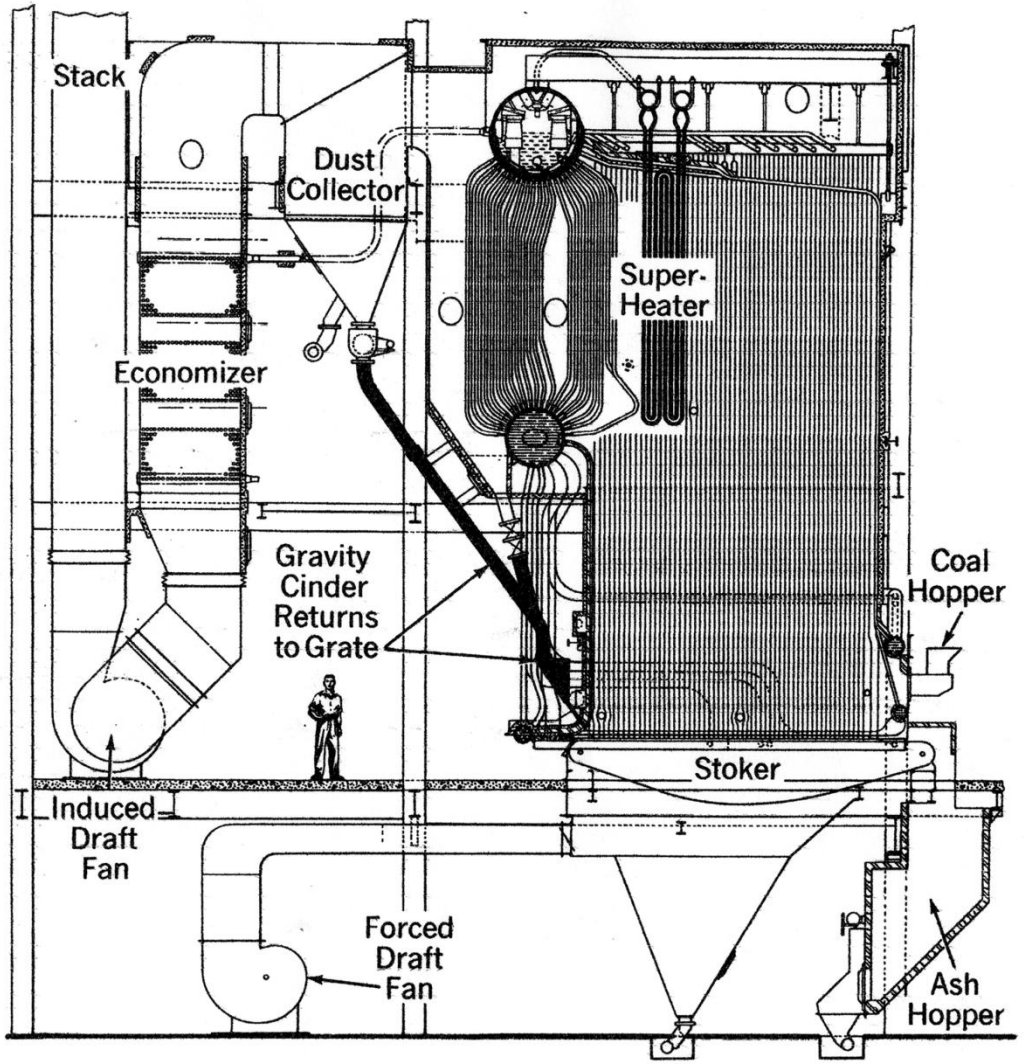
ESSO LNS-CAP Facility, Cold Lake, Alberta, Canada



CCS-Stoker® Project Description

- **Objective**:
  - Reduce operating cost by half
  (switch to low-cost high-sulfur Illinois coal – 2.5 lb. SO_2/mmBtu)
  - Construction Permit w/ waiver NSPS, PSD; no NSR
  - Emissions Warrantee: <0.9 lb. SO_2 /mmBtu, <0.25 lb. NO_x /mmBtu
- **Project Initiated**: Oct 2005,
  Commissioning: Jan 2007
- **CEC Scope** : Process Design & Engineering;
  - Supply all equipment, hardware, electrical, instrumentation / controls
  - Provide Commercial Warrantee & License
- **Client Scope**: Site Construction Management;
  - Equipment Installation, as directed by CLPRC
  - Commissioning & Start-up
- **Project Support**: In part, by the Illinois Department of Commerce and Economic Opportunity through the Illinois Clean Coal Institute and the Office of Coal Development.

Coal-Fired Stoker Boiler
(typical)



CCS Retrofit Modifications

Remove:

Stoker Feeders,
Ash Hopper,
Brick over stoker grate
Control Panel

New Equipment:

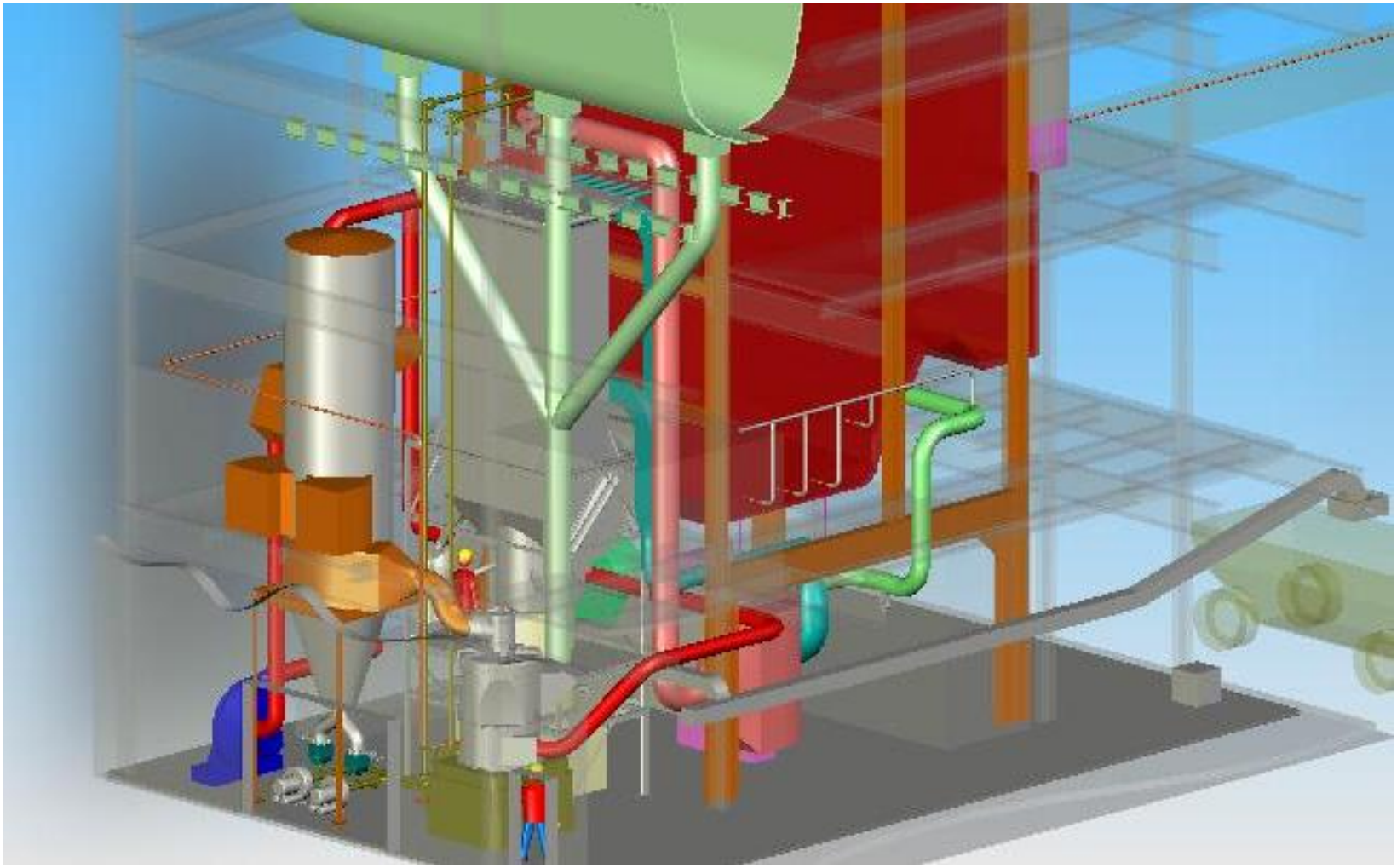
CCS Burner,
Gasification Chamber,
Combustion Air Heater
Boiler Instruments,
Coal Mill, Bag house, FD fan, BM & Combustion Sys,
HMI & PLC Controls
New MCC

Operators (one/shift):

Was all manual operation;
Now with HMI - from cold start to automatic full load operation in 5 hrs.

CCS-Stoker® Retrofit

30 MW (Thermal) - 125 mmBtu/hr – 5 T/hr Coal



Gasification Chamber Installation

Gasification Chamber Installation

- McBurney Corp designed and supplied the GC
- Connected to the boiler drums for natural circulation water cooling
- Shop fabricated membrane wall studded and refractory lined.

CCS-Stoker® Equipment and Operation
Pulverizer

- Refurbished 453 CE/ Raymond mill
- “Indirect Firing” Scheme
- Uses hot combustion flue gas (<10% O_2)
- Fixed sweep gas flow, variable coal flow
- Gas temperature adjusted to give 150F at exit
- Dry powdered coal to bag house

CCS-Stoker® Equipment and Operation
Coal-Air Separator

- Separates coal from sweep gas
- No air (O_2) added for bag cleaning
- Hopper w/ level switches maintains ~30min. coal supply
- Gate & spouts to rotary feeders - meters PC to CCS burners

CCS-Stoker® Operation Observations

Operation @ MCR – Steam Overboard

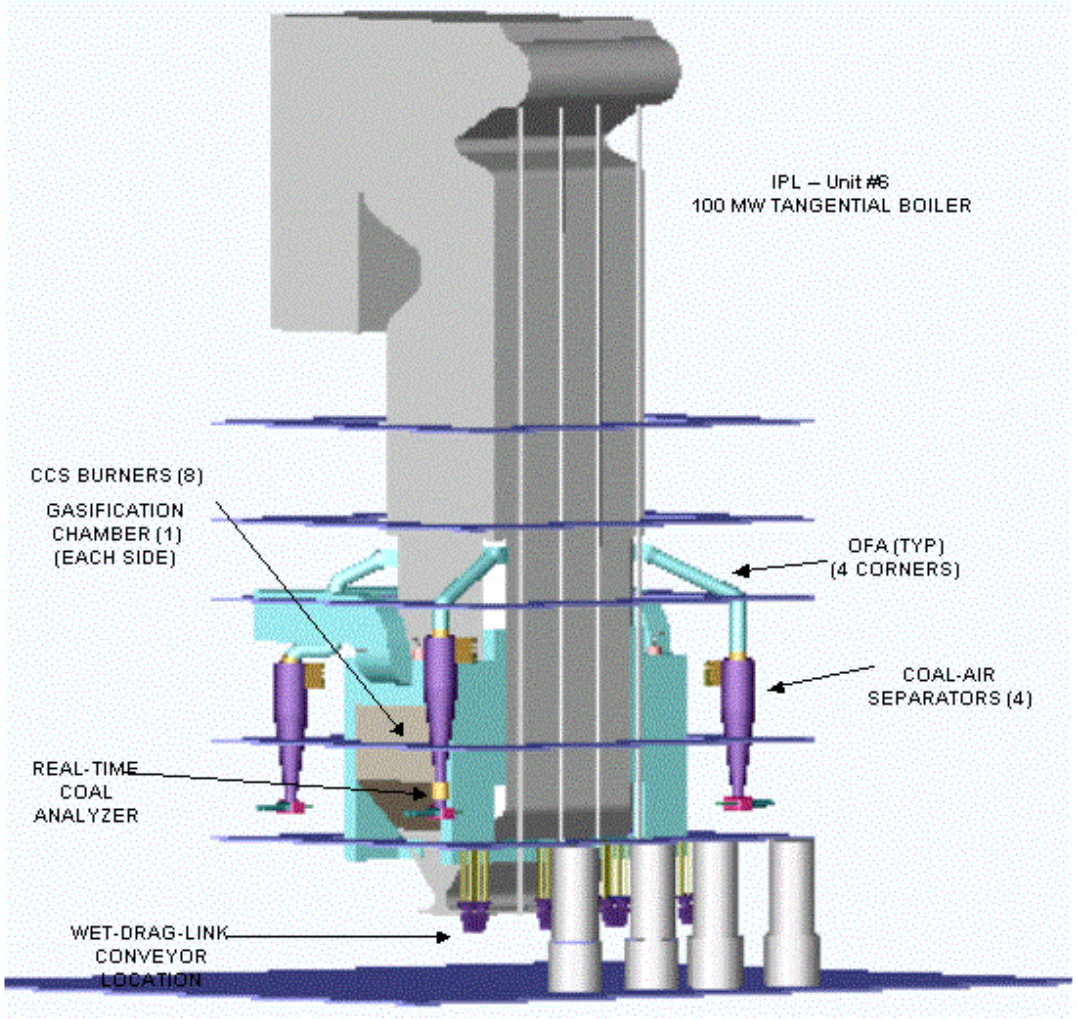
CCS-Stoker® Retrofit Performance

Preliminary Results – Full Load Operation

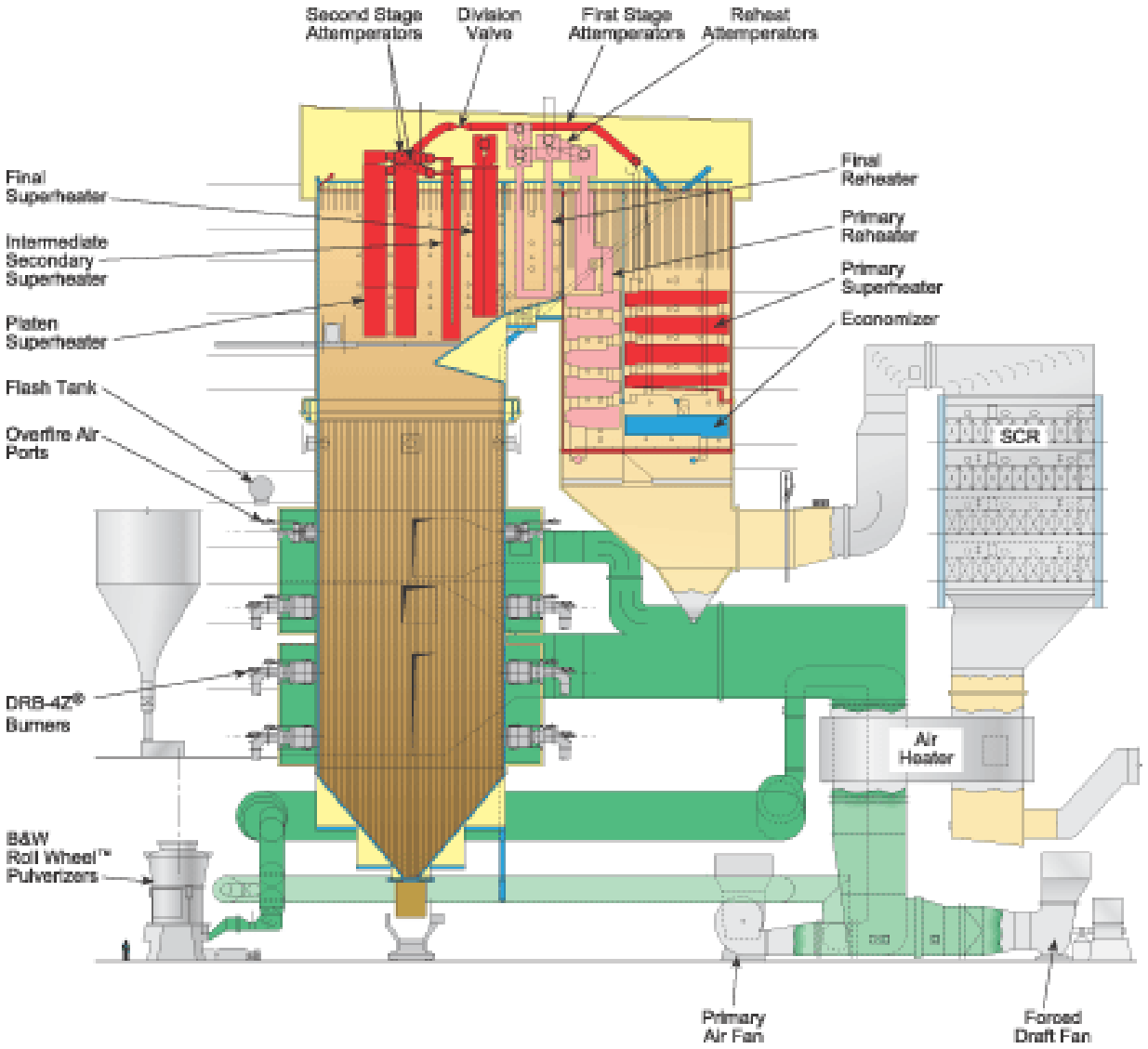
Item	Stoker Base Line Test	Preliminary CCS Performance	% Change from Base Line
SO_2 Stack Emissions (lb/MMBtu)	1.80	0.72	- 67.0 %
NOx Stack Emissions (lb/MMBtu)	0.50	0.14 (88 ppm)	- 72.0 %
Boiler Efficiency	77.0	86.9	+ 12.8 %
CO_2 Emissions - Ton/yr GW credits (% Reduction)	94,019	73,720	20,300T/y (- 21.6 %)
Project Cost Recovery (from firing lower cost coal)		~ 3 years	

CCS-Tangential™ Boiler Retrofit

100 to 300 MW

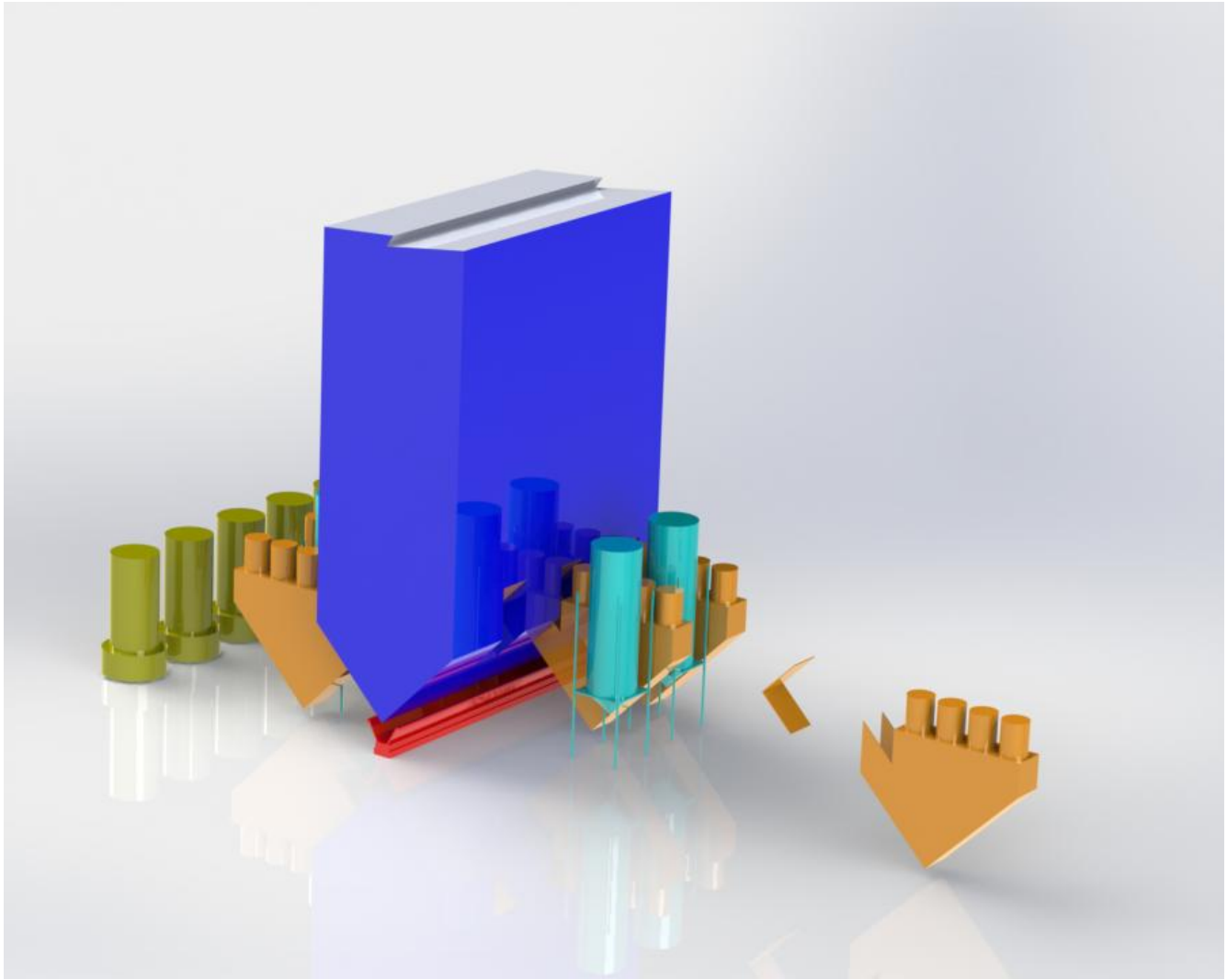


600 MW B&W PC Fired Boiler



CCS Re-Engineered PC Boiler

600 MW – 6 GC's, 24 Burners



Capital & O&M Cost Assessment

FGD + SCR + Baghouse vs. CCS + Baghouse

600 MW Power Plant - PRB Coal (Estimated)

600 MW Power Plant - PRB Coal (Estimated)				
Control Technology	**Retrofit Cost ($/kW)**	**Fuel Cost ($/Yr)**	**Fixed + Variable O&M Cost ($/Yr)**	**Operating Cost ($/kW-hr)**
FGD + SCR + Bag house	**$ 1,165**	**$ 80,000,000**	**$ 24,000,000**	**$ 0.0200**
CCS + Bag house	**$ 425**	**$ 70,000,000**	**$ 11,000,000**	**$ 0.0154**
Delta Savings	**-64%**	**-14%**	**-54%**	**-23%**

600MW Boiler	GIVEN / ASSUMED	Parameter
Stack Temperature	325	F
Heat Rate - Net	9600	Btu/kWh
Plant efficiency	35.5	%
Main Steam Pressure	2440	psig
Main Steam Temperature	980	F
Main Steam Flow	4250	KLB/h
Boiler Feed Water Temperature	425	F
Boiler Feed Water Flow	4250	KLB/h
Low NOx Burners - LOI	7	%
Coal Cost - PRB, Black Thunder	40	$/ton
Capacity Factor	80	%
FGD - SCR Systems	NONE	

Re-Engineered Power Plant with CCS & Coal Beneficiation Processes

Stack Emissions Estimate* firing PRB coals (1.2 lb. SO_2/mm Btu Coal)

- SO_2 = < 0.2 lb./mmBtu (< 105 ppm)
  ~80% reduction
- NO_x = < 0.10 lb./mmBtu (< 75 ppm)
- CO = < 100 ppm
- LOI = < 1% (very low carbon in ash)
- SO_3 = < 0.1 ppm (condensable particulate)
- Mercury = < 40 ppb
- Particulate = < 0.03 lb./mmBtu (bag house)
- Boiler Efficiency = 2 – 10% increase

* Preliminary estimates of performance, includes bag house – no guarantees

CCS Features

Improved Operability, Availability & Reliability

- All equipment off-the-shelf & familiar to the Operators
  - Safe, stable operation,
  - Same startup, shutdown and turndown as a PC burner
- Bottom Ash (slag) removed before furnace
  - low particulate/ash load; clean furnace, less soot blowing
- Sulfur removed from furnace gases - near-zero SO_3:
  - Allows for lower furnace exit temperatures
  - Minimize water-wall wastage & corrosion,
  - Can use hot boiler exhaust for pulverizer sweep air:
    - Dry the coal – reject moisture
    - Improves coal pulverizer safety from fire & puffs (low O_2)
- Improved Boiler Efficiency (2 to +10%)
  - Reduce CO_2 emissions
  - High combustion efficiency (LOI < 1%)
- Limestone is only "chemical" required
- No waste water for disposal

CCS Summary
(Key Strategic Issues)

- From Fundamental Combustion Theory to Commercial Operation
- Fire lower cost coals - reduce plant operating cost
- Meets EPA's new stringent CAIR initiatives for SO_2 & NO_x
- Allow power plant upgrade with waiver of NSPS & PSD - No NSR
- May generate CO_2 – SO_2 – NO_x emission credits
- Low Retrofit Cost; maintain older, smaller power boilers competitive - improve capacity factor & dispatch
- Fits within Plant & Boiler Site Footprint
- No waste water discharge
- Coal waste is inert and may be land filled
- Ash products have value (sell bottom ash & fly ash)
- No Hazardous or Toxic Chemicals Required

It's ADVANCED COAL GASIFICATION TECHNOLOGY!

CastleLight Energy Corp
Re-Engineering Programs

- CastleLight Energy Corp. provides advanced environmental engineering consulting services.
- Re-engineer / upgrade gas, oil and coal-fired plants:
  - To burn coal with reduced operating cost
  - Extend competitive life for 20 or more years
  - And meet stringent new EPA emission regulations.

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