American Coal Council

Efficiency Improvements to the Existing Coal-Fired Fleet

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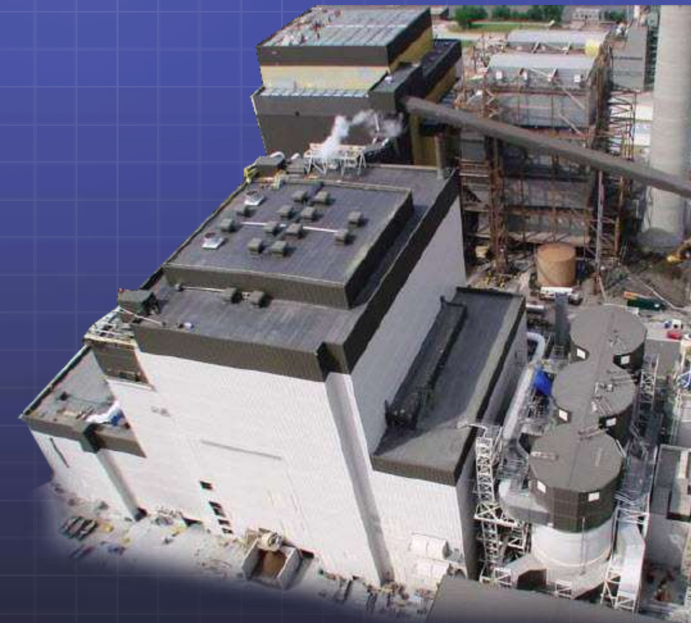
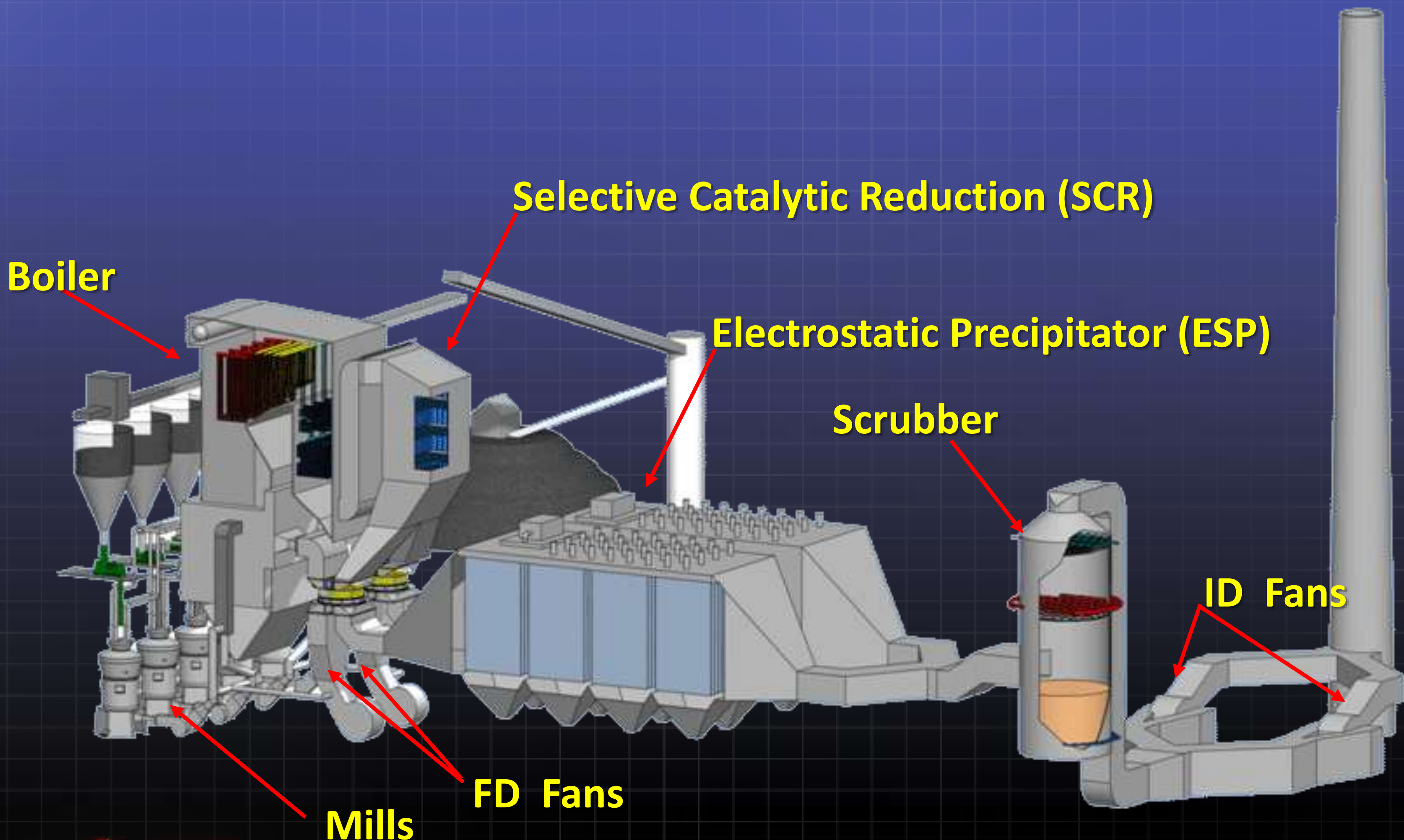
Introduction

- Coal fleet has average 40 yrs
- Investment to improve emissions
  - SCR's (Selective Catalytic Reactors)
  - FGD (Flue Gas Desulfurization)
  - Bag houses or ESP's
- 1960's coal fleet were designed for net heat rates well below 10,000Btu/kWhr
- Net thermal efficiency designs in the range of over 38%
- Today, the average old coal net plant heat rate remains about 33%



Typical 500 MW Coal Fired Plant



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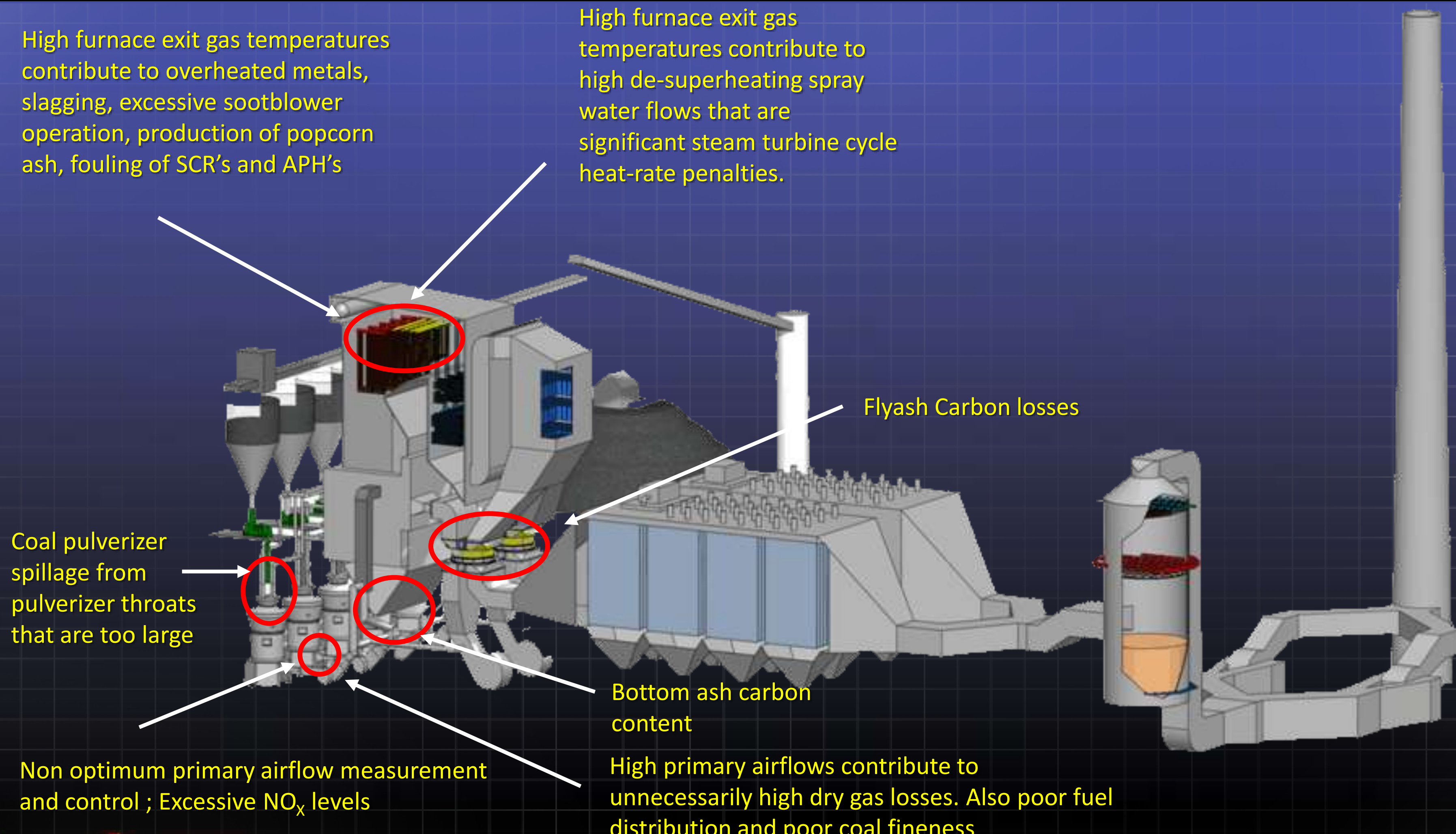
Our Business is Improving Overall Coal Plant Performance



Optimum Combustion Overview

Reduce air in-leakage to less than 0.5% oxygen rise from furnace to economizer exit

Reduce Spray-flows

Reduce furnace exit gas temperature peaks to 150°F below ash softening temp.

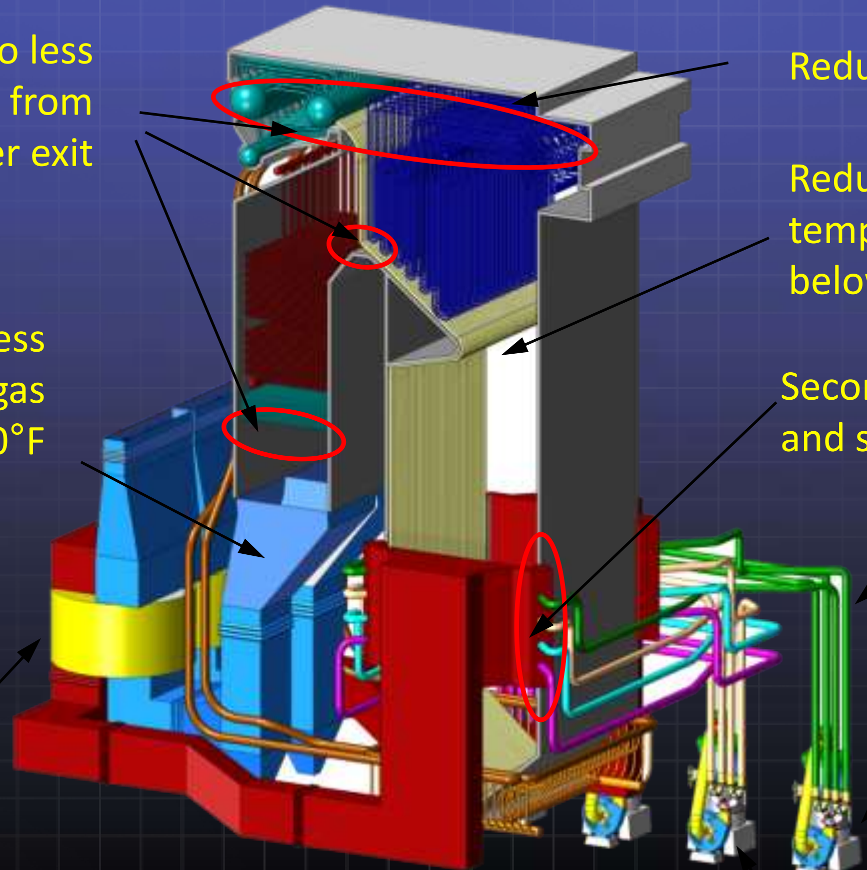
Achieve boiler cleanliness for maximum exit gas temperature of 750°F

Secondary air properly balanced and stage ±5%

Improve fuel distribution to better than ±10%

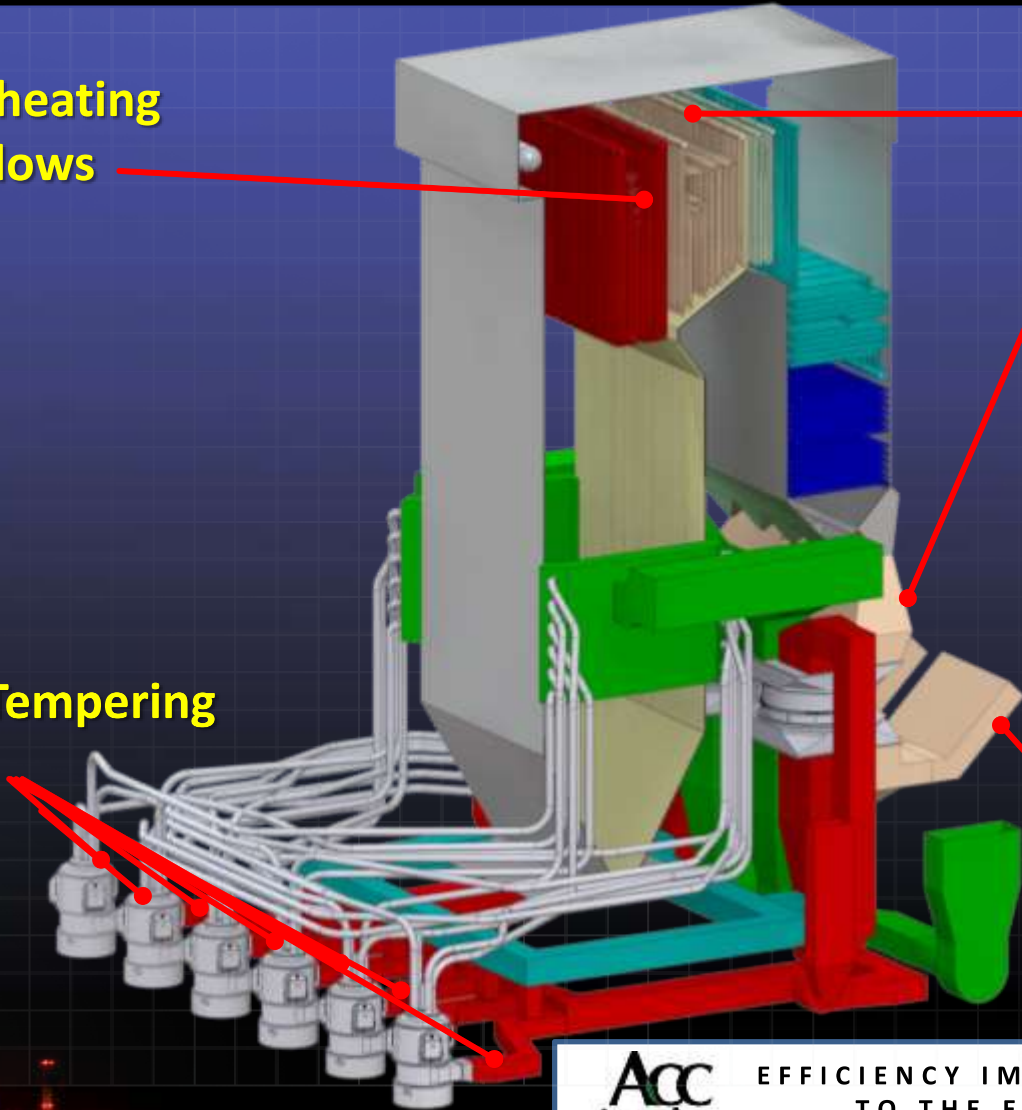
Capability to use lower cost fuels

Max. Airheater leakage of 10%



Improve pulverizer and classifier performance for fineness >75% passing 200 mesh and <0.1% remaining on 50 mesh

Stealth Opportunities



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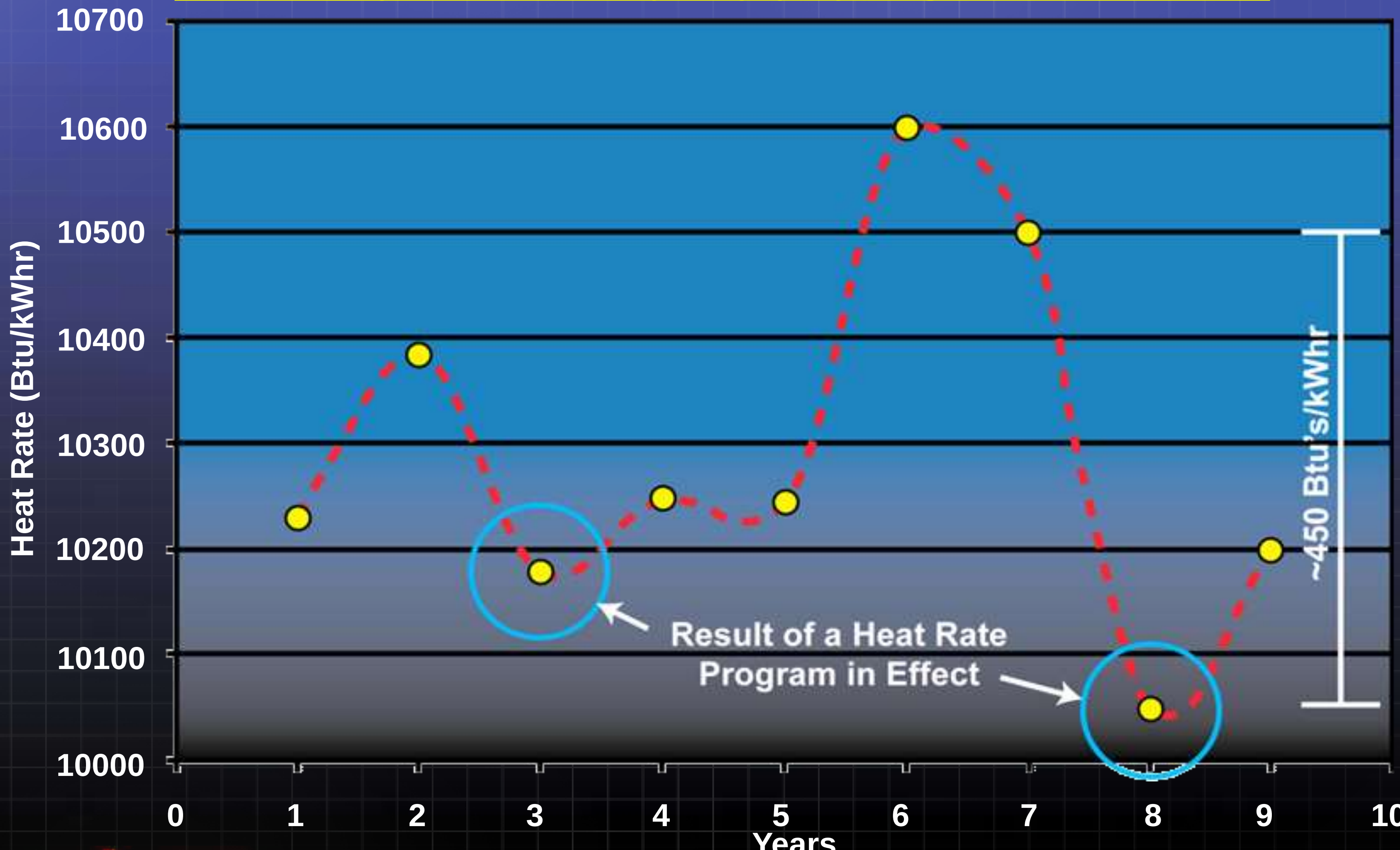
Example Heat Rate Curve of What Can Be Accomplished By Applying The Basics



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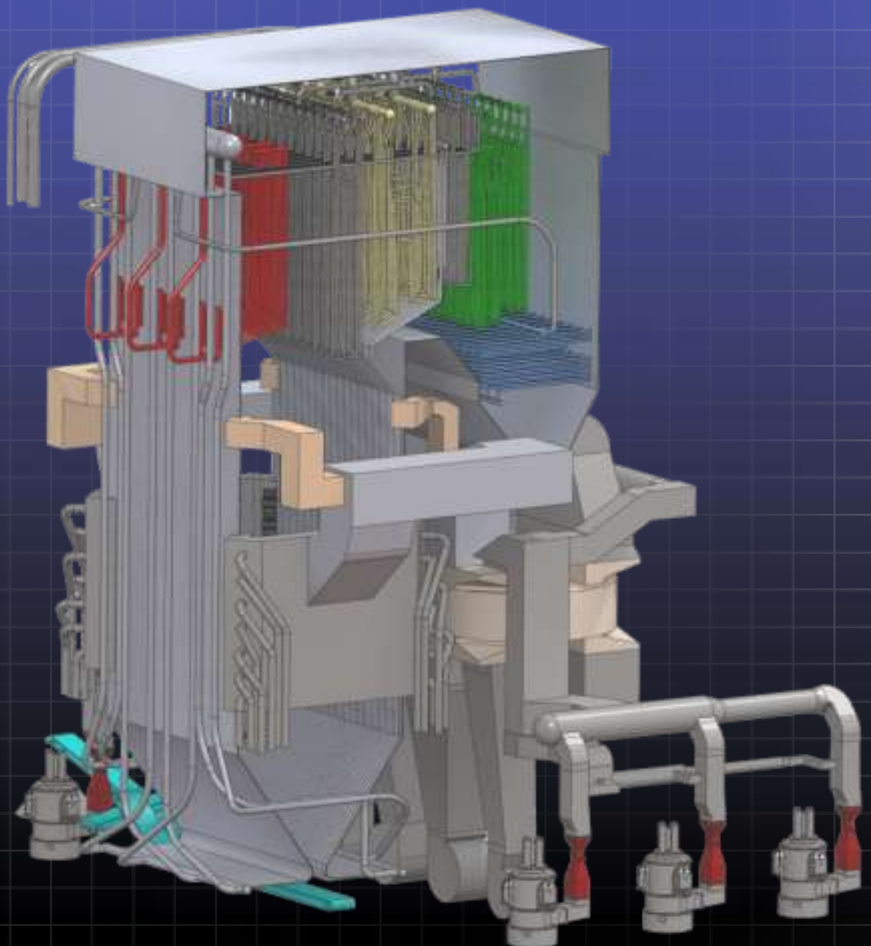
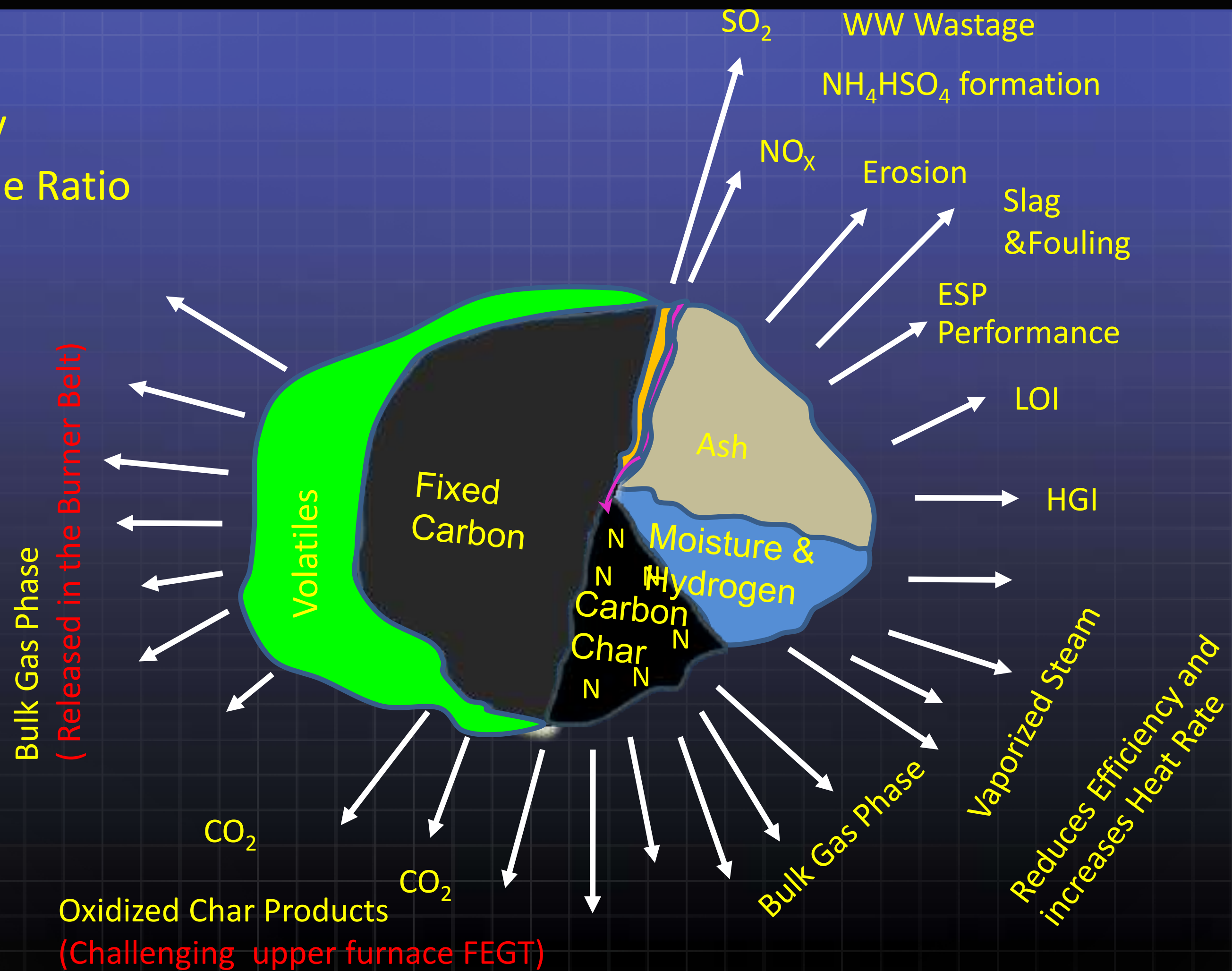
13 Essentials of Optimum Combustion for Low NOx Burners

1. Furnace exit must be oxidizing preferably, 3%.
2. Fuel lines balanced to each burner by "Clean Air" test ±2% or better.
3. Fuel lines balanced by "Dirty Air" test, using a Dirty Air Velocity Probe, to ±5% or better.
4. Fuel lines balanced in fuel flow to ±10% or better.
5. Fuel line fineness shall be 75% or more passing a 200 mesh screen. 50 mesh particles shall be less than 0.1%.
6. Primary airflow shall be accurately measured & controlled to ±3% accuracy.
7. Overfire air shall be accurately measured & controlled to ±3% accuracy.
8. Primary air/fuel ratio shall be accurately controlled when above minimum.
9. Fuel line minimum velocities shall be 3,300 fpm.
10. Mechanical tolerances of burners and dampers shall be ±1/4" or better.
11. Secondary air distribution to burners should be within ±5% to ±10%.
12. Fuel feed to the pulverizers should be smooth during load changes and measured and controlled as accurately as possible. Load cell equipped gravimetric feeders are preferred.
13. Fuel feed quality and size should be consistent. Consistent raw coal sizing of feed to pulverizers is a good start.

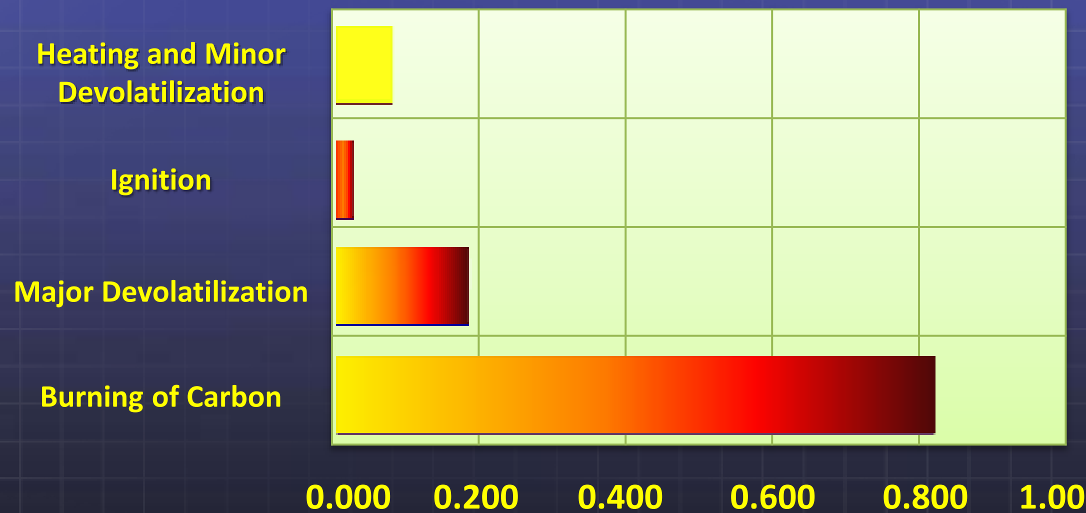


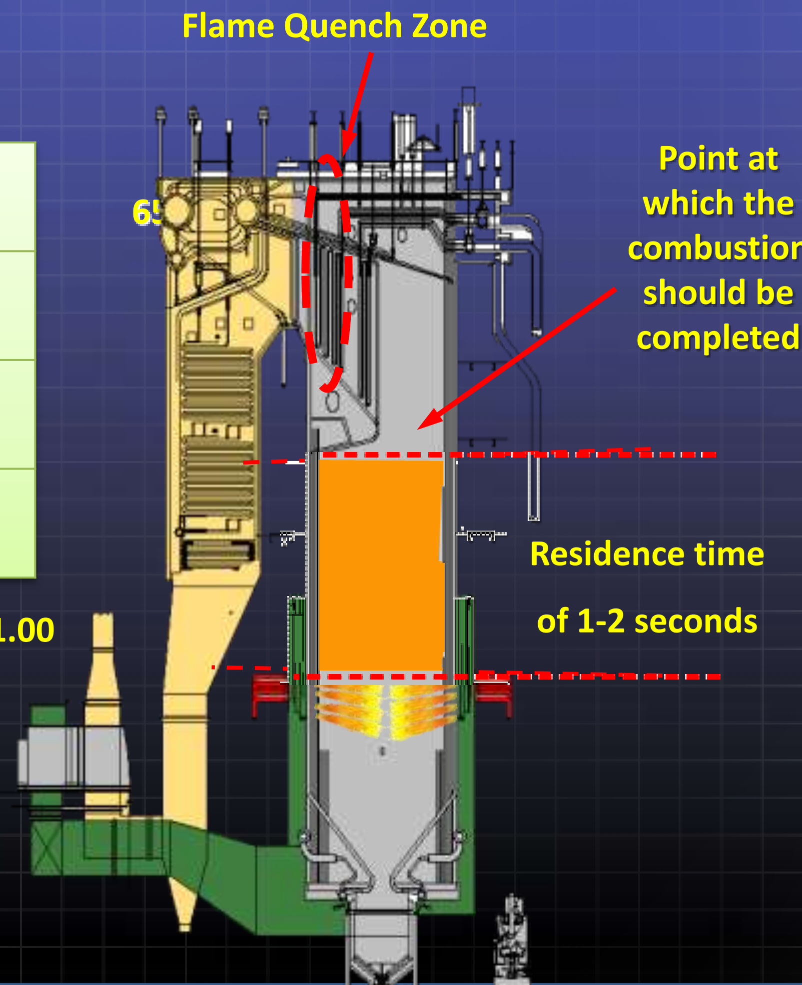
Coal Quality

- Fuel HGI
- Fuel Moisture - HHV
- Fixed Carbon: Volatile Ratio
- Sulfur Content
- Nitrogen Content
- Ash Mineral Matter



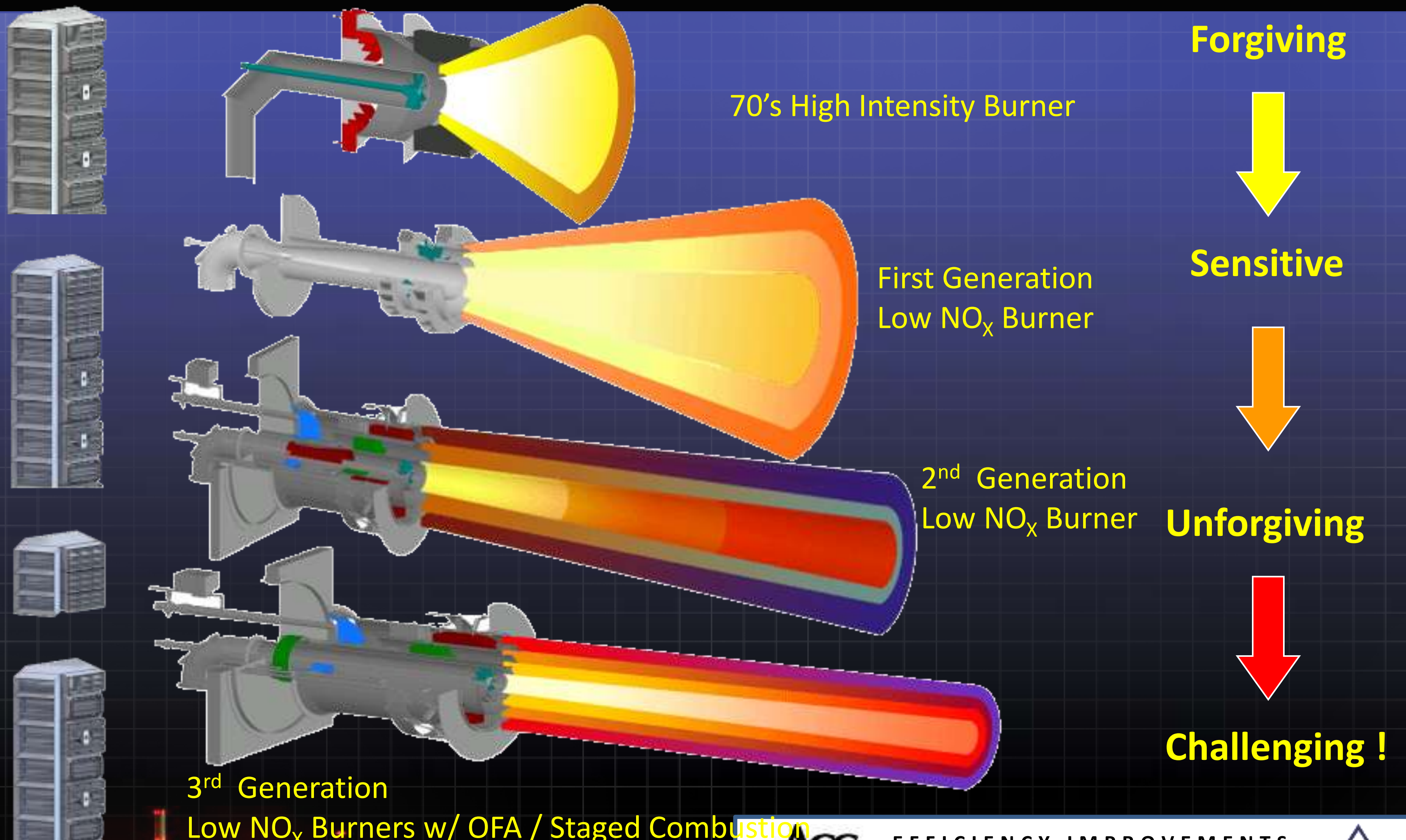
Furnace Residence Time / Carbon Burnout

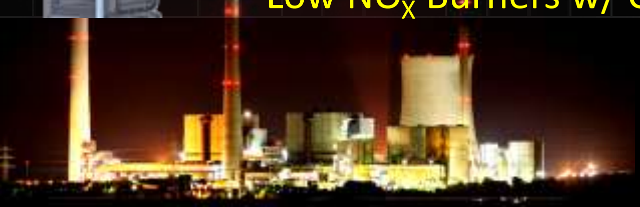




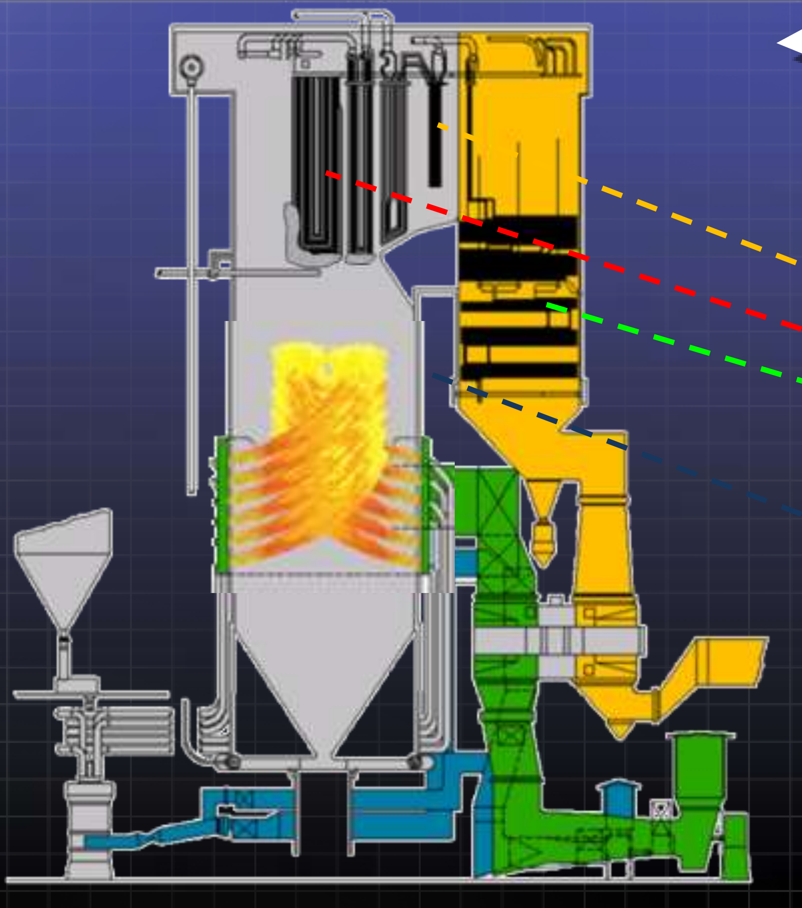
This graph illustrates typical time requirements for combustion of coal. These times will vary with different coals & firing conditions but the combustion of carbon always requires the most time

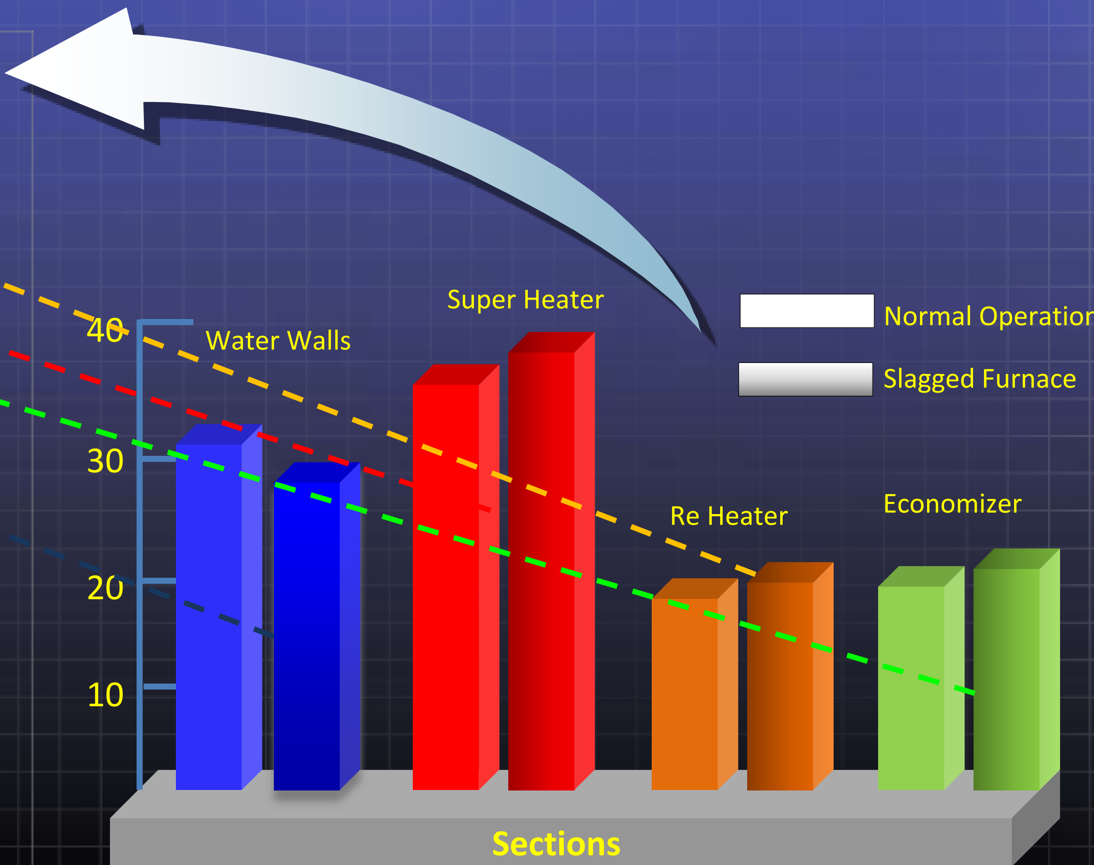
The Evolution of Low NOX Burners





Slag & Fouling Impact on FEGT

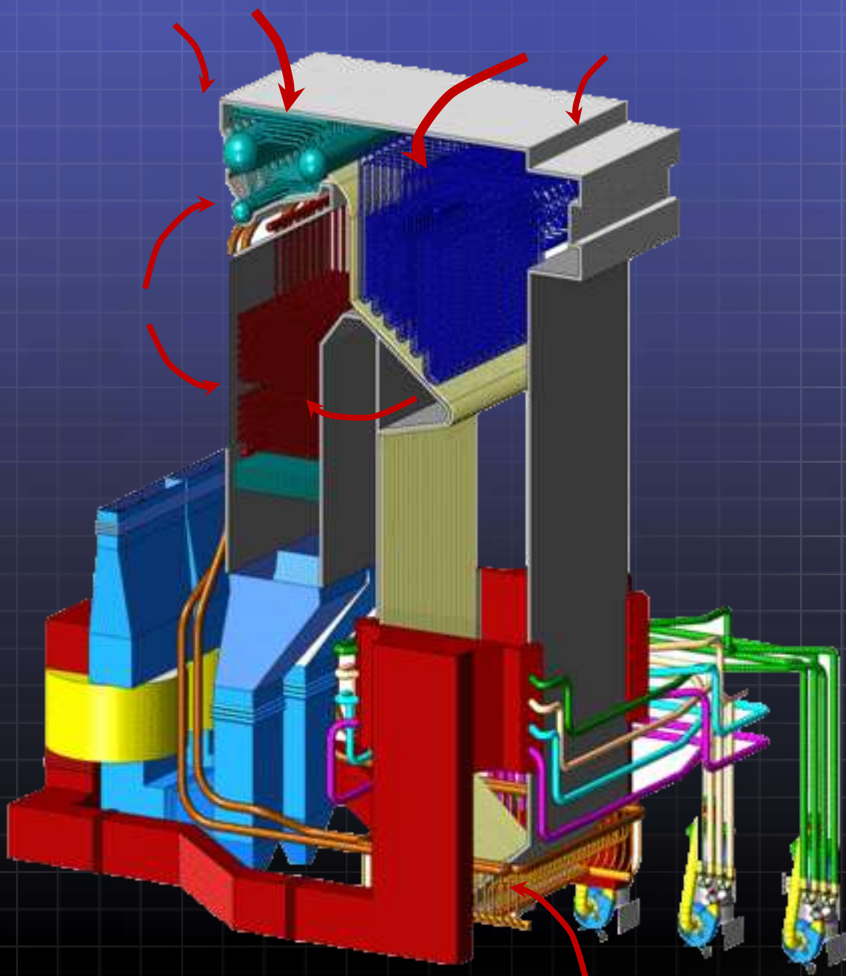




Boiler Absorption Distribution
2400 psig Unit

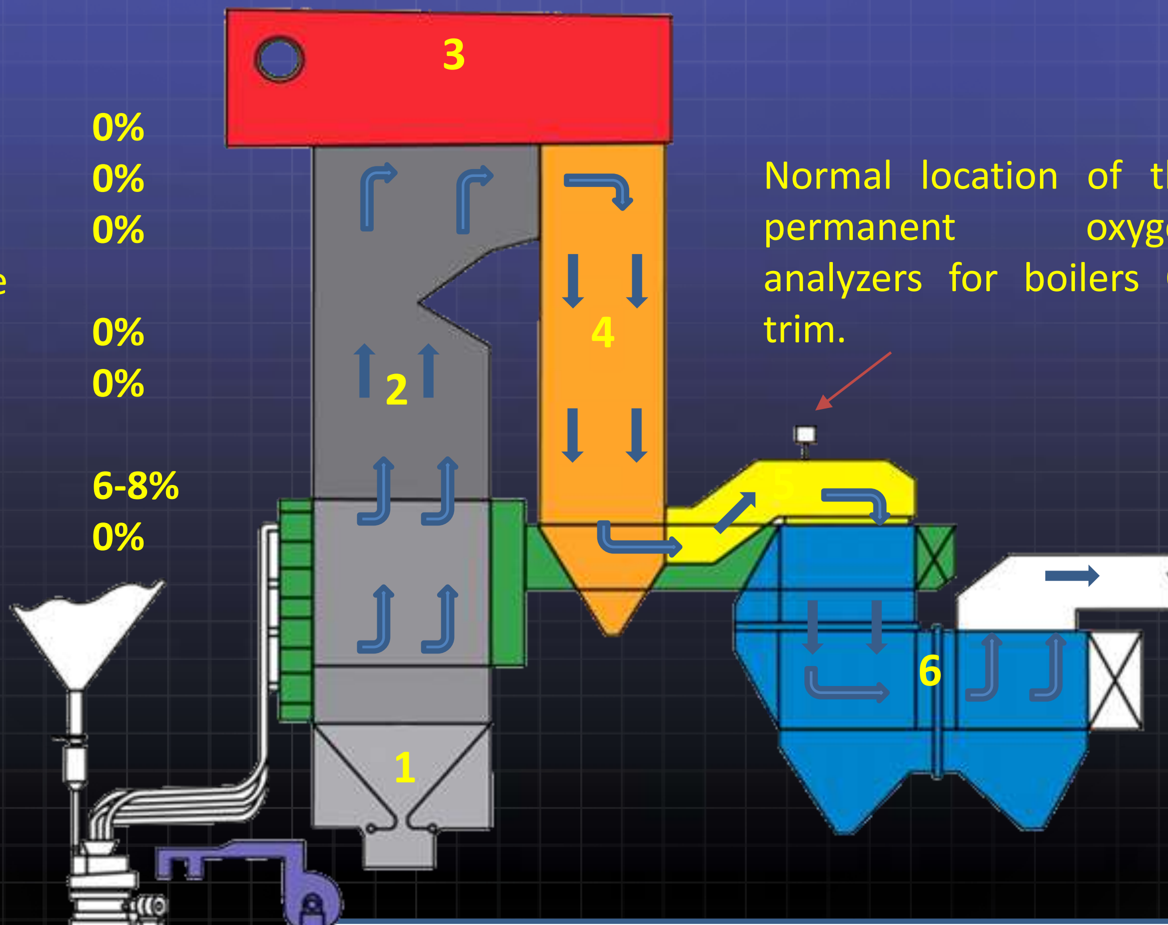
Air In-Leakage

- Penalties due to air in-leakage (up to 300 Btu's/kWh
- PTC-4 does not take into account. Thus, we call them "Stealth Losses"
- In addition to the thermal penalty, artificially high oxygen readings can have serious performance impacts on good combustion
- Leak path between penthouse and air heater inlet gas
- Bottom ash hopper seals
- Air heater leakage and penalties



Ideal Air Flow Path

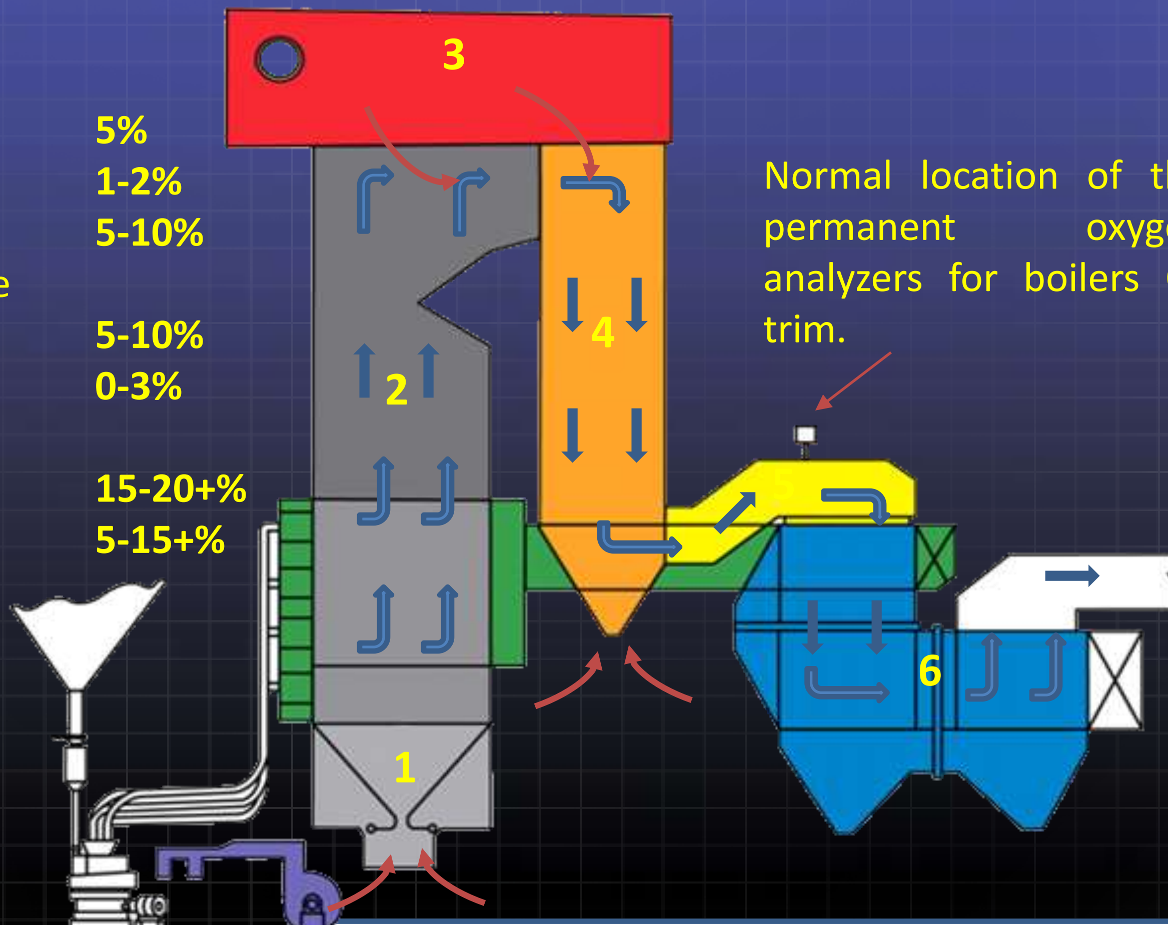
1. Lower Furnace / Water Seal — 0%
2. Furnace — 0%
3. Penthouse — 0%
4. Convention Pass & Economize Hopper — 0%
5. Flue Gas Duct — 0%
6. Air PreHeater
   - Regenerative — 6-8%
   - Tubular — 0%



Normal location of the permanent oxygen analyzers for boilers O_2 trim.

Non-Ideal Air In Leakage

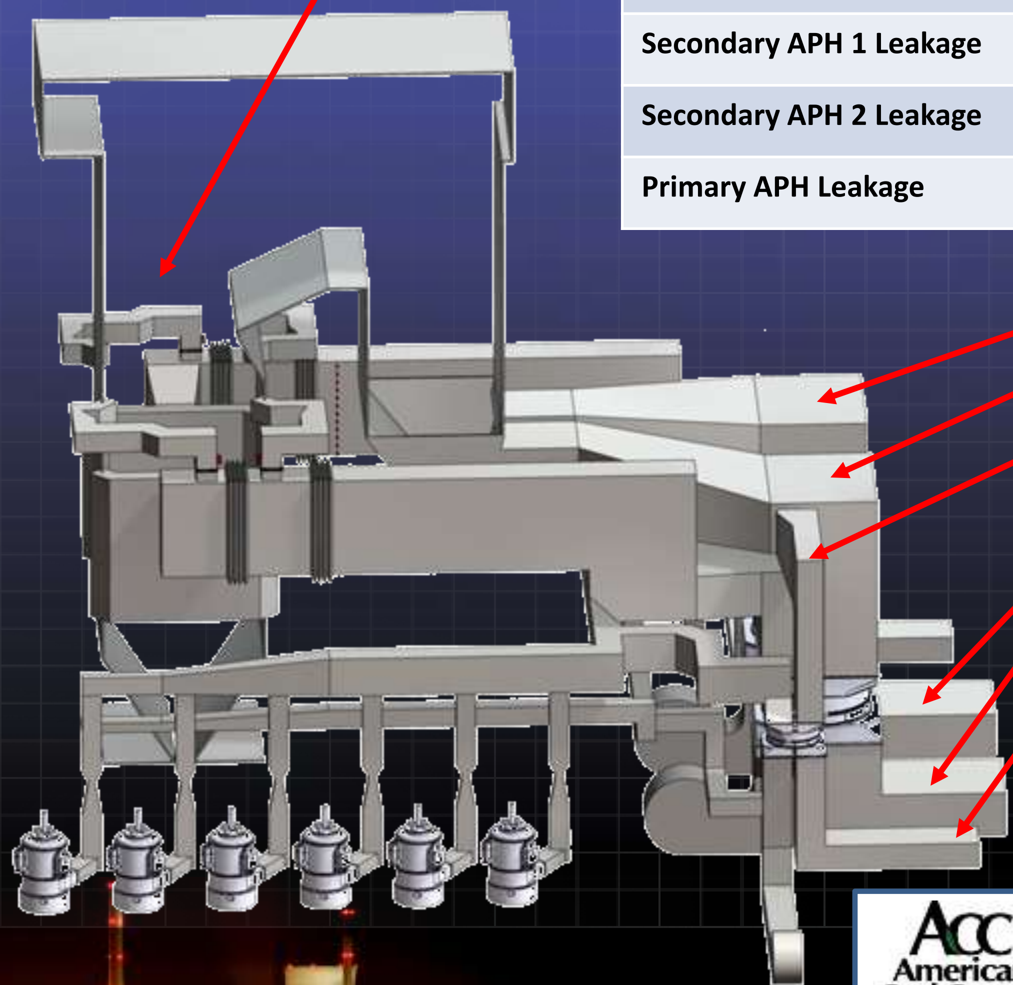
1.	Lower Furnace / Water Seal	5%
2.	Furnace	1-2%
3.	Penthouse	5-10%
4.	Convention Pass & Economize Hopper	5-10%
5.	Flue Gas Duct	0-3%
6.	Air PreHeater	
	Regenerative	15-20+%
	Tubular	5-15+%



Normal location of the permanent oxygen analyzers for boilers O_2 trim.

Tracking Oxygen in the Boiler

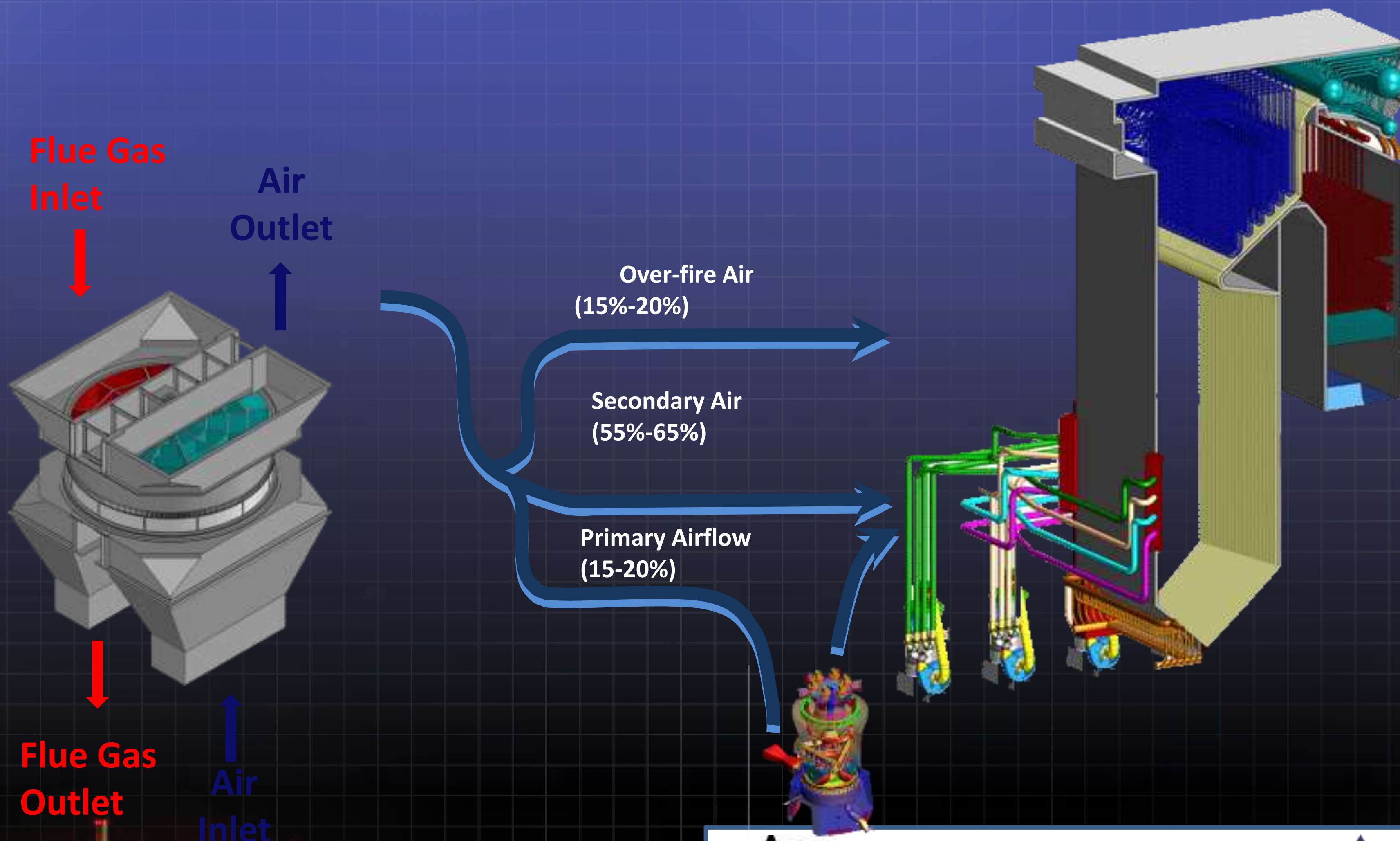
Location	Leakage	Additional KW's Required
Furnace Leakage (Avg)	19.37%	660
Secondary APH 1 Leakage	9.29%	21
Secondary APH 2 Leakage	19.51%	187
Primary APH Leakage	61.11%	432



How Can You Identify Air In-Leakage?

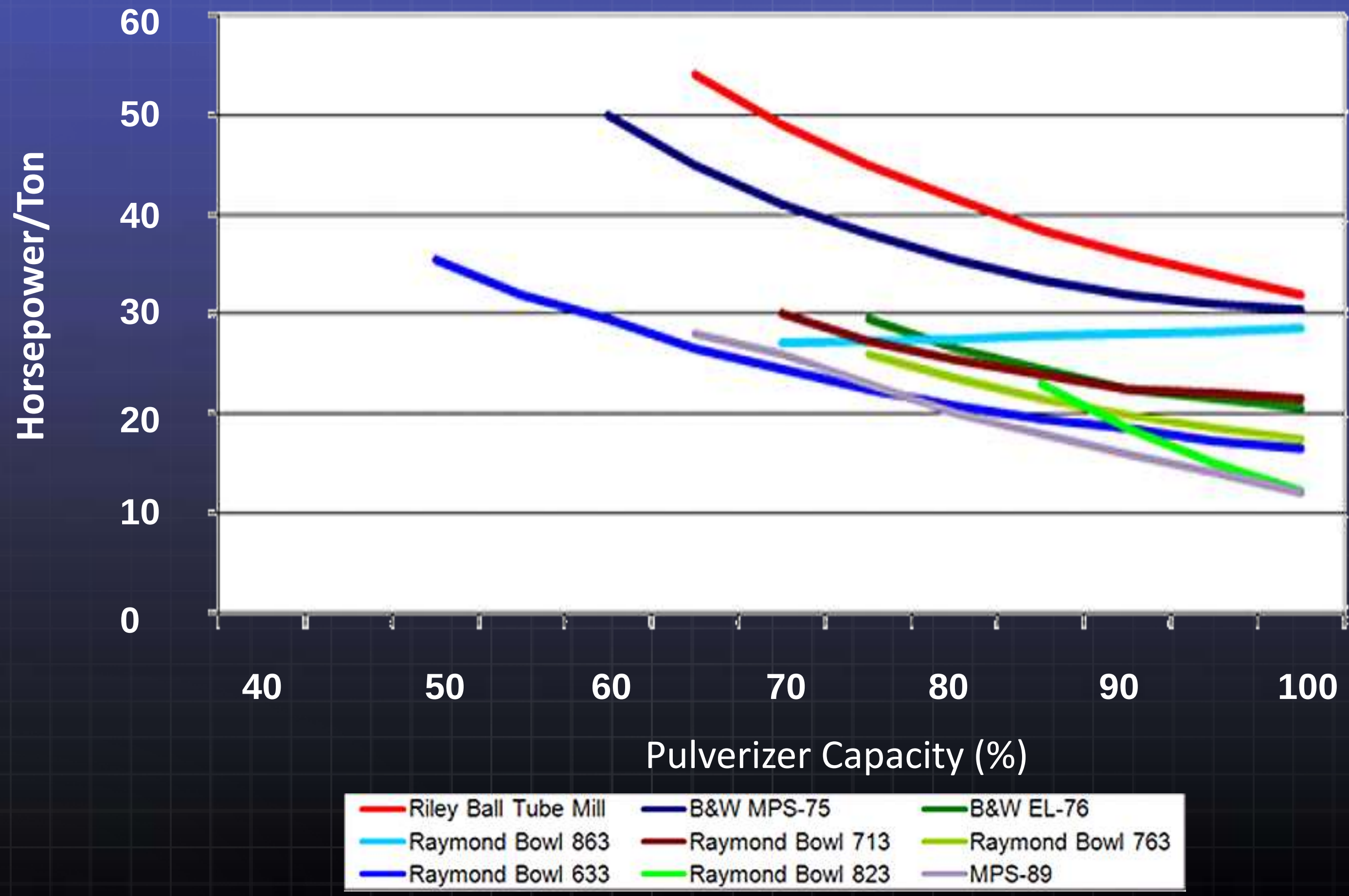
- Obtain good reliable, representative flue gas analyses
- Perform oxygen rise testing from furnace to ID fans
- Monitor the stack CO_2 or O_2
- Combine the intelligence and conditions found of boiler inspections with test data and experience.

Typical Combustion Air Proportioning

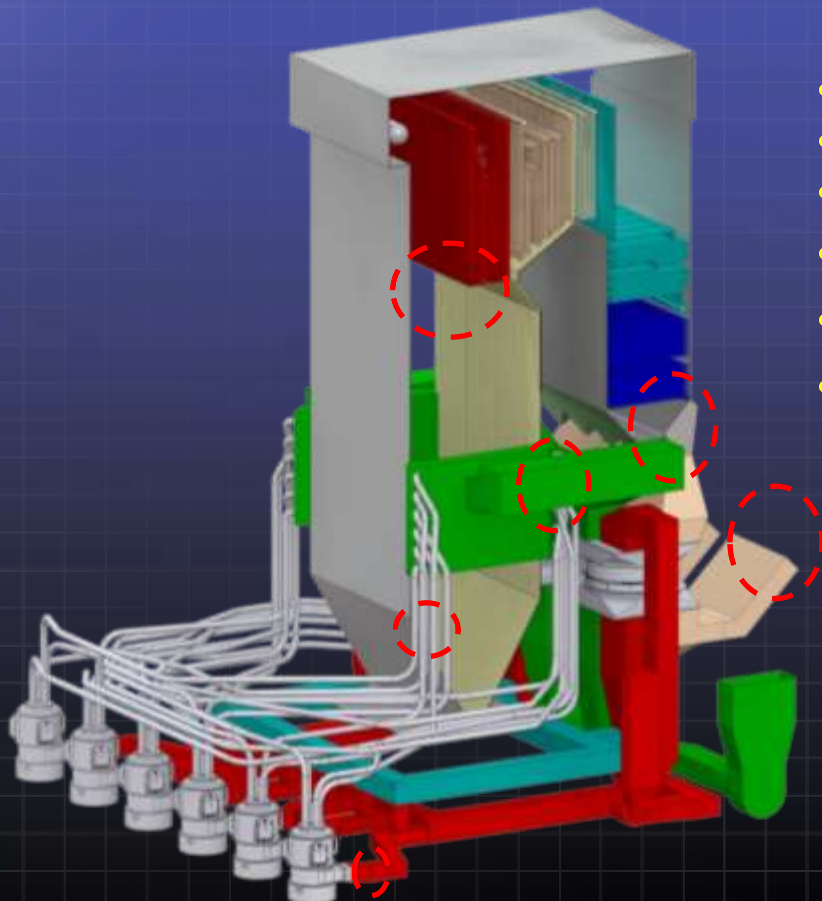


The Pulverizers are Not The Auxiliaries to Save Auxiliary Power! More Pulverizer Power= Better Combustion

Horsepower/Ton Consumption



Comprehensive Evaluation and Application of the Basics



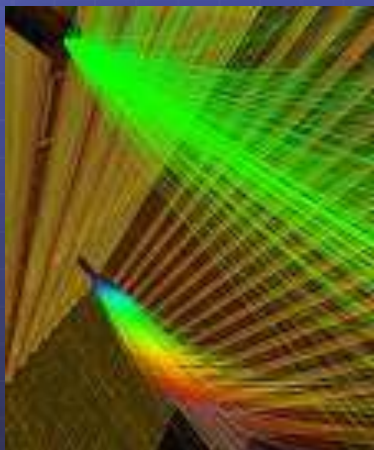
- Fuel Line Performance Measurements & Mill Optimization
- Mill Inlet Primary Airflow Calibrations
- Total Secondary Airflow Measurement & Calibration
- Furnace Exit Gas Temperature & Flue Gas Constituents
- Economizer Outlet Flue Gas Measurements
- ID Fan Discharge / Stack Inlet Flue Gas Measurements
- “Stealth Loss” Evaluation, Optimization & Preservation



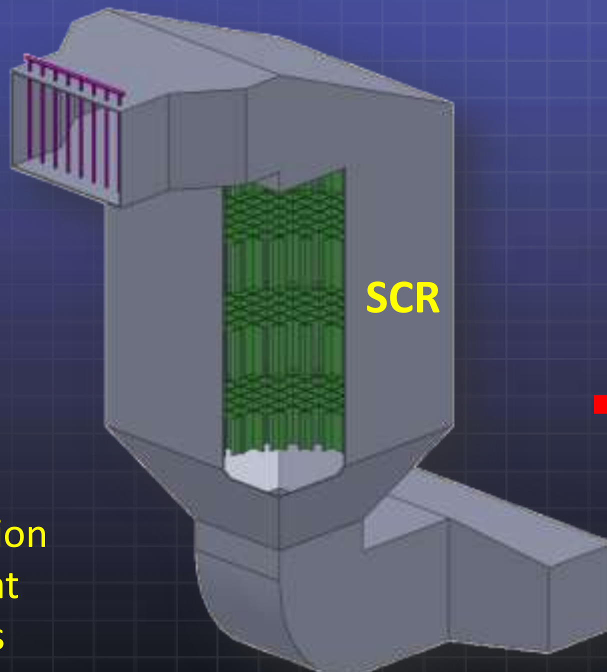



Challenges with High Sulfur Coal

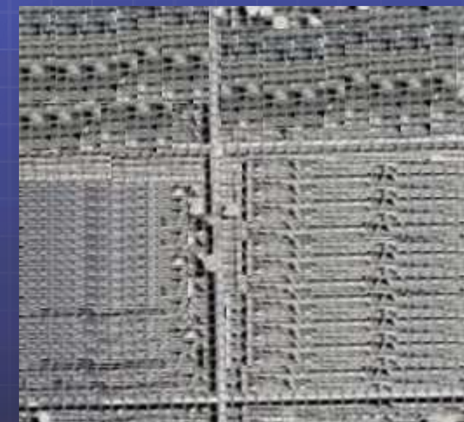
SNCR & SCR Performance Challenges



Optimized Furnace Combustion Reduces "Popcorn Ash" that tends to plug SCR catalysts

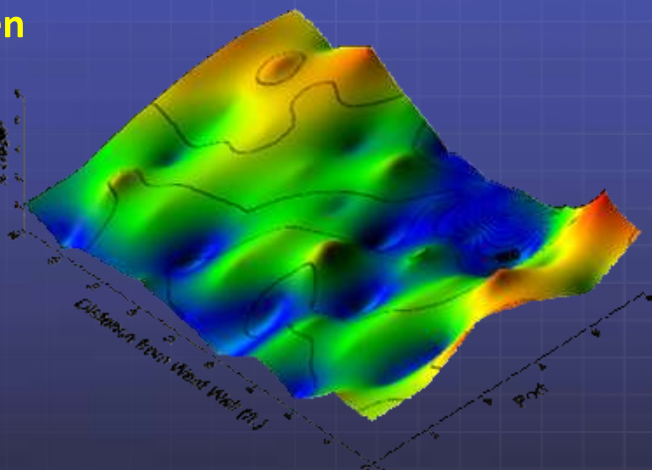


Ash build-up & plugging half of a catalyst due to popcorn ash

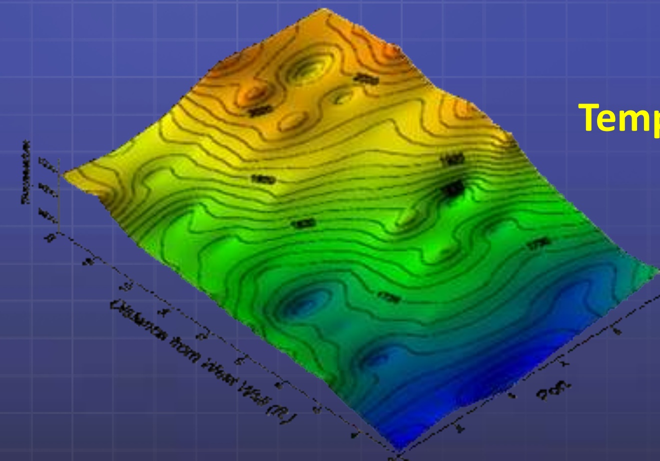


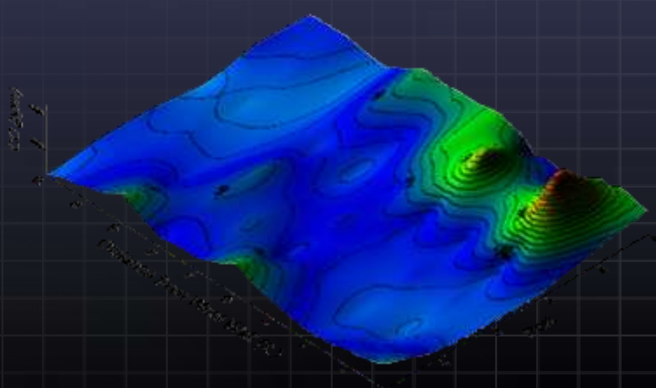
Flue Gas Measurements (Typical)

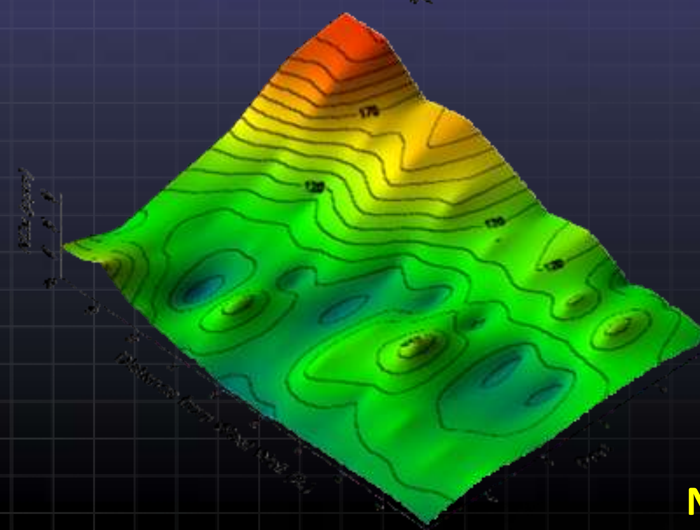
Oxygen



Temperature







CO

NO_X

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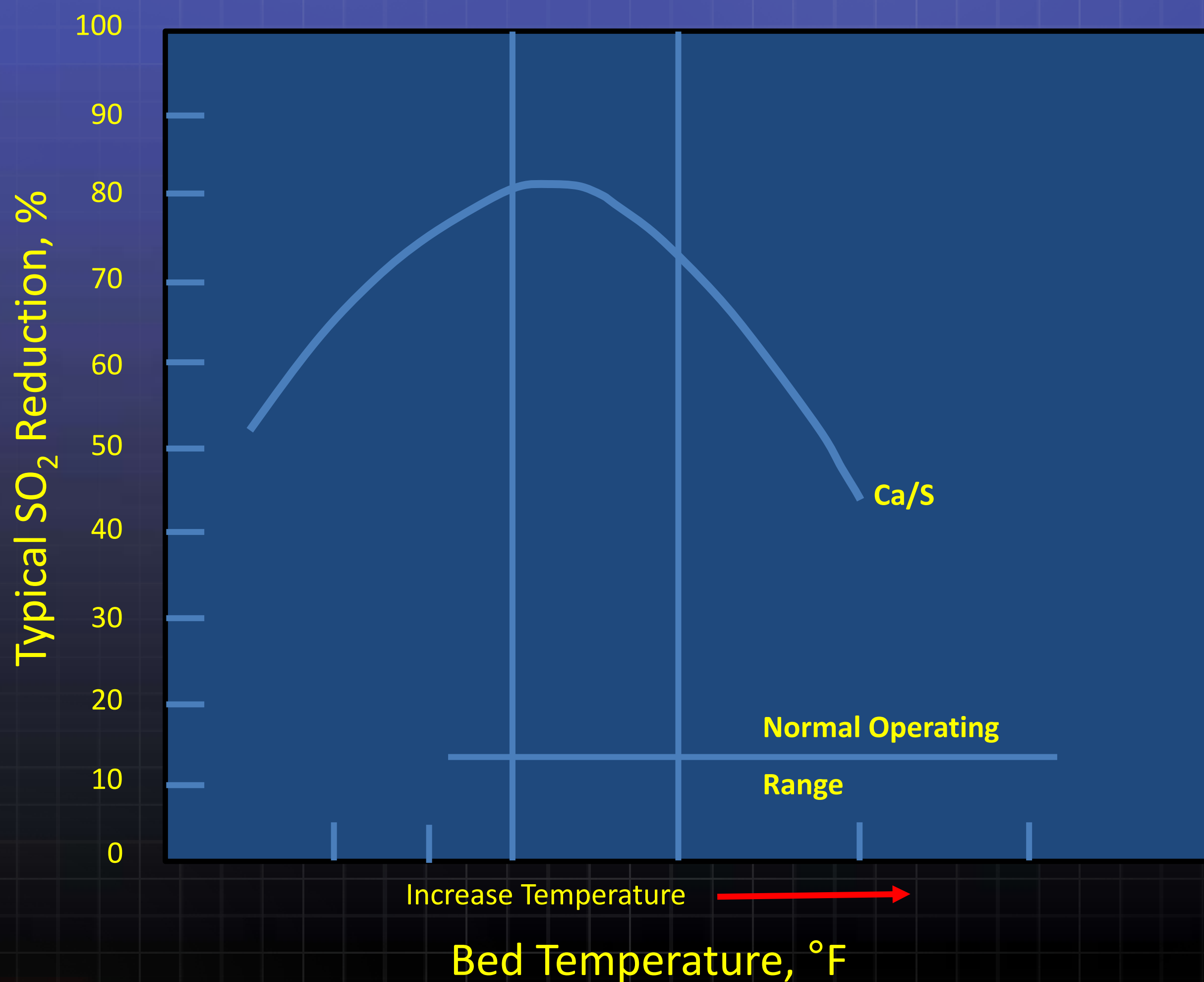
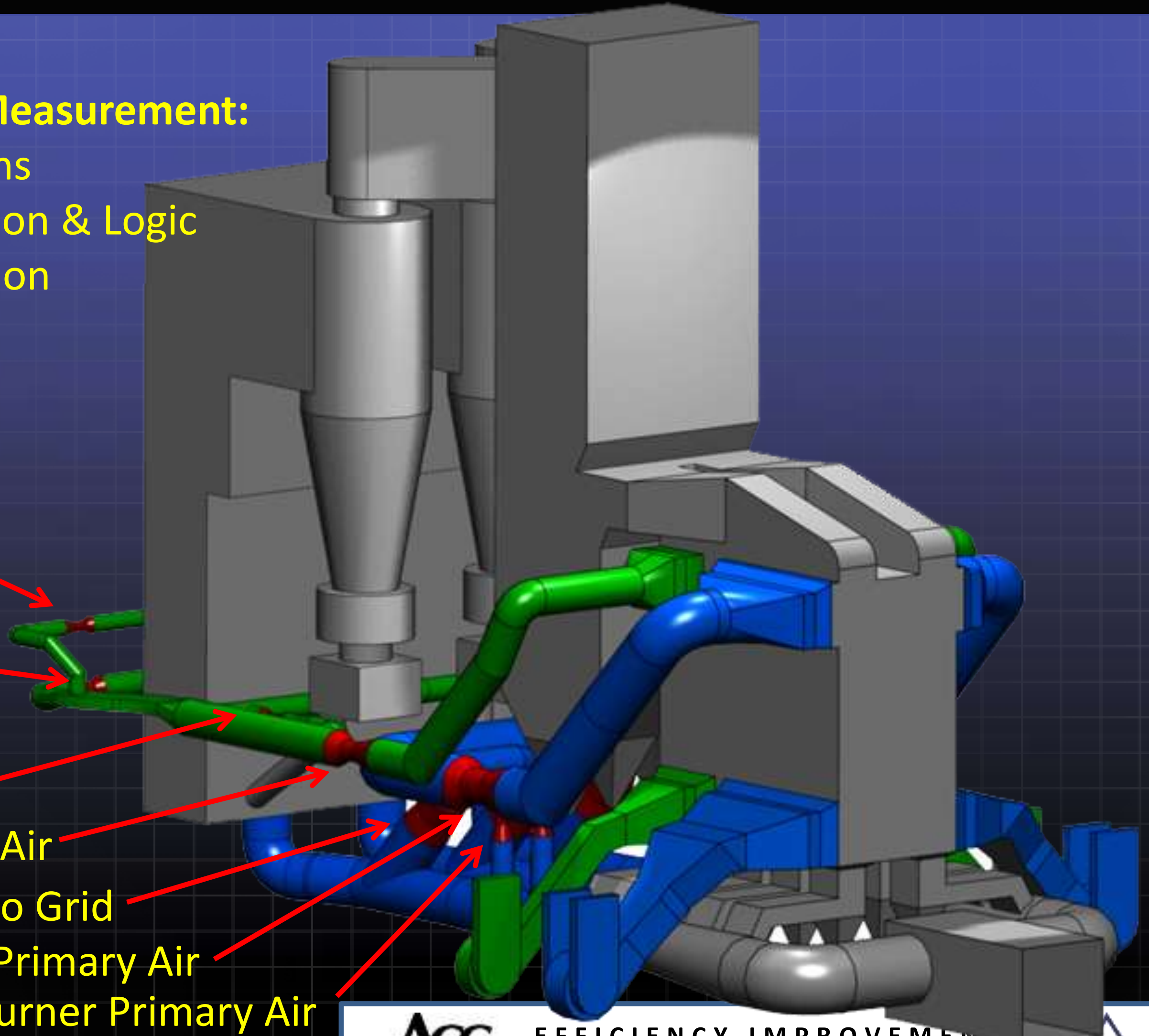
SO_2 Reduction vs. Combustion Temperature



CFB Boiler Airflow Management System

Keys to Accurate Airflow Measurement:

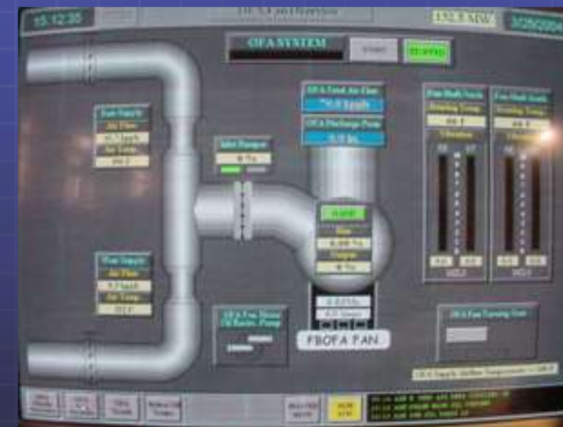
- Design Criteria & Locations
- Temperature Compensation & Logic
- Sensing Tap Size & Location
- Field Calibration



Optimization Components / Online Metering Equipment

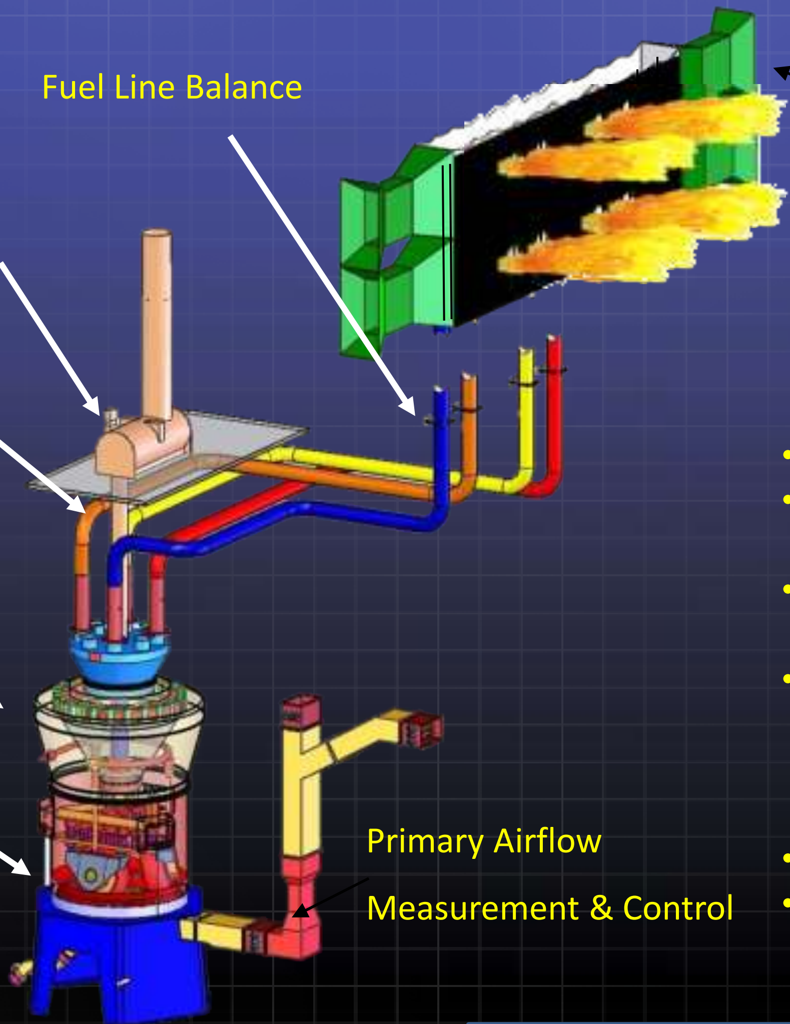
Cameras, CO Monitors at Economizer Outlet, FEGT Measurement, Dedicated Optimization Screens







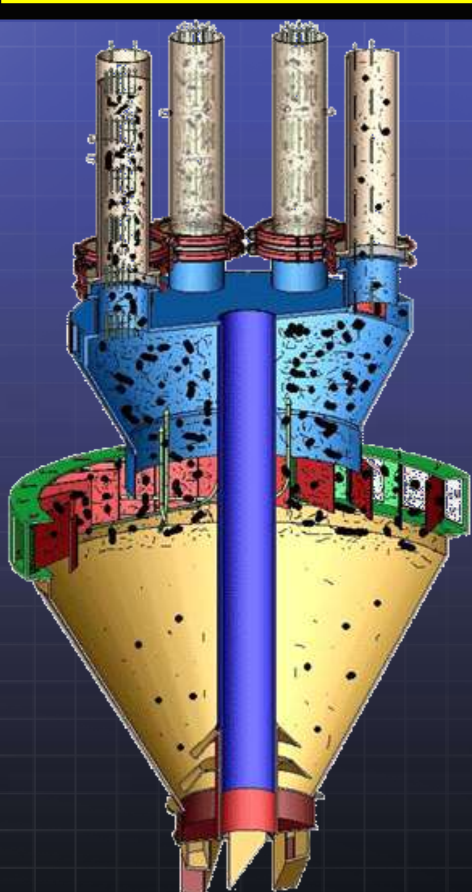

The STORM Solid Fuel Injection System Approach



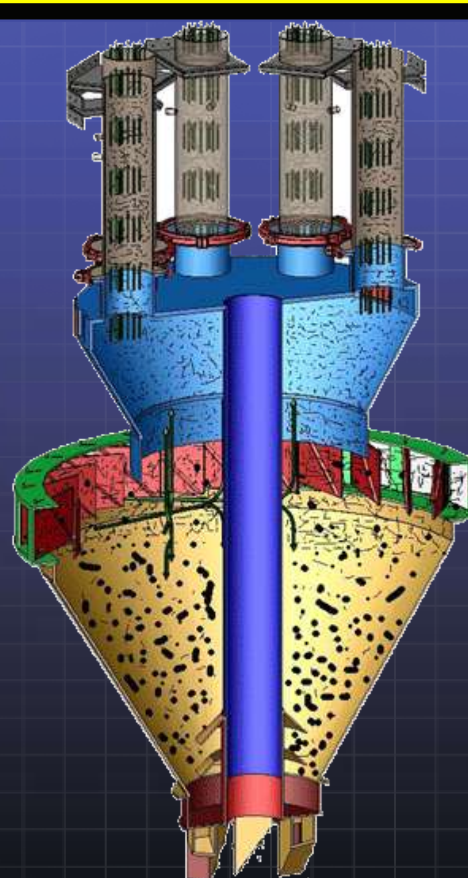
The Six Step Approach to Fuel Line Balancing

- Clean Air Balancing with ±2%
- Measured Primary air Hot "K" Factor calibration ± 3%
- Dirty air velocity measurements w/ balance of ± 5%.
- Fuel line fineness and distribution testing by air/fuel ratio sampling& ensuring optimum fineness level is achieved.
- Fuel line balance ± 10 %
- Pulverizer "blue printing"

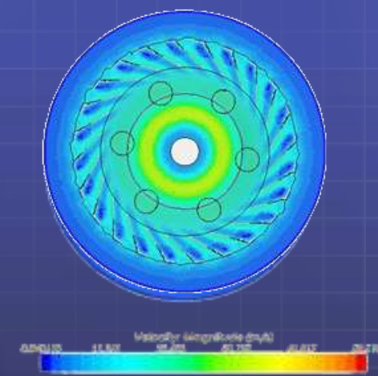
Classifier & Fuel Line Performance

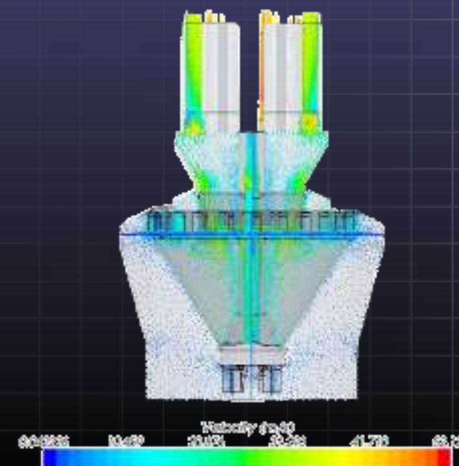


Poor Coal Fineness often yields poor distribution



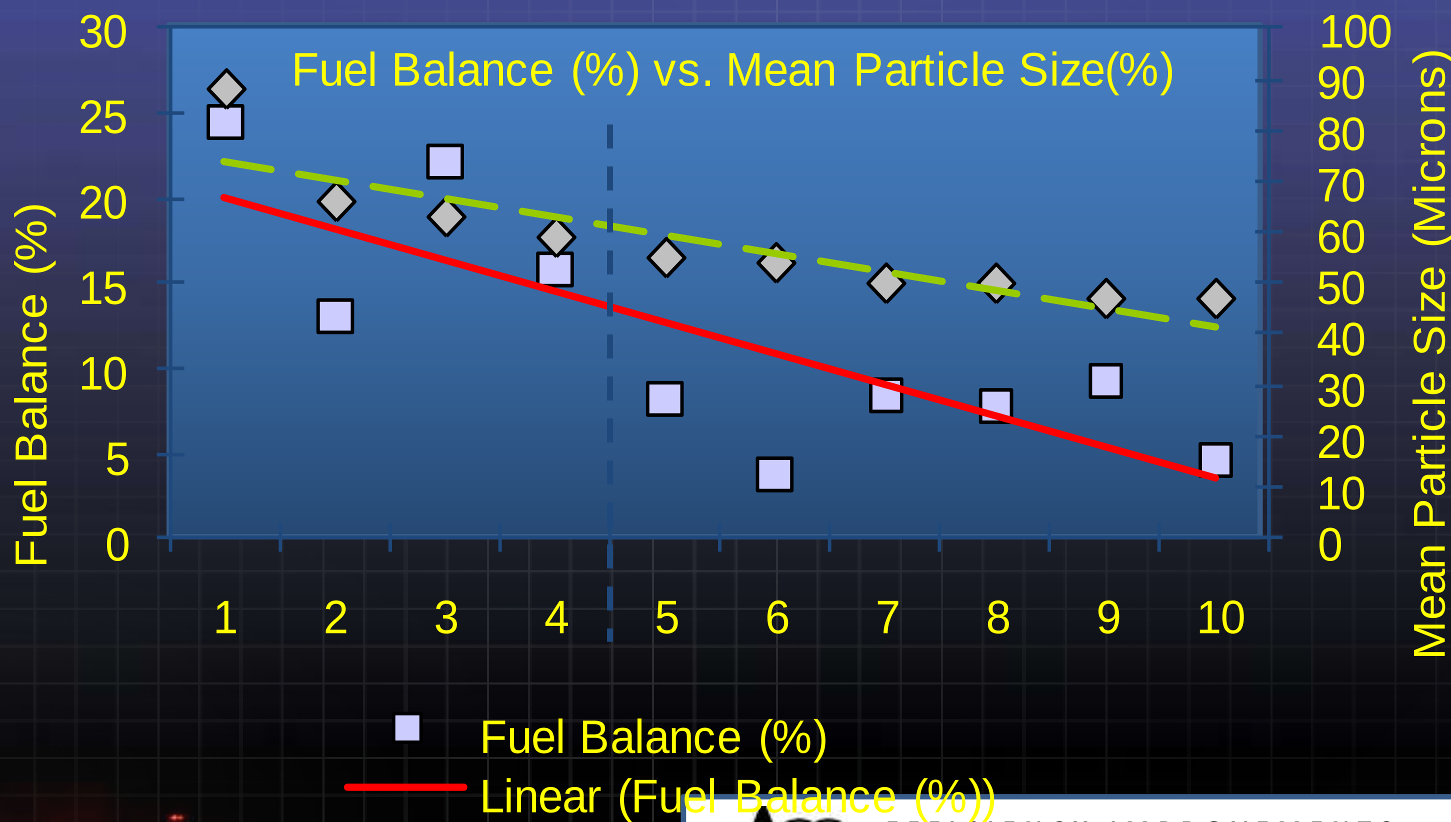
Good Fineness Creates a homogenous & balanced mixture & will produce a more homogenous mixture if mechanical synchronization is optimum



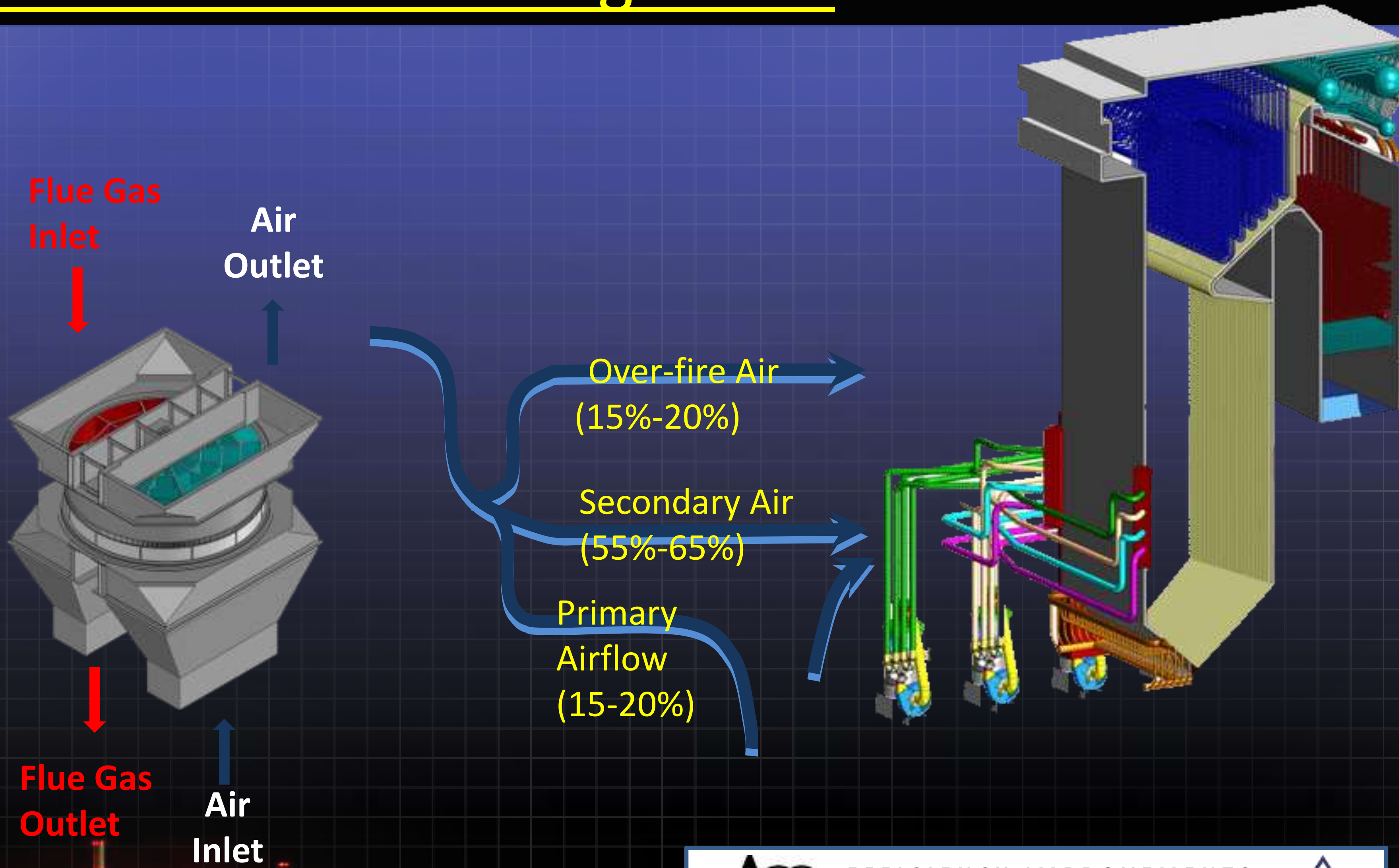


Performance Testing Results

Note: Coal is 1,000 times more dense than air. The finer the product the better the distribution *(as finer coal acts more like a fluid or gas).*



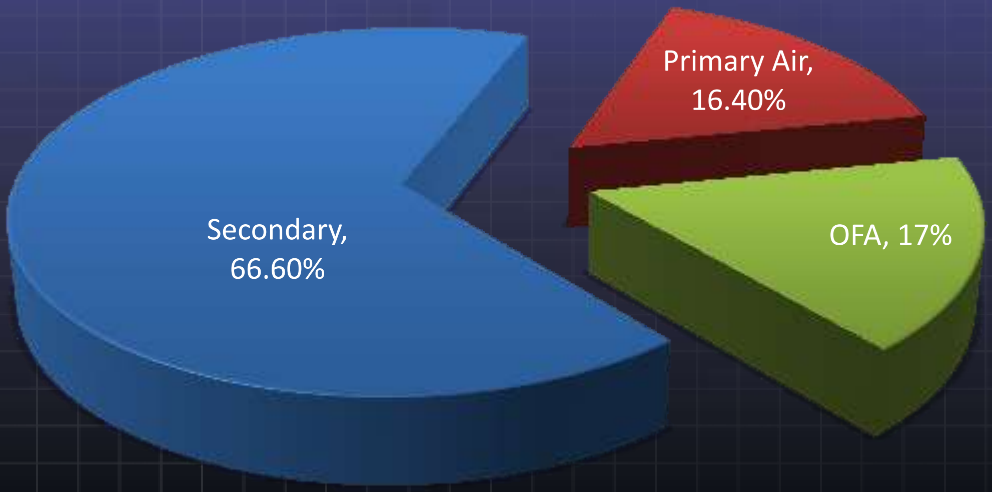
Boiler Airflow Management



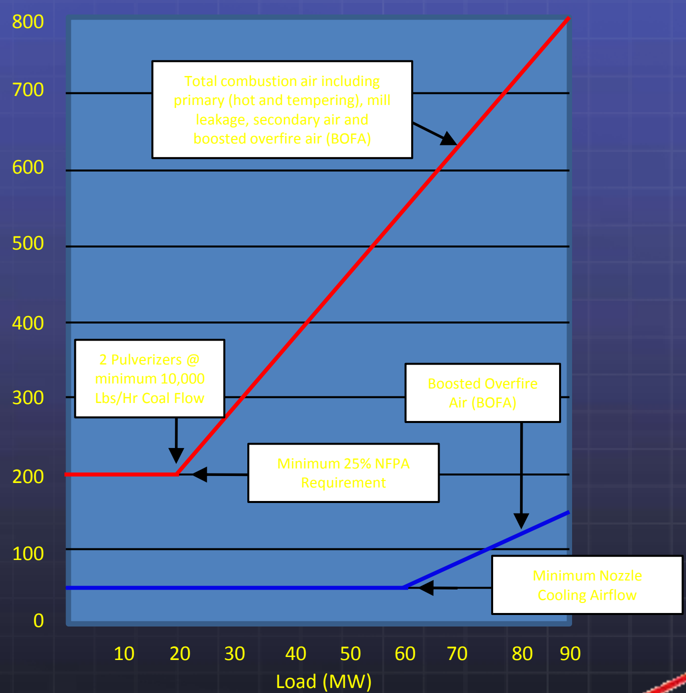
Management & Staged Combustion Airflow

Over-fire air staging for combustion and emission control is not always measurable or closely controlled. Because of the importance of stoichiometry control with high sulfur coals and the possible impacts of WW wastage, the task of airflow measurement & control must be taken seriously.

After the process measurement and control devices are correctly calibrated, the control system can also be optimized. Many improved functional control schemes are required for improved unit response, ramp rates, and for fine control tuning of combustion and primary airflows, fuel flows, and better excess oxygen control.



Controlled Boiler Stoichiometry

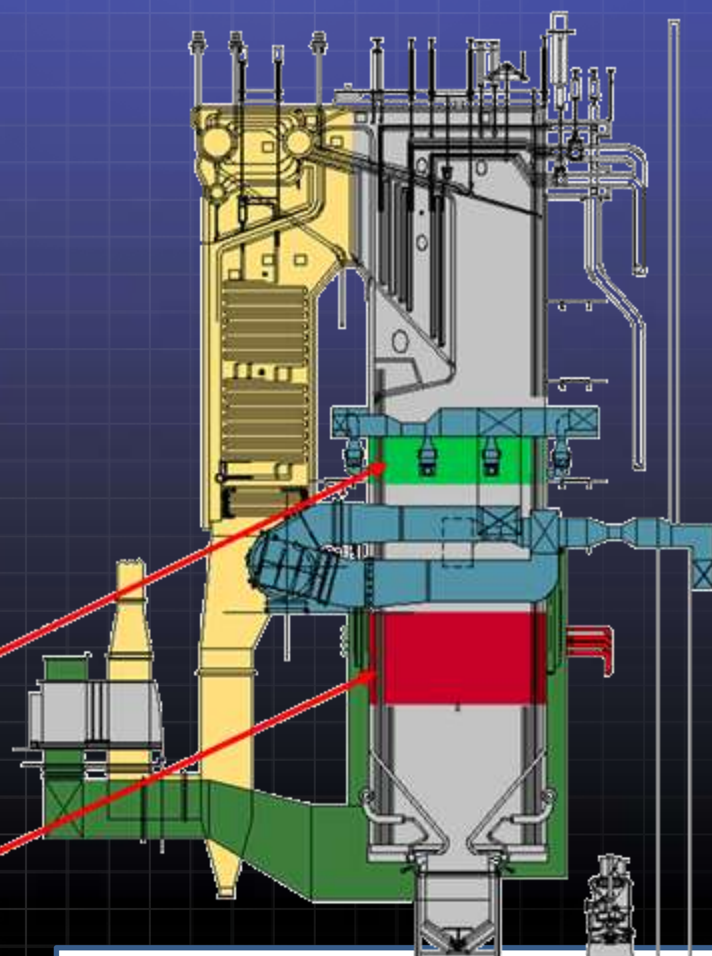


OFA Zone to Complete Combustion

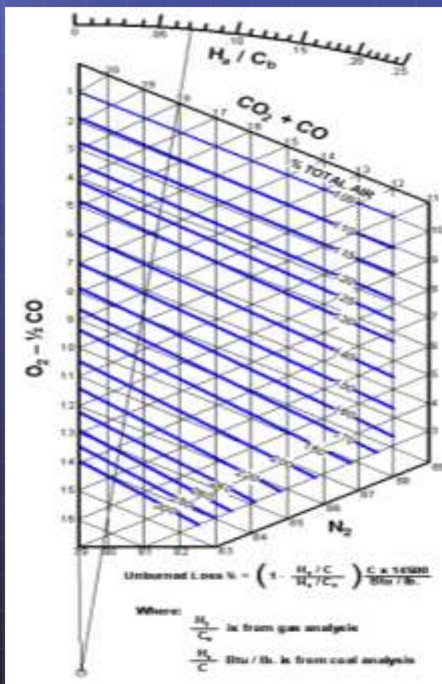
Stoichiometry = 1.15

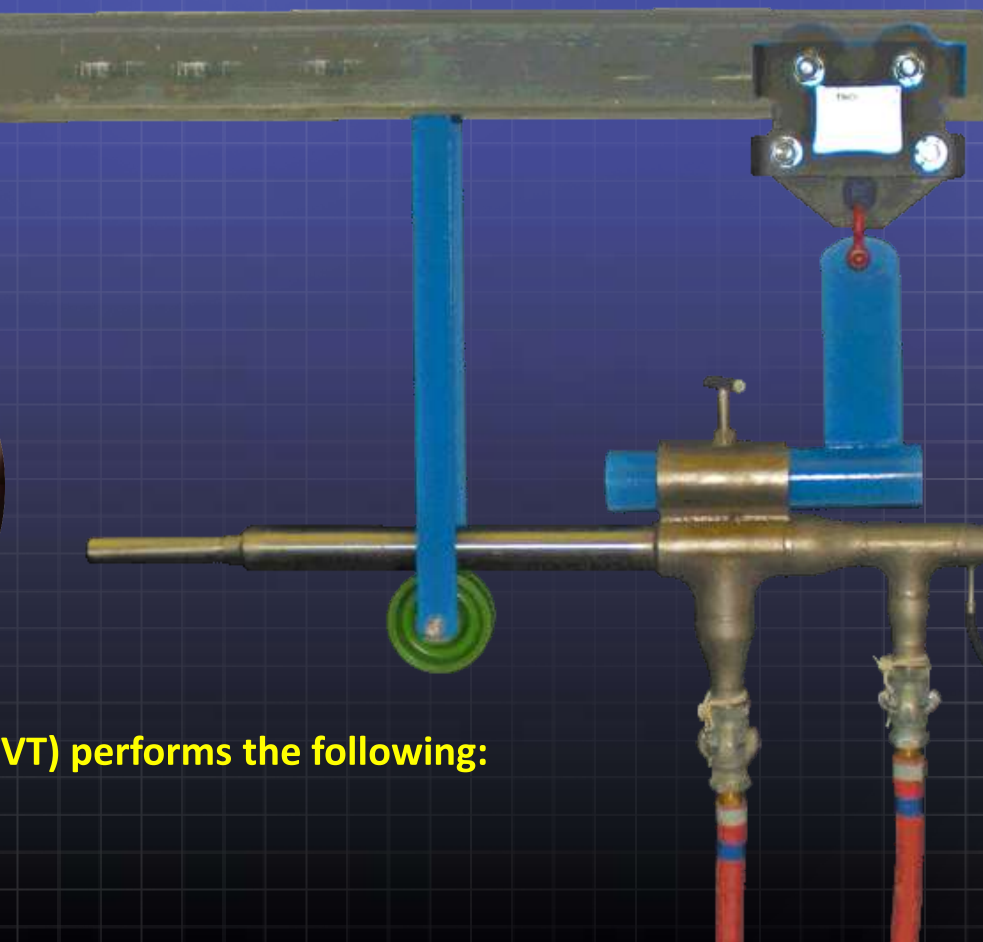
Burner Zone

Stoichiometry ≤ 1.00



Water-Cooled Furnace Profiling Assembly





A Furnace High Velocity Thermocouple Traverse (HVT) performs the following:

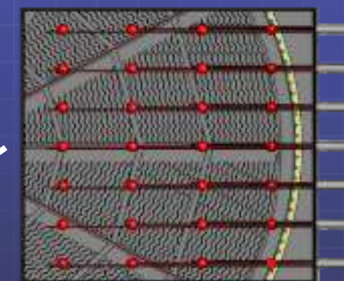
- Quantifies furnace exit gas temp. (FEGT)
- Ascertains furnace temperature profile
- Quantifies furnace oxygen level
- Ascertains furnace oxygen profile

Multipoint Emission System

Benefits:

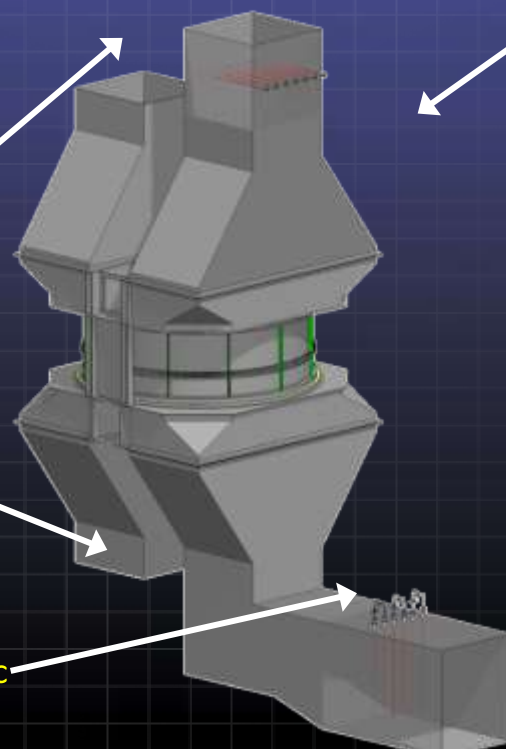
1. Representative Ash Sample collections for daily monitoring
2. Excess Oxygen Probe Verifications
3. Air In-Leakage Measurements
4. Corrected Gas Outlet Temperature, X-Ratio, Gas Side Efficiency
5. Boiler Efficiency Measurement

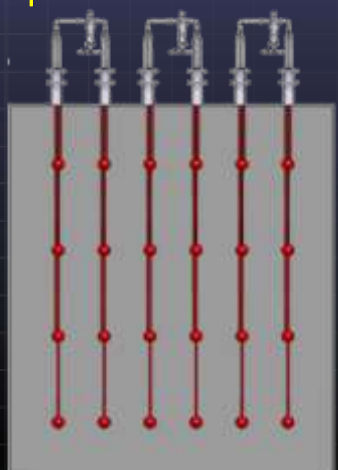
*** Patent Pending**



Gas Inlet Test Grid (Temperature, % Oxygen, CO ppm, NO_X ppm & Static Pressure)

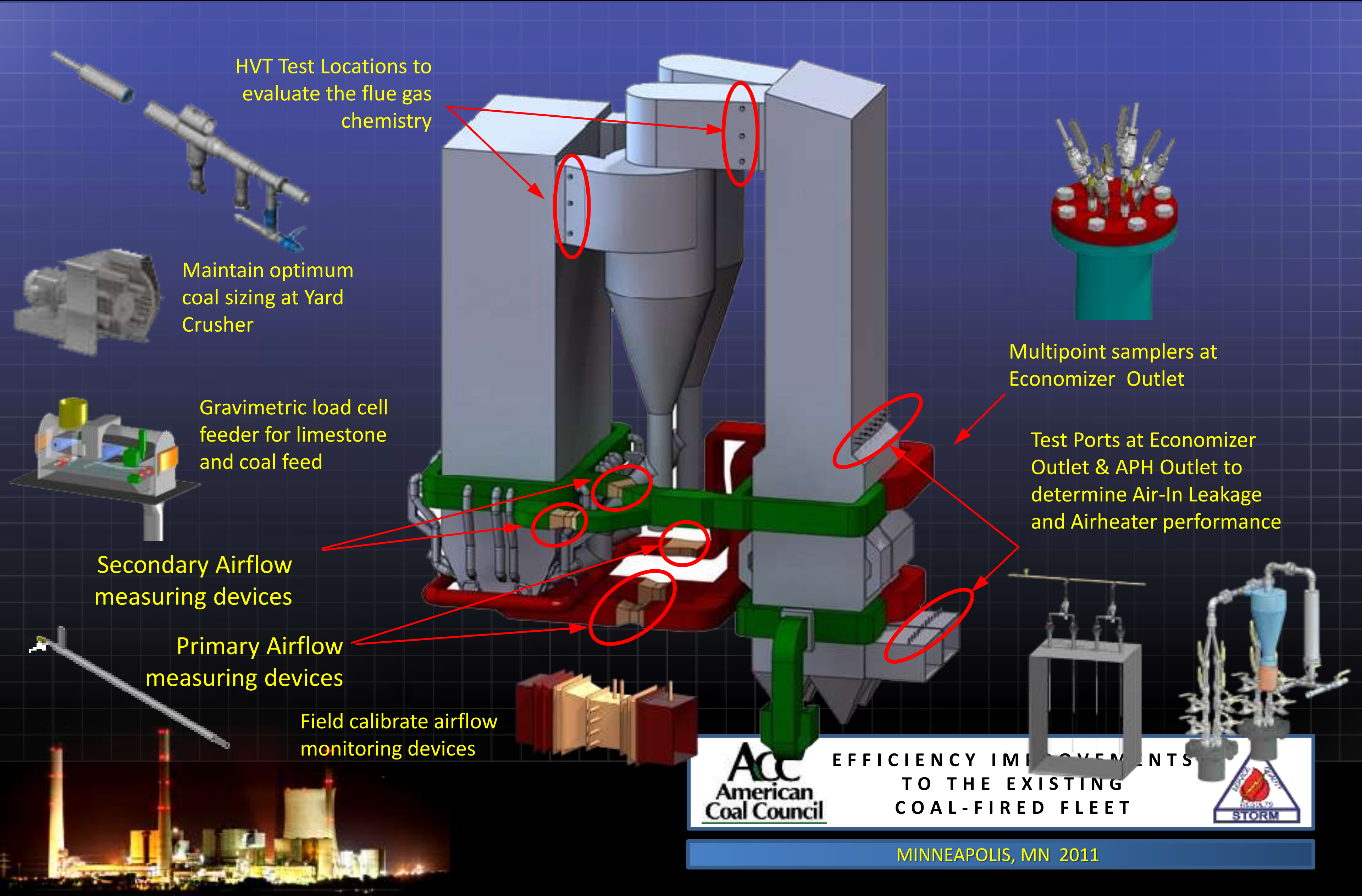
Inlet and outlet air temperature and pressure averages required for complete air heater performance analysis



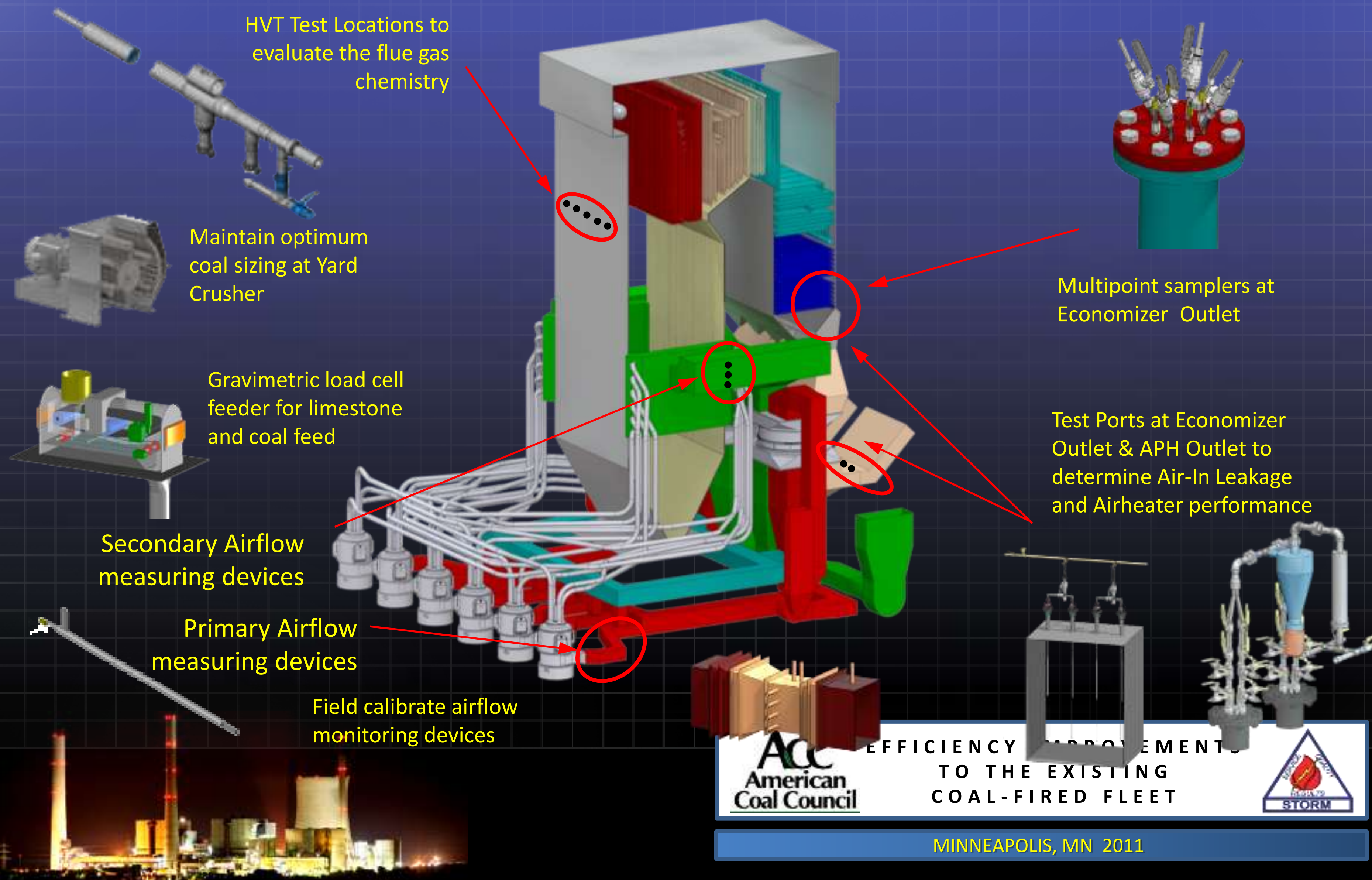


Gas Outlet Test Grid (Temperature, % Oxygen, CO ppm, NO_X ppm & Static Pressure)

CFB Test Locations for Efficiency & GHG Reduction

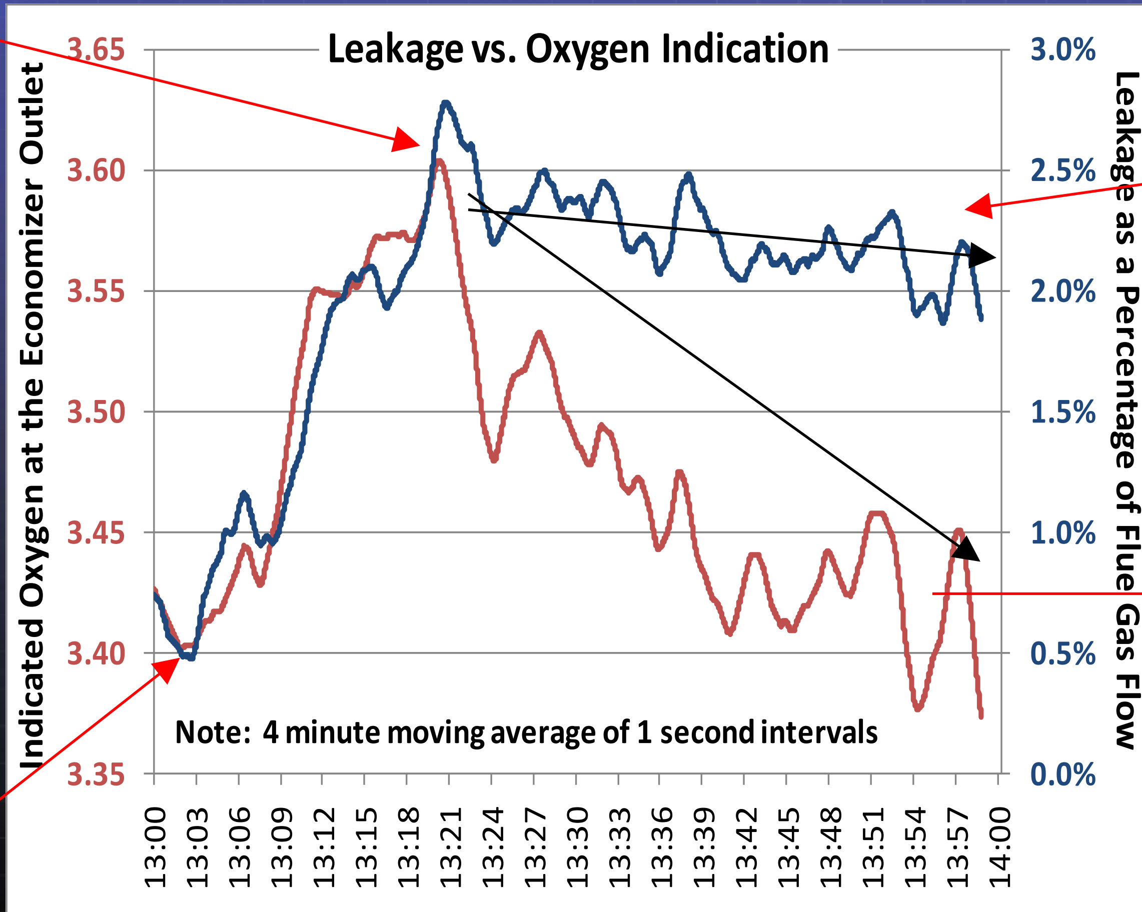


Typical Test Locations



Online Air In-Leakage System Developed by STORM

Airflow into the unit stabilizes

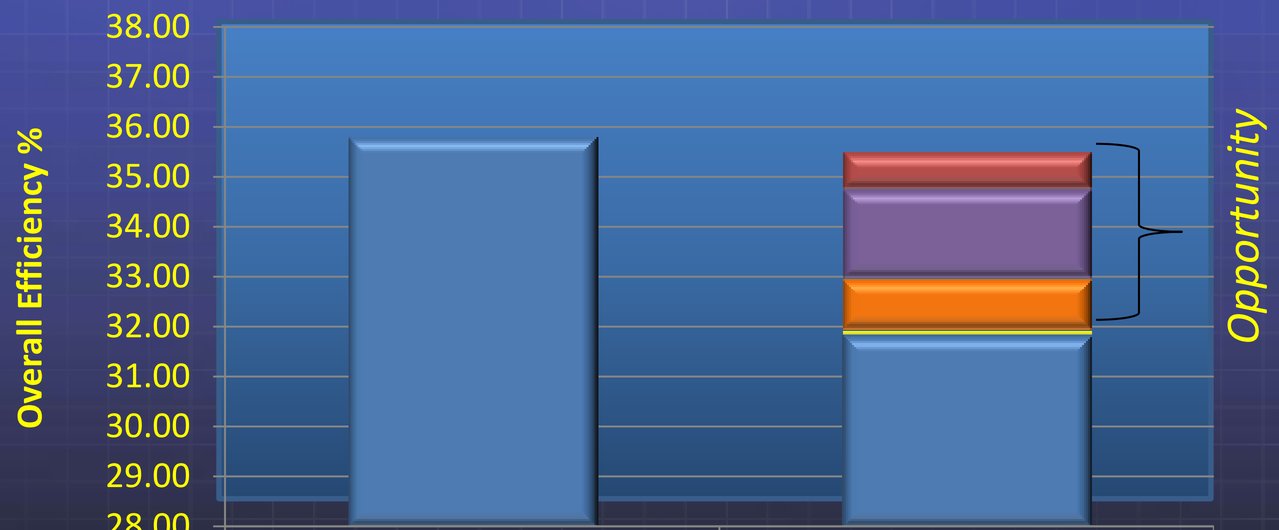


Leakage indication remains relatively constant despite a reducing excess O_2

Oxygen trim "pulls" air out of the unit to return to the set-point

Observation Doors Opened

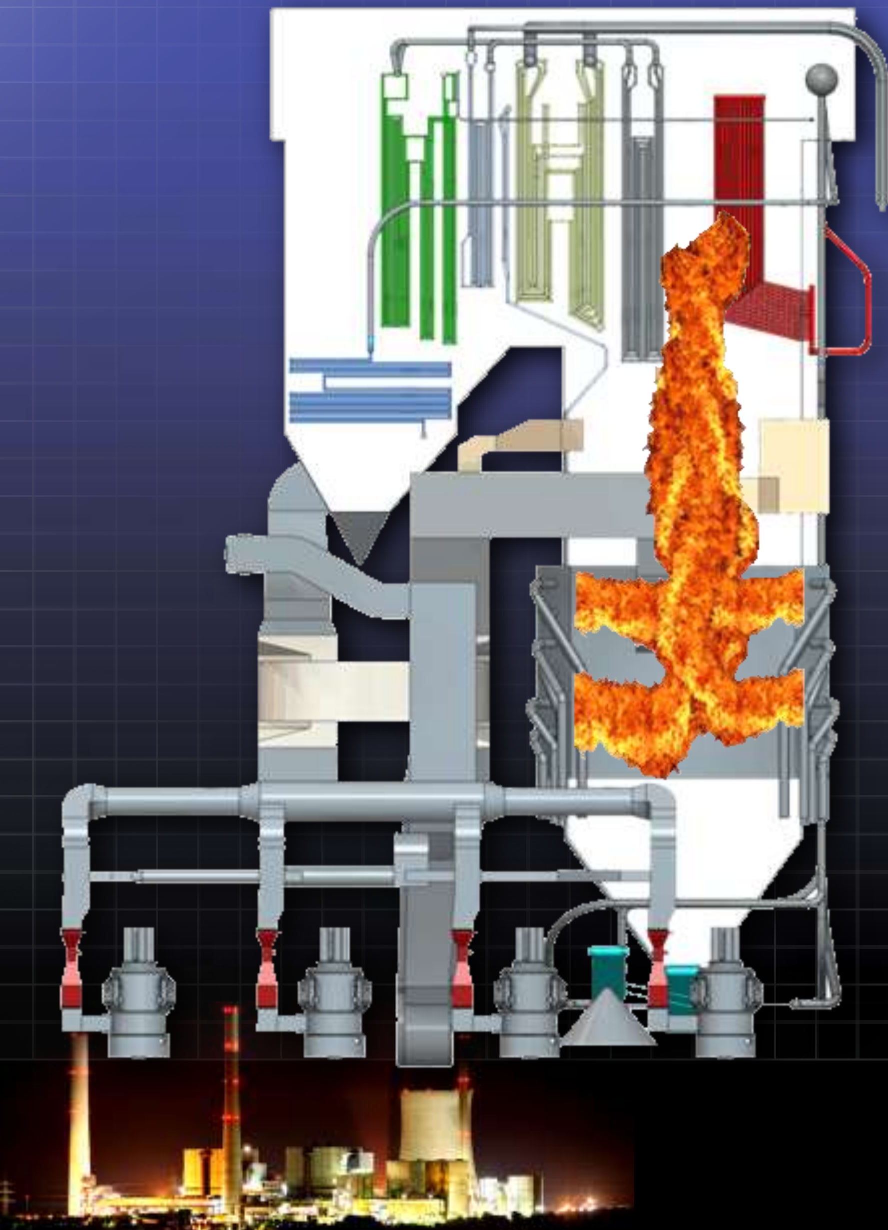
Measuring Plant Efficiency Vs. Design



	Typical (Design)	As Fired
Boiler Opportunities		0.75
Turbine Opportunities		1.79
LOI and Rejects		1.04
Aux. ID Fan HP Opportunities		0.09
Design vs. Actual	35.83	31.85

Thermal Efficiency Deviation from Design ~ 4%

What Causes High Reheat Sprays?

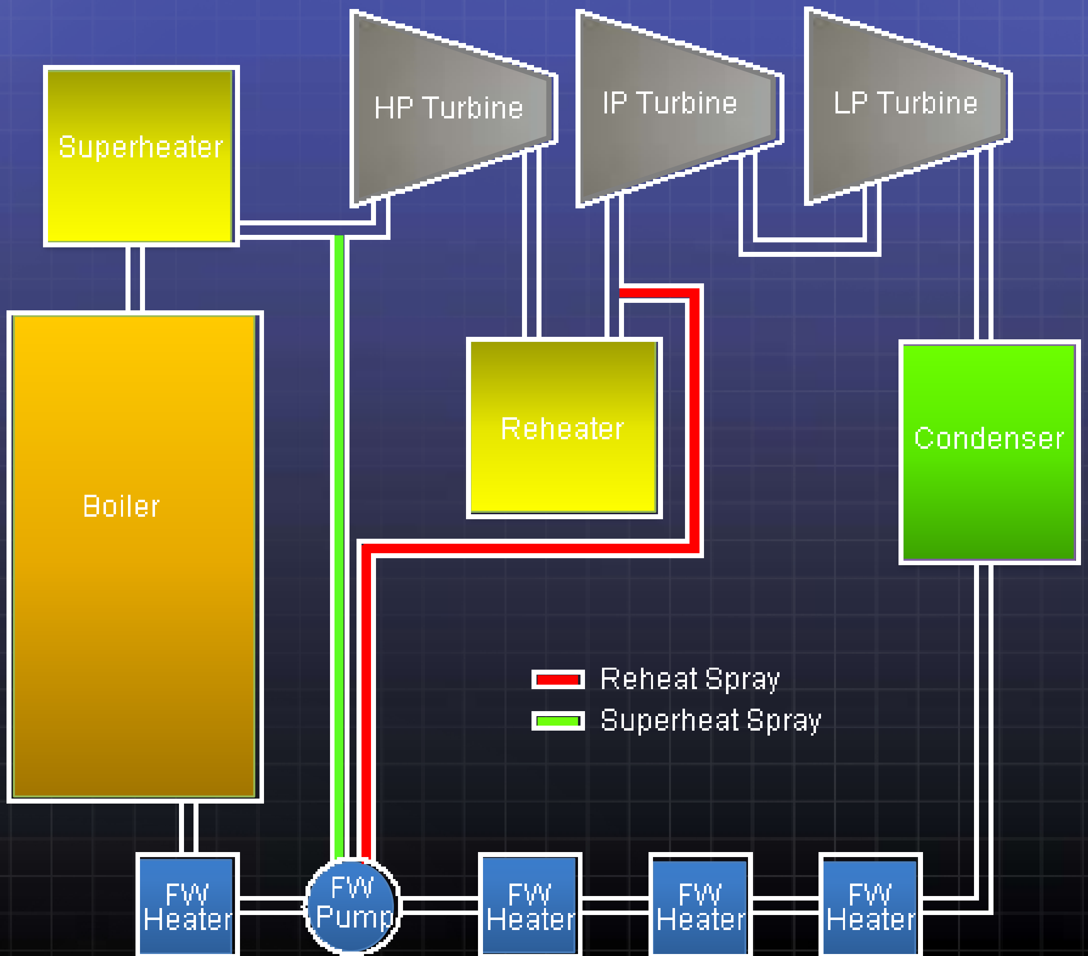


What Causes High Reheat Sprays?

	Gross Costs	Net Costs
Design Superheater Spray Cost (2%)	$120,088	
Cost at 4%	$240,177	$120,088
Cost at 6%	$360,265	$240,177
Cost at 8%	$480,353	$360,265
Cost at 10%	$600,441	$480,353
Design Reheater Spray Cost (0%)	$0	
Cost at 5%	$2,411,560	$2,411,560
Cost at 10%	$4,823,120	$4,823,120

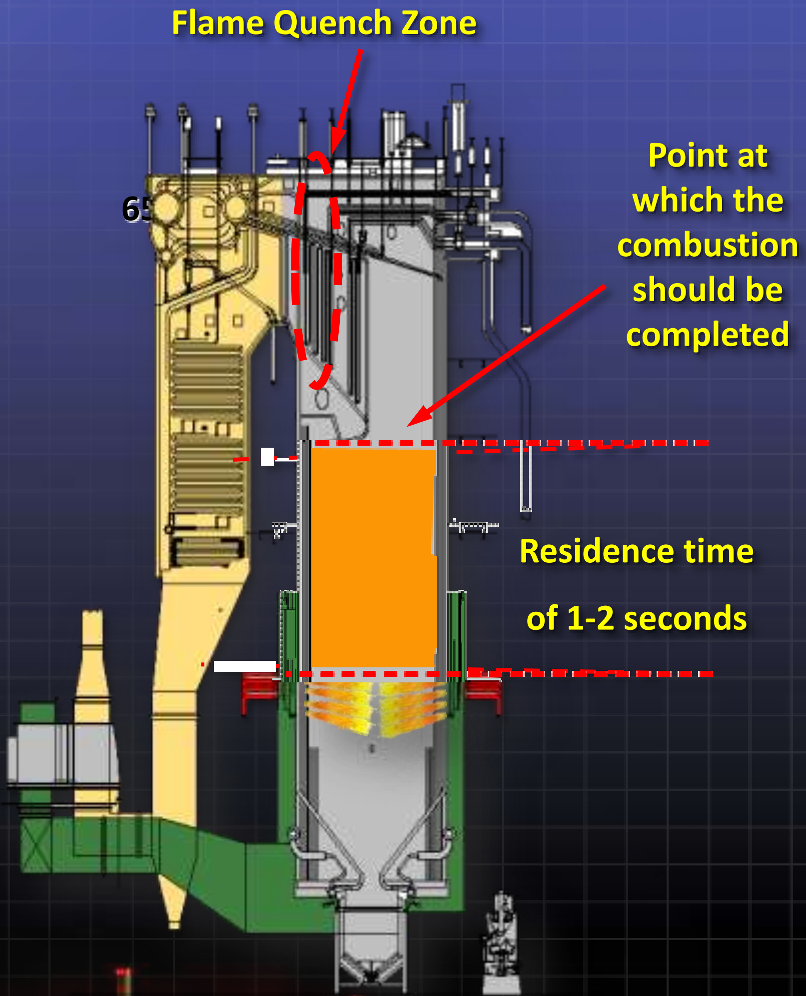
Based on typical 500 MW unit

Typical Spray Paths



- Superheat sprays miss the boiler and top level feedwater heaters
- Reheater sprays miss not only the boiler and top level feedwater heaters, but the high pressure stages of the turbine as well

High Carbon in Ash



When flames carry over into the superheater, the tubes quench the flames causing the combustion of carbon to stop

“Good Combustion” LOI

- Benefits of good LOI
  - Improved heat rate
  - Indicative of “Optimum Combustion” (If LOI is good, so must combustion!)
  - Flyash utilization for concrete
  - Less sootblowing
  - Less cinders (popcorn ash to plug SCR and APH)

High Carbon in Ash

- Example
  - The worst measured LOI for a plant we have conducted business with was 35.88%
  - This was an efficiency penalty of 4.71% (Higher than the dry gas loss)
  - A simple classifier change brought the LOI and efficiency penalty down to 20.7% and 2.19% respectively.

Fuel Type	Good	Average	Poor
Eastern Bituminous	< 5%	8% - 12%	> 10%
Western (Lignite / PRB)	< 0.2%	0.2 – 0.7%	> 1%

- Typically only flyash LOI is measured, but it is important to account for potentially high bottom ash LOI as well.
- Bottom ash usually accounts for 5% to 20% of the total chemical ash remaining.

High Primary Air Flows and What it Means for Heat Rate

- Lower X-Ratios and gas side efficiencies are penalties of the dry gas loss

	Good	Average	Poor
Gas Side Efficiency	> 62%	52% - 58%	< 50%

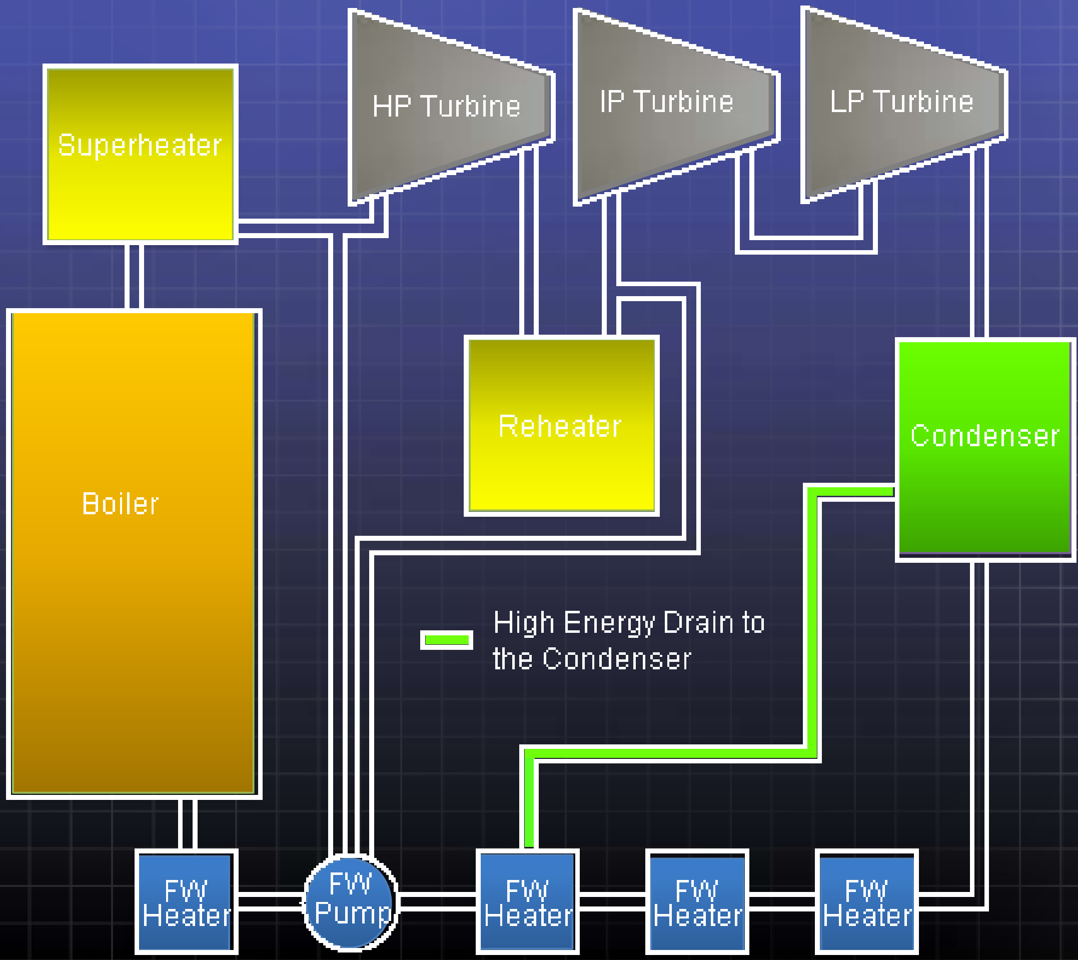
- Usually contributes to long flames, higher furnace NO_x production and increased slagging of the upper furnace
- Wear is increased of coal piping and burner nozzles
- Increased slagging, increased sootblowing to clean SH and RH leads to increased cinder production which then creates air heater and SCR fouling, increased draft losses, increased fan power consumption and steam cycle losses for the increased soot blowing.

Another "Stealth Loss"

- Steam Cycle Losses
  - High Energy Drains. Valve leak-by
  - Feedwater Heater Emergency Drains
  - SH and RH high energy drains to blowdown tank or condenser should be checked regularly. Often 100+ Btu's can be attributed to drain leakages. Especially Reheat drains to condenser

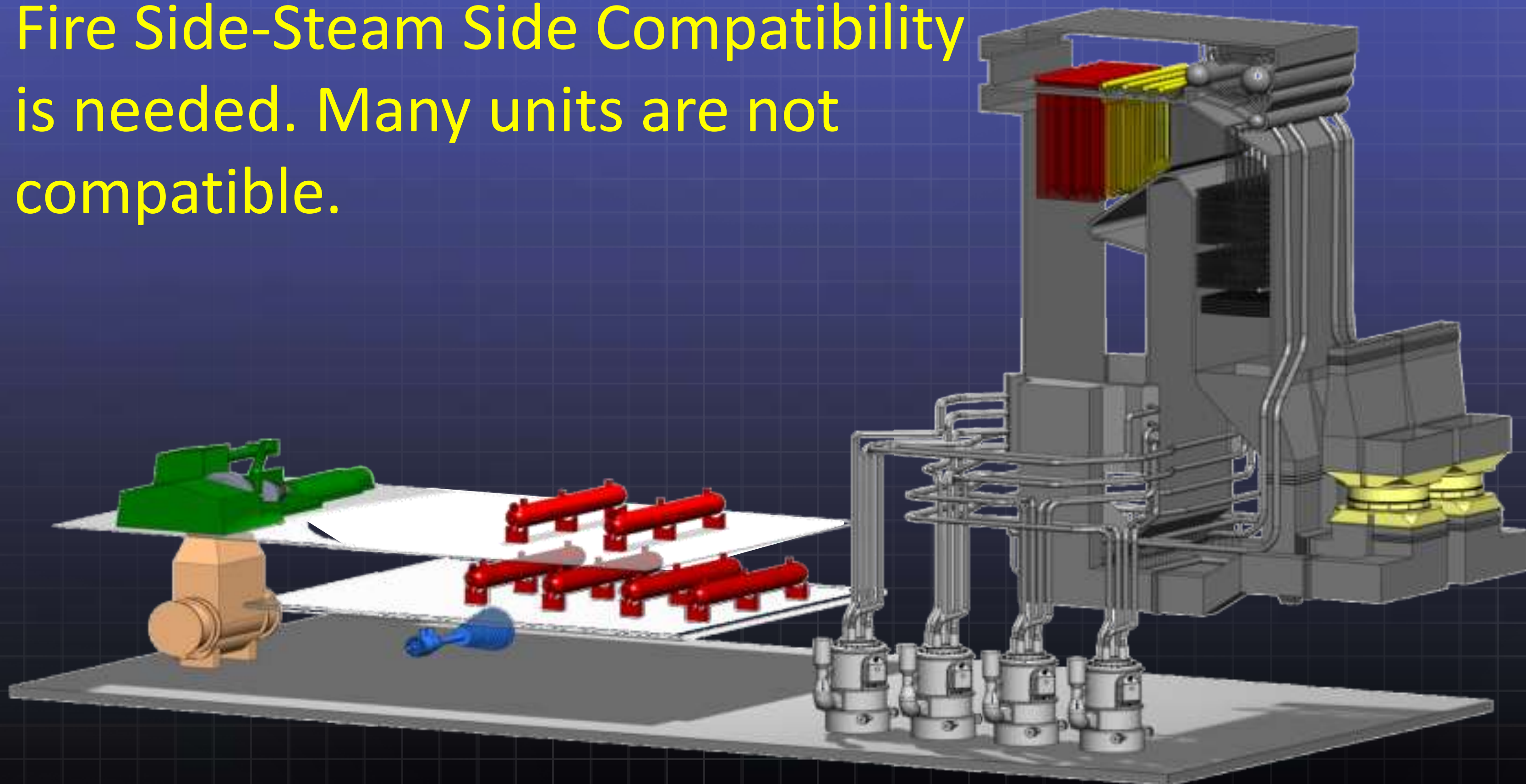
Steam Side Opportunity Example

- Approximately 40MW oil electric utility plant limited on load.
- An emergency drain to the condenser was found to be open resulting in an immediate load increase of 3MW (Greater than 7% of total generation capacity!)



How About NSR? Here Is An Example:

- Fire Side-Steam Side Compatibility is needed. Many units are not compatible.



22 Controllable Heat Rate Variables

1. Flyash Loss On Ignition (LOI)
2. Bottom ash carbon content
3. Boiler and ductwrk air in-leakage
4. More precise primary airflow measurement and control / Reduced tempering airflow (which bypasses the airheaters)
5. Reducing pulverizer air in-leakage on suction mills
6. Pulverizer throat size and geometry optimization to reduce coal rejects and compliment operation at lower primary airflows
7. Secondary airflow measurement and control for more precise control of furnace stoichiometry, especially important for low NOX operation
8. Reduction of extremely high upper furnace exit (FEGT) peak temperatures, which contribute to “Popcorn Ash” carryover to the SCR’s and APH’s, high spray flows, boiler slagging and fouling, and high draft losses due to fouling. The high draft losses cause increased in-leakage, increased fan auxiliary power wastage and increased associated losses with the high spray flows
9. High de-superheating spray flow to the superheater
10. High de-superheating spray flow to the reheater
11. High air heater leakage (note: Ljungstrom regenerative airheaters should and can be less than 9% leakage)

22 Controllable Heat Rate Variables

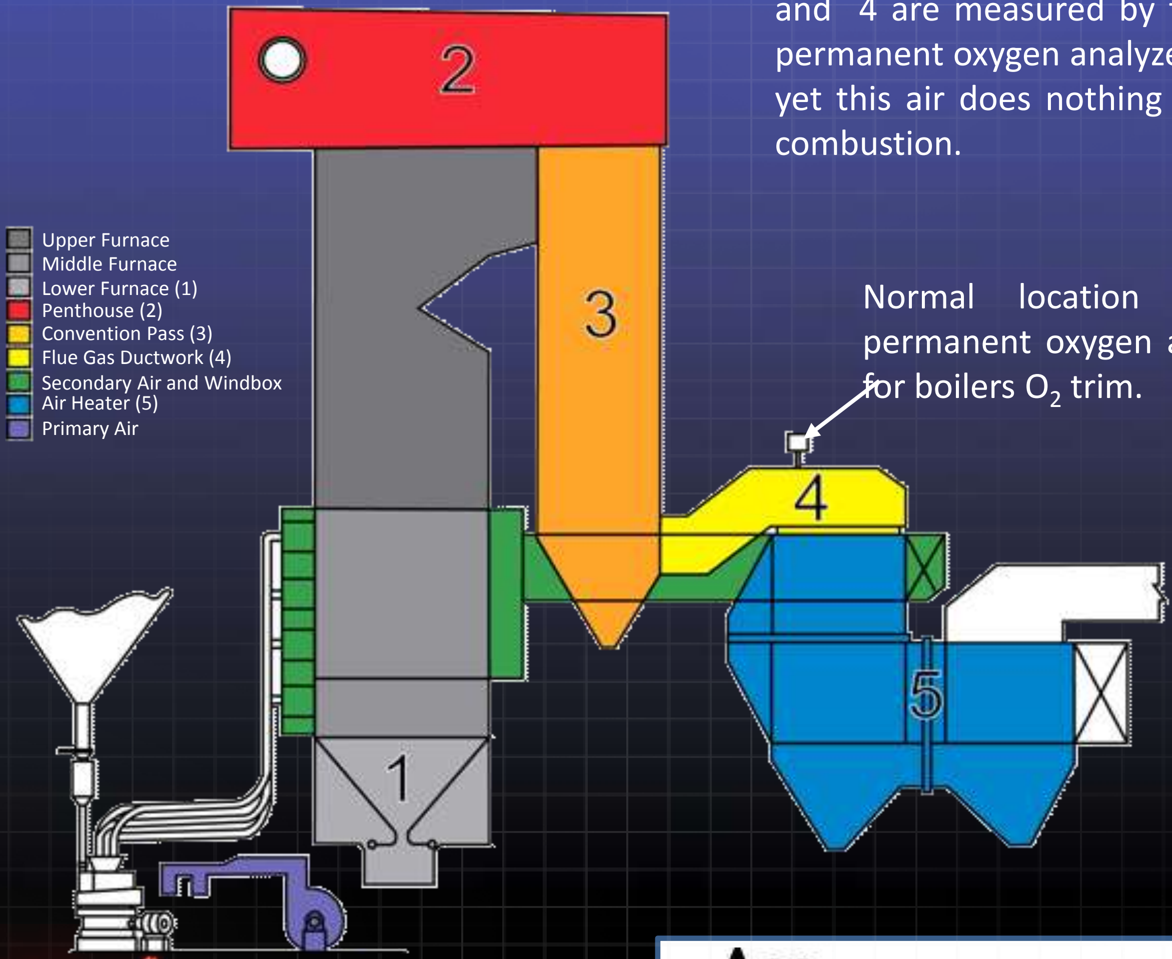
12. Auxiliary power consumption/optimization i.e., fan clearances, duct leakage, primary air system optimization, etc.
13. Superheater outlet temperature
14. Reheater outlet temperature
15. Airheater outlet temperature
16. Airheater exit gas temperature, corrected to a "no leakage" basis, and brought to the optimum level
17. Burner "inputs" tuning for lowest possible excess oxygen at the boiler outlet and satisfactory NOX and LOI. Applying the "Thirteen Essentials"
18. Boiler exit (economizer exit) gas temperatures ideally between 650°F to 750°F, with zero air in-leakage (no dilution!)
19. Cycle losses due to valve leak through – i.e. spray valves, reheater drains to the condenser, superheater and re-heater drains and vents, and especially any low point drains to the condenser or to the hotwell
20. "Soot blowing" Optimization – or smart soot blowing based on excellence in power plant operation. (Remember, soot blowing medium is a heat rate cost, whether compressed air or steam)
21. Feed water heater level controls and steam cycle attention to detail
22. Steam purity and the costly impact of turbine deposits on heat rate and capacity

What can you do? Here are some suggestions:

- Train the O&M Staff in the basics of what can be gained by attention to small factors, such as airflow management, reducing air in-leakage and monitoring excess oxygen levels through the boiler and ductwork to the stack.
- Combine Performance Testing with Maintenance Planning, we call it “Performance Driven Maintenance”
- Convince management to push back on foolish NSR rules, get support from friends. NSR is a problem for improving efficiency of the fleet of old coal plants and serves no purpose anyway with most units that have been upgraded with stack clean up systems anyway.

Typical Locations of Air In-Leakage

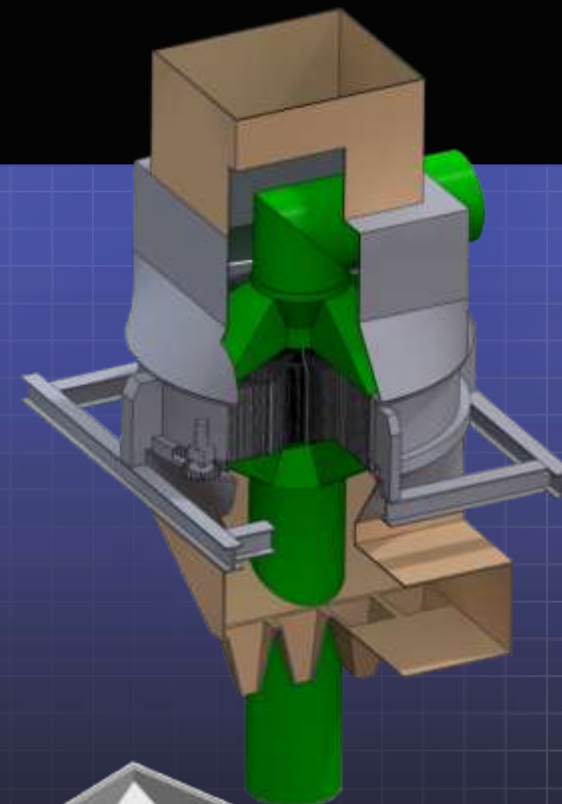
Air in-leakage into zones 2,3 and 4 are measured by the permanent oxygen analyzers, yet this air does nothing for combustion.

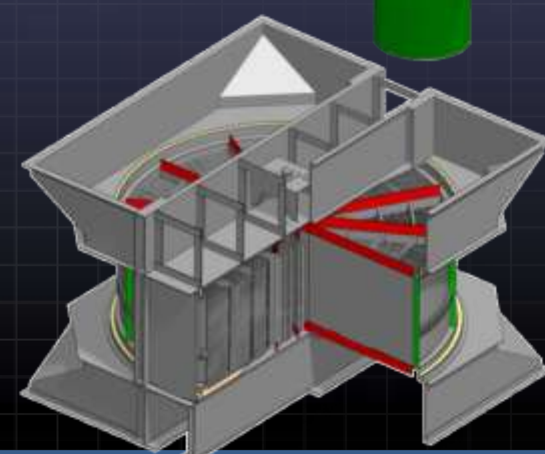


Normal location of the permanent oxygen analyzers for boilers O_2 trim.

Heat Rate Improvement

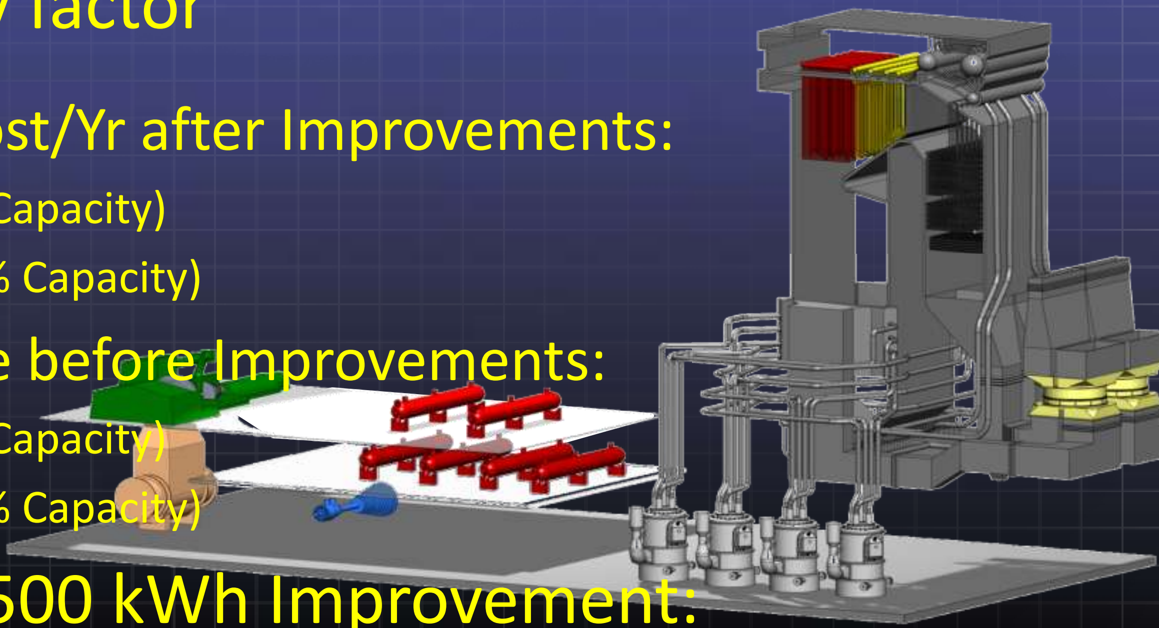
- Reduce secondary airheater leakage
  - Reduce 25-32% down to 12-15%
  - Rothemuhle leakage rates can be reduce by 50%
- Reduce the secondary airheater's differential
  - Clean APH basket is a must
  - High differential exacerbates both APH leakage & duct in-leakage
  - Compounds auxiliary power consumption losss
- Repair Primary Airheater Leakage





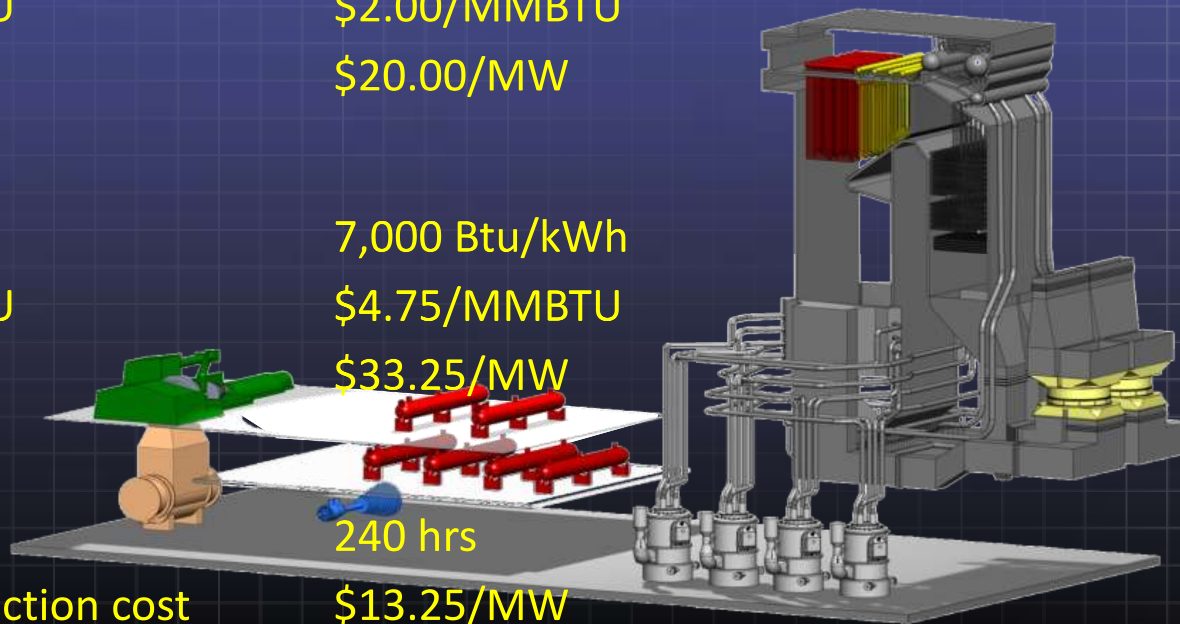
Cost/Benefit Summary

- Summary calculations for a 500 Btu/kWhr heat rate improvement on a 400 MW plant at $2/MMbtu Coal cost, 70% capacity factor
  - Estimated Fuel Cost/Yr after Improvements:
    - $42,560,000 (70% Capacity)
    - $60, 800,000 (100% Capacity)
  - Original Heat Rate before Improvements:
    - $44,800,000 (70% Capacity)
    - $64, 000,000 (100% Capacity)
- Reduced cost for 500 kWh Improvement: **$2,240,000.00**

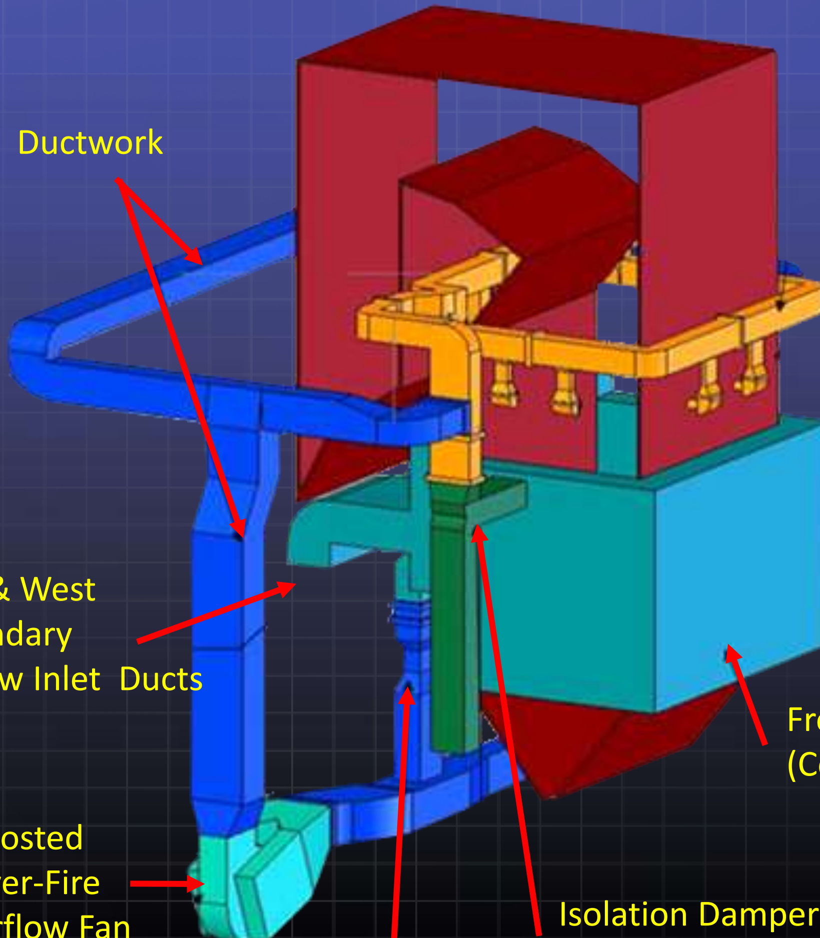


Cost/Benefit Summary (cont')

- Cost to replace downtime with gas at $4.75/MMBtu
  - Coal fuel Cost
    - Coal fired heat rate — 10,000 Btu/kWh
    - Coal cost $/MMBTU — $2.00/MMBTU
    - Fuel cost for coal — $20.00/MW
  - Gas fired cost
    - Gas fired heat rate — 7,000 Btu/kWh
    - Coal cost $/MMBTU — $4.75/MMBTU
    - Fuel cost for gas — $33.25/MW
  - Hours
    - Lost hours — 240 hrs
    - Difference in production cost — $13.25/MW
- Replacement production cost: **$1,272,000.00**

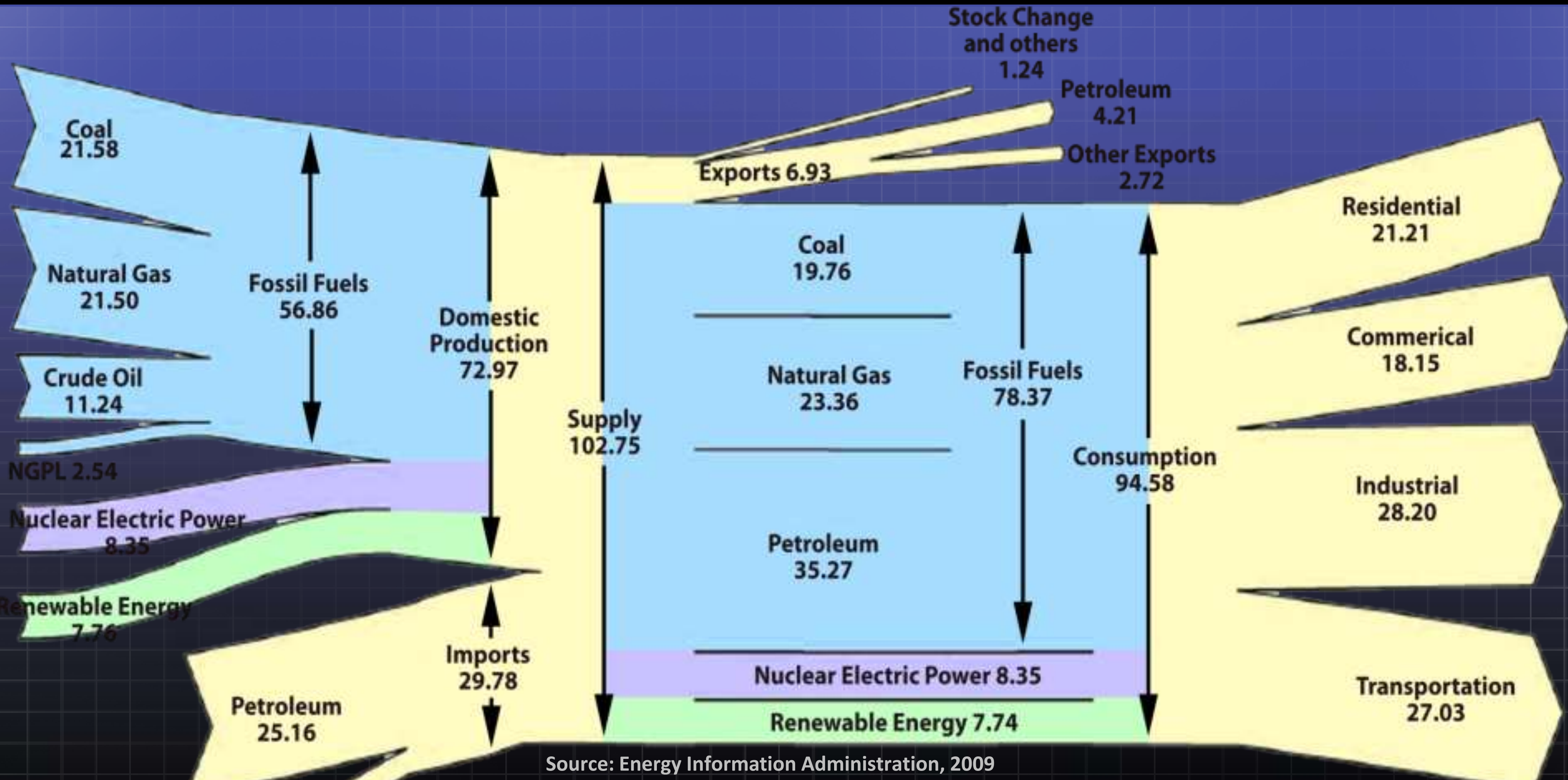


Fan Booster Over Fired – Case Study



All Energy Flow to Power America

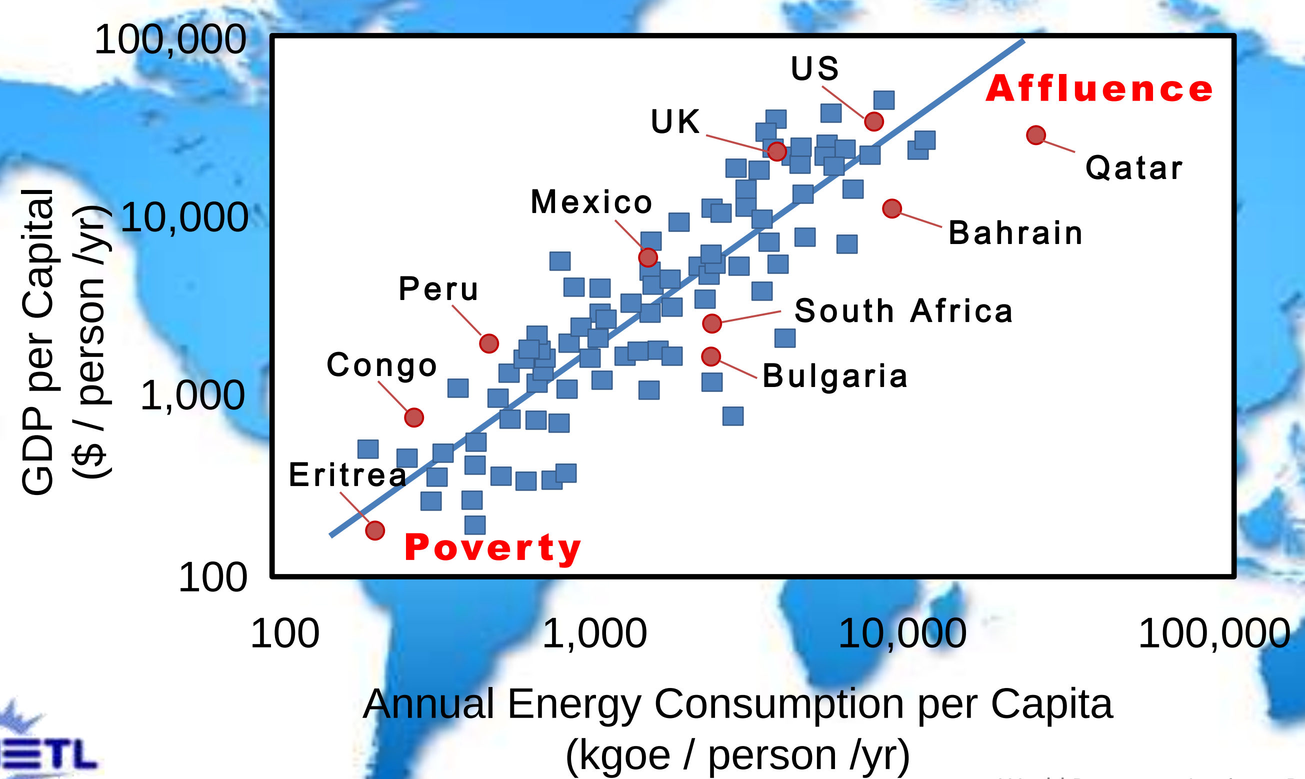
2009 (Quadrillion Btu)



Source: Energy Information Administration, 2009

Note: In 2008 the consumption was over 100 Quadrillion BTU's (compared to 2009's 94.58) – This decline shows the correlation of energy and economic prosperity

Annual Energy Consumption per Capita



World Resources Institute Database, accessed June 1, 2005
http://earthtrends.wri.org/searchable_db/

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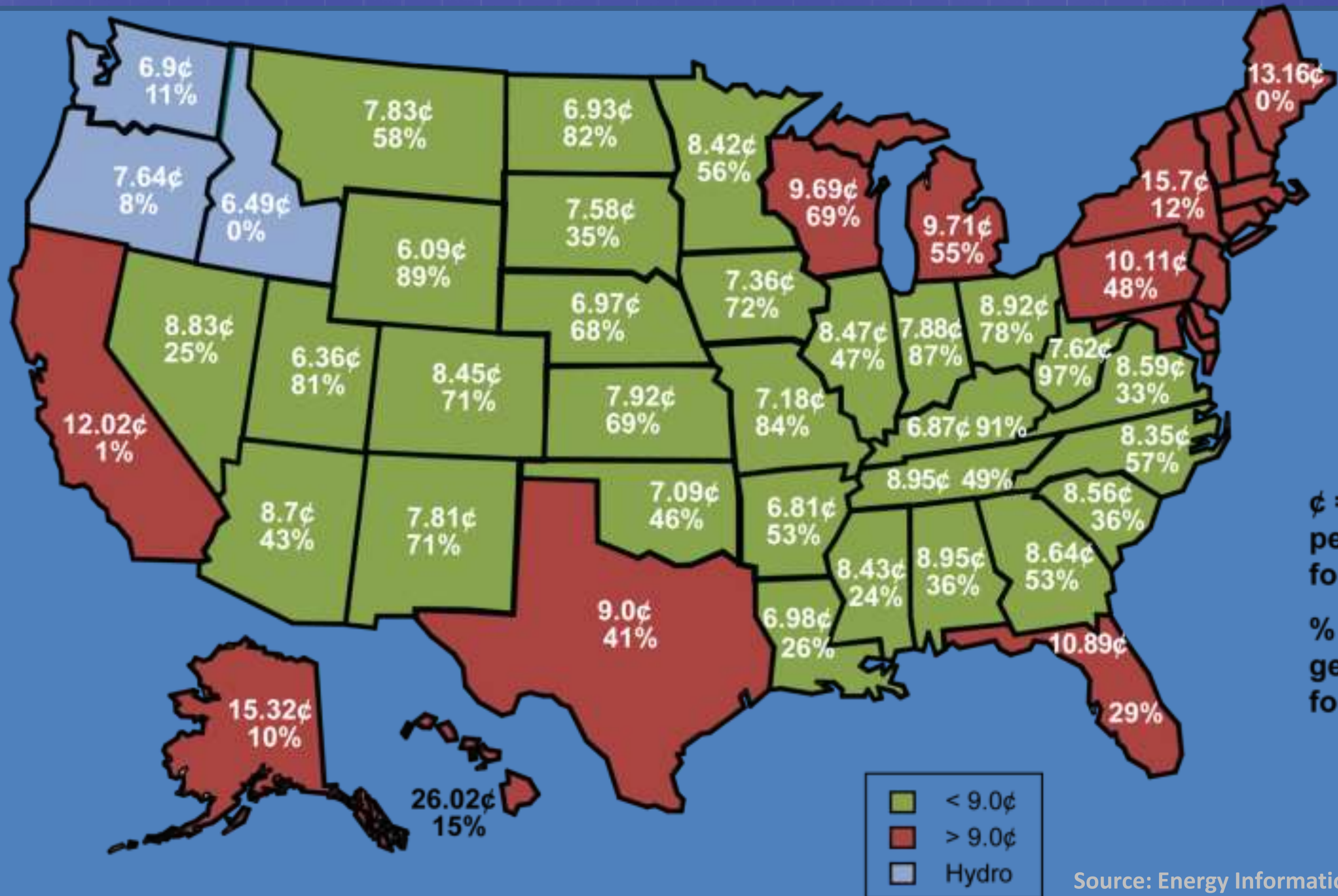
States that Rely on Coal Have Low-Cost Electricity



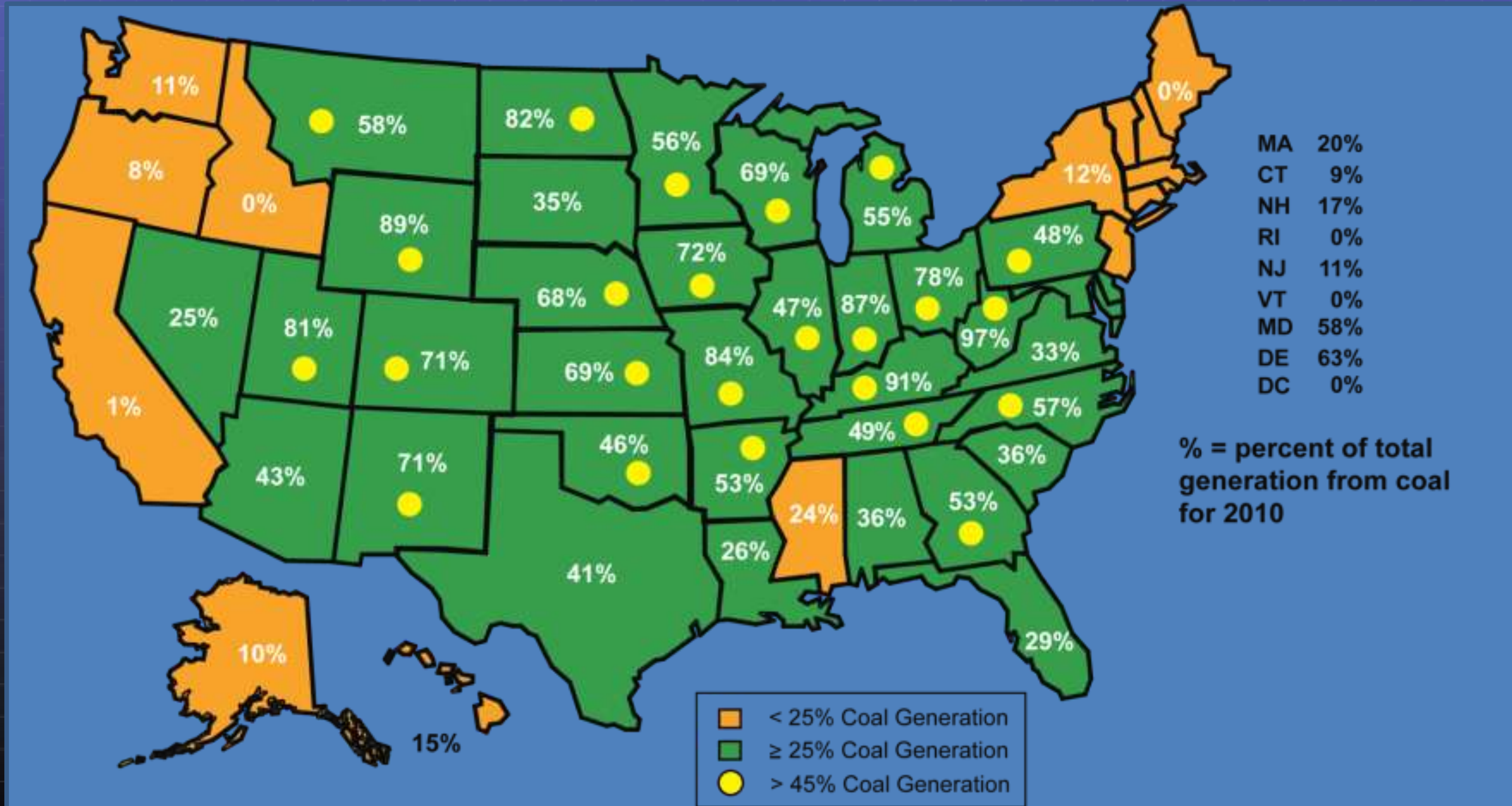
MA	14.4¢	20%
CT	17.01¢	9%
NH	14.89¢	17%
RI	13.44¢	0%
NJ	14.03¢	11%
VT	13.49¢	0%
MD	12.29¢	58%
DE	11.94¢	63%
DC	13.26¢	0%

¢ = average retail price per kilowatt hour for 2010

% = percent of total generation from coal for 2010

Source: Energy Information Administration, 2010

States that Rely on Coal Have Low-Cost Electricity



Source: Energy Information Administration, 2010

ACC American Coal Council

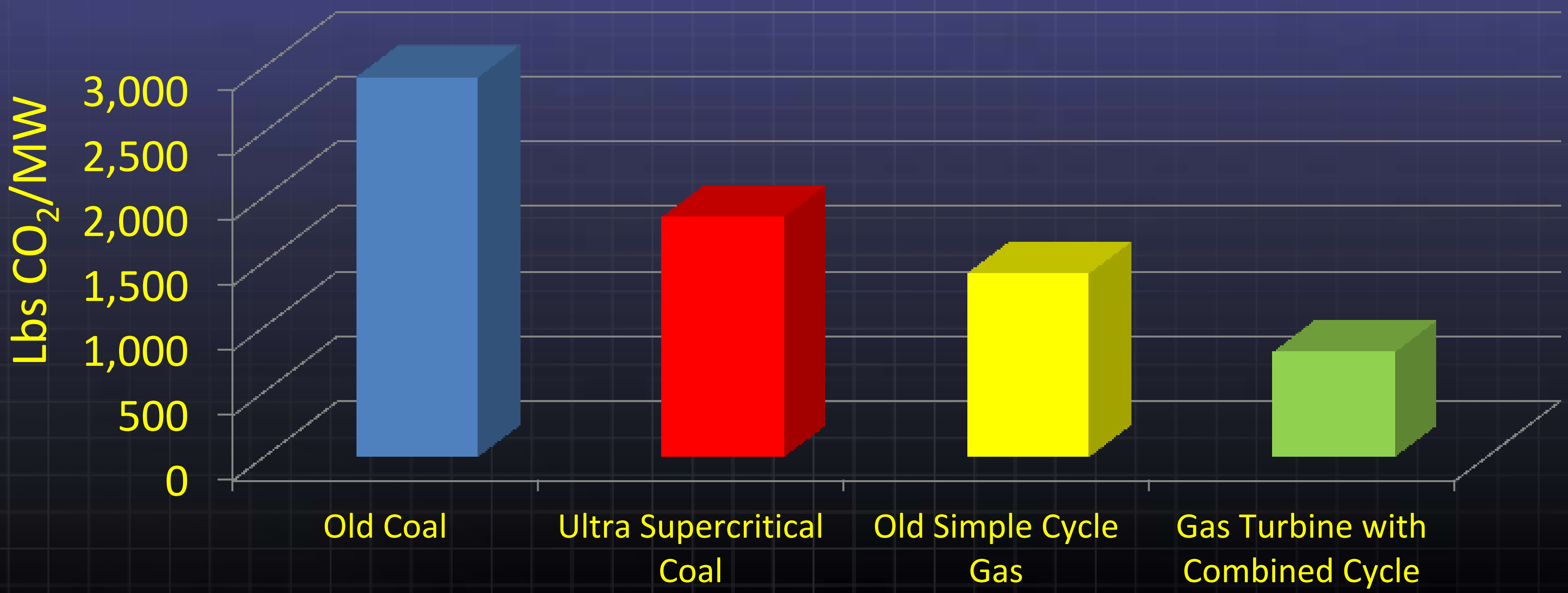
EFFICIENCY IMPROVEMENTS
TO THE EXISTING
COAL-FIRED FLEET

STORM

MINNEAPOLIS, MN 2011

CO2 Production per MegaWatt

Natural Gas does emit less CO_2, but it is not carbon free.
Depending on the efficiency of the end use, natural gas may result in a carbon footprint that is 70% or more of an equivalent amount of energy from coal.



Coal to Generate More Electricity

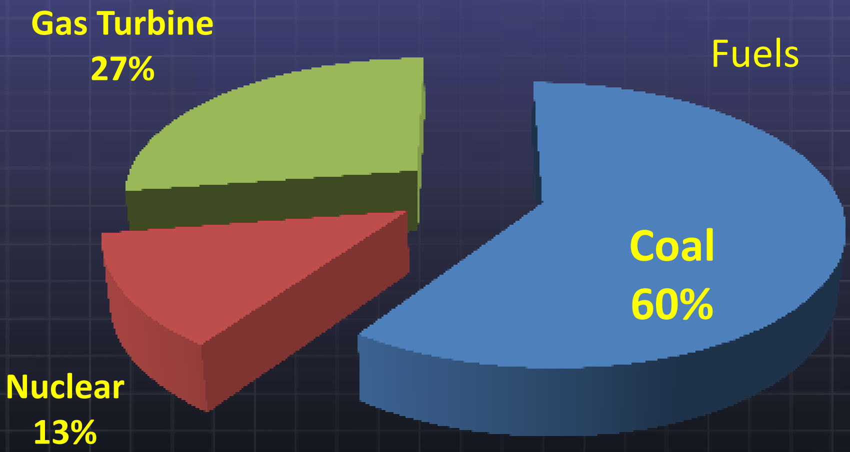
Coal fuels the industrialized world to power manufacturing to "build things" and create wealth.

That is how the USA obtained our wealth and strength in the 20th century – and how Asia is gaining theirs in the 21st century.

International Coal Facts

Source: eia.gov

- 2008 – 78% of electricity generation in China was from coal.
- 2009 – China coal consumption was at 3.5 billion tons per year vs. US coal consumption at 1.0 billion tons per year.



Global Electric Generating Capacity, 2020
(1000 MW)

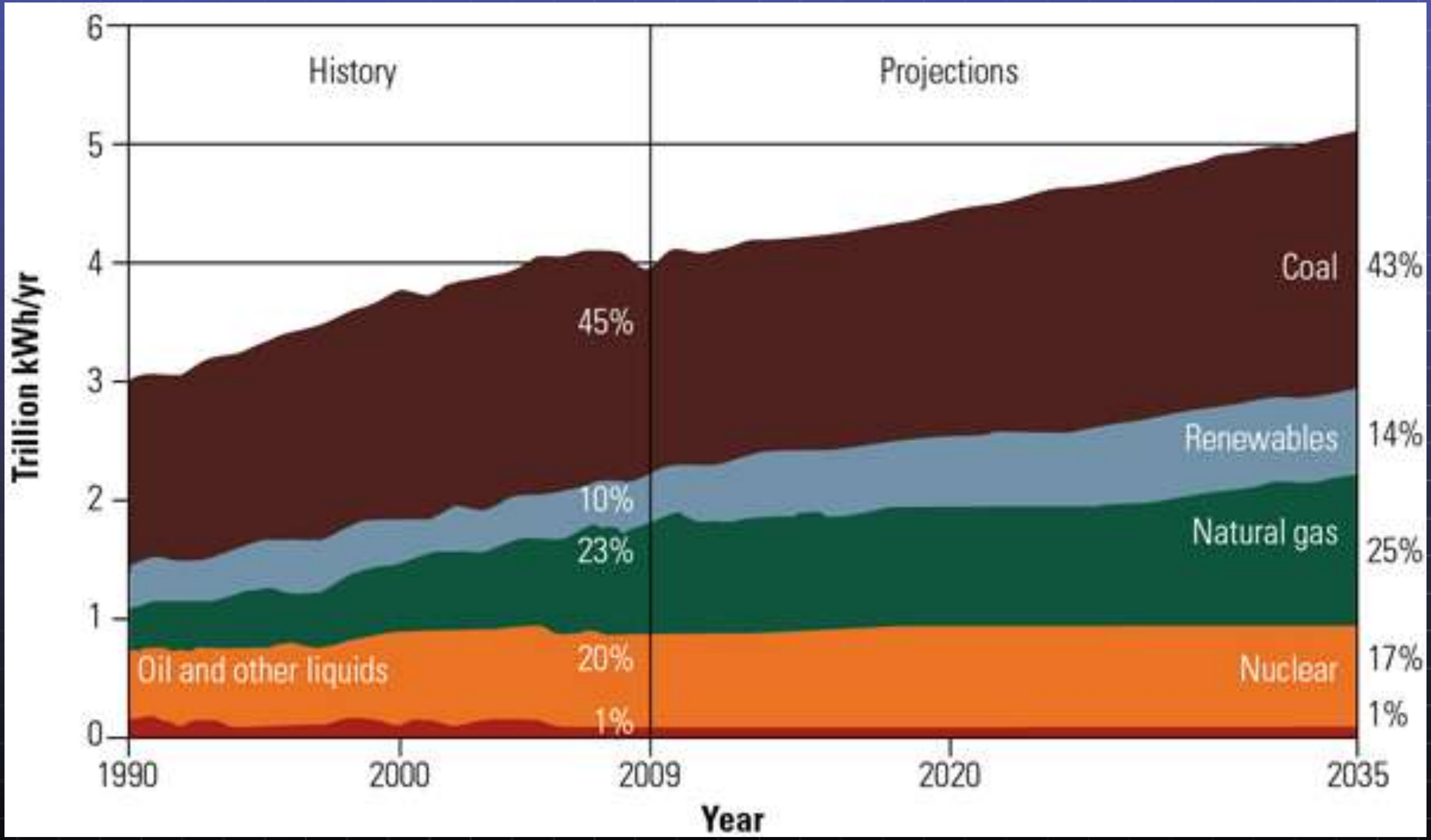
Source: Mcilvaine Company

Coal Fired Generation Prediction

U.S. Energy Information Association (EIA) predictions of U.S. electricity generation estimate that the percentage of U.S. electricity generated by the combustion of coal will decline by 2%, from 45% to 43%, between 2009 and 2035.

EIA Annual Energy Outlook 2011

- An estimated 21 GW will be added during this 25 yr period.
- Coal will remain the dominant energy source.
- Heavy reliance on the existing coal-fired fleet to meet nation's demand.



Electricity generation by fuel, 1990–2035. Data is shown as net electricity generation. *Sources: Historical data from EIA, Annual Energy Review 2009; projections from National Energy Modeling System, run REF 2011, D120810C*

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EFFICIENCY IMPROVEMENTS TO THE EXISTING COAL-FIRED FLEET

STORM

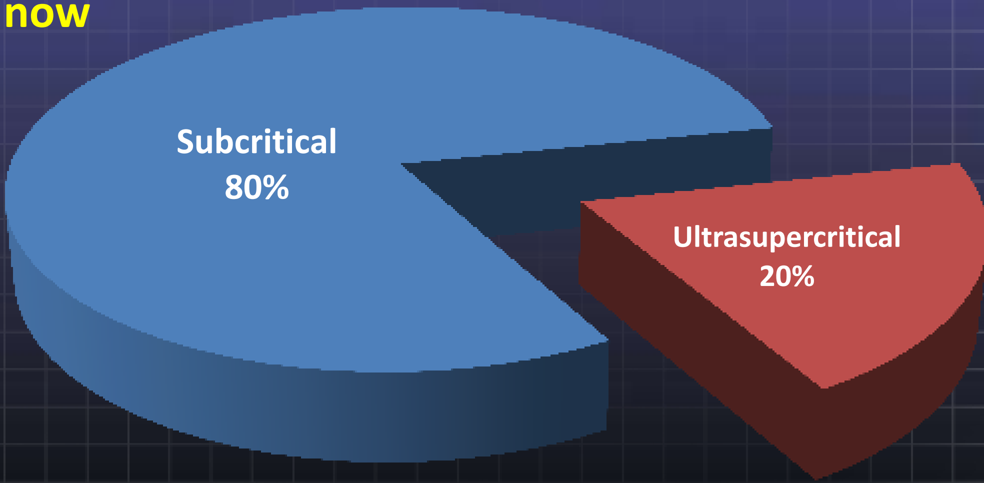
MINNEAPOLIS, MN 2011

The Existing Coal-Fired Fleet

The current portfolio of coal-fired generation in the U.S. was a shade over 338 GW of installed nameplate capacity for 1,436 units at the end of 2009, the last full year for which EIA data is available. These units are generally conventional pulverized coal (PC) plants based on either subcritical (80% of the units) or supercritical (20%) boiler technology.

3 Conventional Boiler Technologies available now

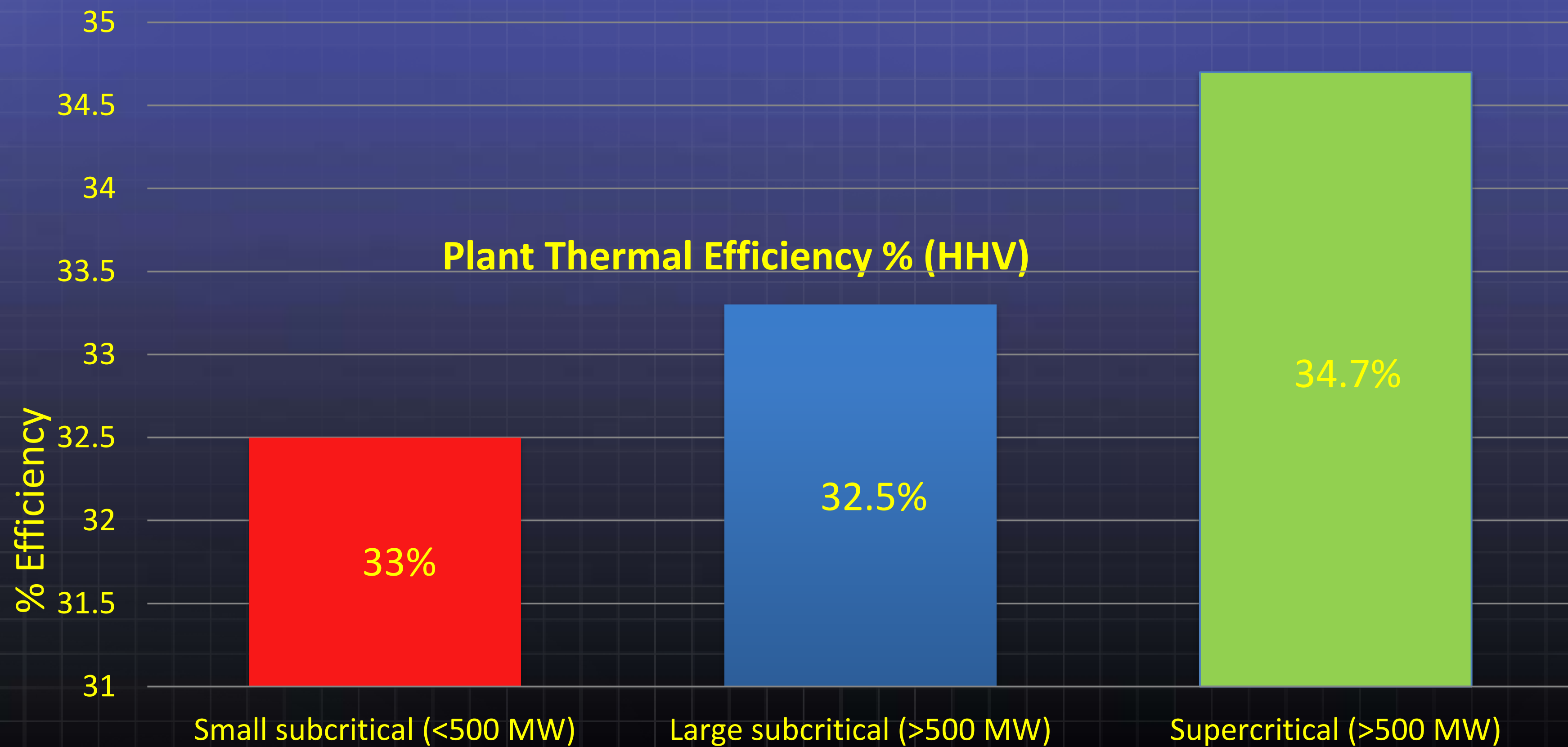
1. Subcritical steam generators
   - Operates at steam pressure < 3,208 PSI
2. Conventional supercritical steam generators
   - Operates at steam pressure > 3,208 PSI and steam temp generally in 1,000F – 1,050F
3. Ultrasupercritical (USC) steam generators
   - Operates at steam pressure > 3,208 PSI and steam temp > 1,100F



Today's Coal-Fired Fleet

Coal-Fired Generation Cost and Performance Trend. *Sources: Power Magazine, May 2011. Article by Dale Probasco, managing director with Navigant's Energy Practice and Bob Ruhlman, associate director with Navigant's Energy Practice.*

Supercritical Units = Better Efficiency



Coal-Fired Generation Cost and Performance Trend. *Sources: Power Magazine, May 2011. Article by Dale Probasco, managing director with Navigant's Energy Practice and Bob Ruhlman, associate director with Navigant's Energy Practice.*

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EFFICIENCY IMPROVEMENTS TO THE EXISTING COAL-FIRED FLEET

MINNEAPOLIS, MN 2011

Why Ultra Supercritical Units?

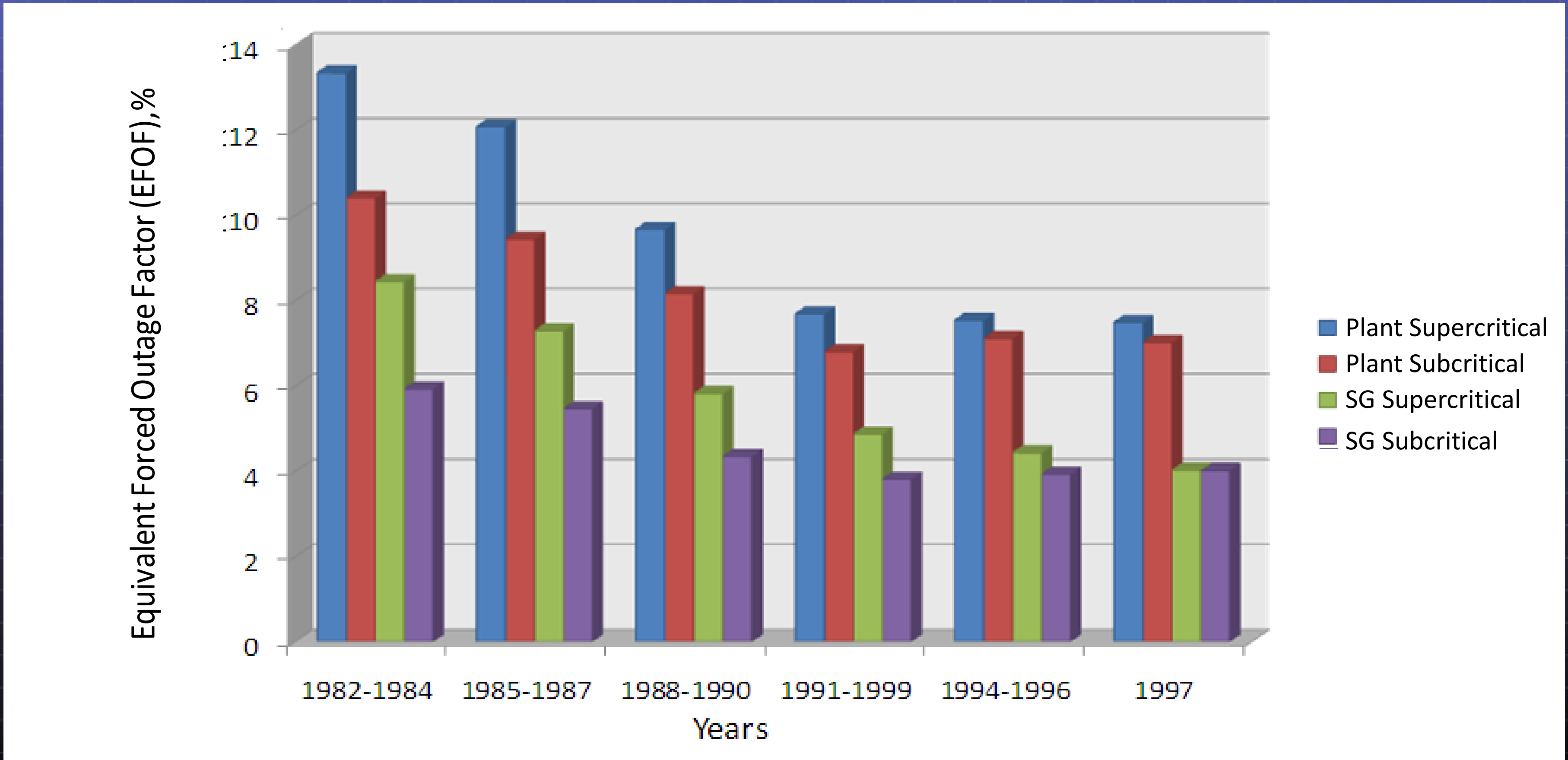
Dramatic Improvement in
39% Efficiency

- Most efficient technology for producing electricity fueled by pulverized coal.
- Operates at supercritical pressure and steam temp. of 1,100°F
- Temp and pressures enable more efficient operation of Rankine cycle.
- Increase in efficiency reduces fuel consumption, and thereby reduces emissions.
- Turk plant shown at right has 39% efficiency, while other USC has ~40-41% efficiency.

Architect's rendering of AEP's John W Turk Jr Plant, the first ultra-supercritical generating unit.

Source: www.aep.com - Supercritical Fact Sheet

Availability of Subcritical versus Supercritical Units – N. America



Advanced Designs and Materials

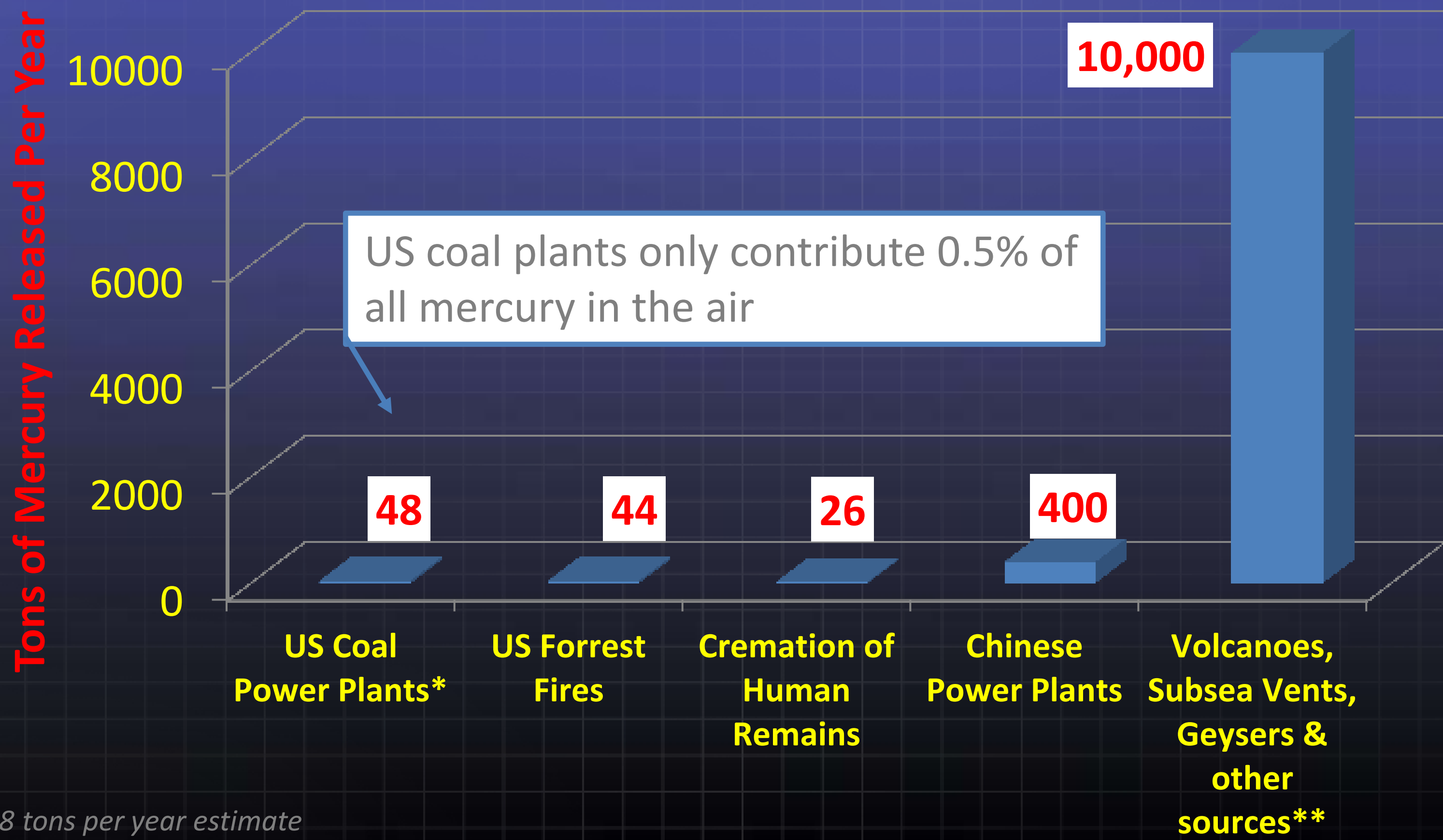
(Courtesy MitsuiBabcock) Pressure (psi) Main Steam/Reheat Temp	**SUBCRITICAL** 2400 1005F/1005F	**SUPERCRITICAL** 3600 1060F/1055F	**SUPERCRITICAL** 3800 1075F/1075F	**ULTRASUPERCRITICAL** 4200 1110F/1150F
High Temperature Superheater and Reheater	**T22**, **T91**	**T91**, **TP347H**	**T91**, **TP347H**	**TP347H**, **TP310HCbN**
Primary Superheater, Intermediate & Outlet Surfaces	**T12**	**T23**	**T23**	**T91**
Primary Superheater Inlet	**T1a**	**T12**	**T12**, **T23**	**T23**
Reheater Inlet Bank in Rear Pass	**SA192**	**SA192**	**SA210C**	**SA210C**
Waterwalls	**SA210C**, **T1a**	**T12**	**T12**	**T12**, **T23**
Furnace Roof	**T12**	**T12**	**T23**	**T23**
Rear Cage	**T1a**	**T12**	**T23**	**T23**

Supercritical State of the Art Technology

- Latest units in Europe 4000 psig, 1105/1110°F (Ultra Supercritical)
- China moving up to 3800 psig, 1120/1135°F
- Most aggressive unit in Japan 3950 psig, 1121/1153°F
- Typical U.S. supercritical boilers are generally around 3700 psig, 1080/1080°F
- Most advanced U.S. plant in Engineering Phase at 3800 psig, 1112/1135°F
- With advanced materials and careful design, ultra supercritical units have maintenance and availability similar to more recent standard supercritical units.
- An ultra efficient, clean coal fleet would reduce emissions further for all pollutants.

Source: Worley Parson Resources and Energy

The Myth of Killer Mercury



**41-48 tons per year estimate*
***9,000-10,000 tons per year estimate*

Source: Wall Street Journal

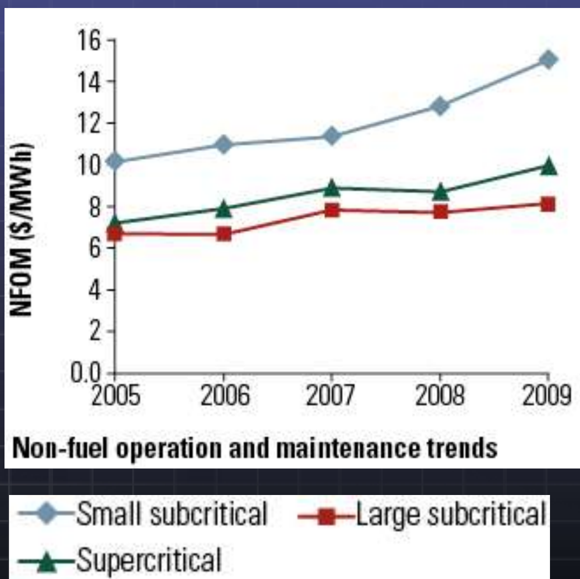
The Straight Facts on Mercury

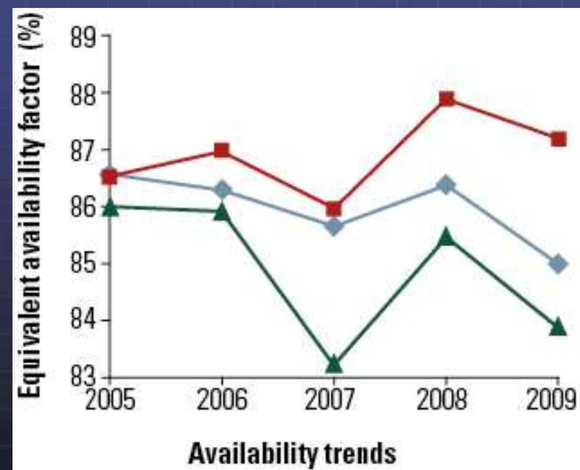
- Mercury has always existed naturally in Earths' environment.
- 2009 study found mercury deposits in Antarctic ice across 650,000 years.
- Mercury is found in air, water, rocks, soil and trees.
- 200 Billion tons of mercury presently in seawater have never posed a danger to living beings.
- America's coal-burning power plants emit an estimated 41-48 tons of mercury per year.

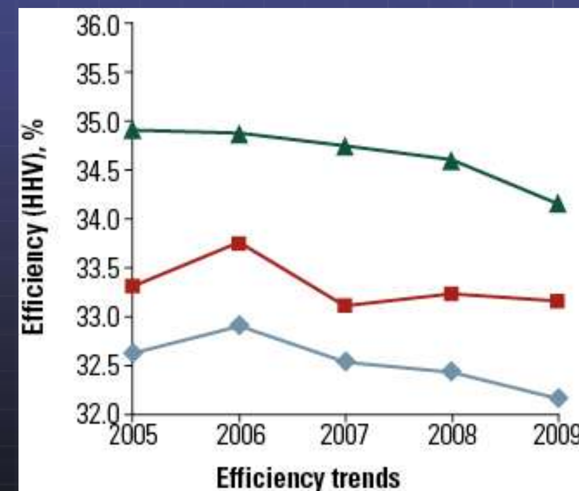
- **<u>Bottomline</u>: An ultra efficient, clean coal fleet" would not only create millions of jobs and revitalize American manufacturing, but it would also reduce emissions further for all pollutants.**

Existing Coal-Fired Fleet Performance Trends, 2005-2009

The net drop in average efficiency is greatest for supercritical units (–0.7%), followed by small subcritical units (–0.4%) and large subcritical units (–0.2%).







Coal-Fired Generation Cost and Performance Trend. *Sources: Power Magazine, May 2011. Article by Dale Probasco, managing director with Navigant's Energy Practice and Bob Ruhlman, associate director with Navigant's Energy Practice.*

Capital costs for coal-fired generation

Technology	Project	Nominal capacity (MW)	Year completed	Approximate total cost ($/kW)
Subcritical	JK Spruce	750	2010	1,333
	Plum Point	720	2010	1,388
			Subcritical average cost	**1,361**
Conventional supercritical	Comanche	750	2010	1,733
	Iatan	850	2010	1,470
	Oak Creek	1,230	2011	1,935
	Trimble County	750	2011	1,579
			Supercritical average cost	**1,679**

Coal-Fired Generation Cost and Performance Trend. *Sources: Power Magazine, May 2011. Article by Dale Probasco, managing director with Navigant's Energy Practice and Bob Ruhlman, associate director with Navigant's Energy Practice.*

Average Cost

Capital cost review of recently completed projects employing both subcritical and supercritical technology

New coal plants designed today will likely cost **$3,000/kWh** installed cost

EIA Cost Estimates for Coal-Fired Units

Estimates Cost

Technology	Nominal capacity (MW)	Efficiency (%)	Overnight capital cost (2010 $/kW)	% change from previous year
Coal				
Single-unit advanced PC	650	38.8	$3,167	
Dual-unit advanced PC	1,300	38.8	$2,844	25%
Single-unit advanced PC with CCS	650	28.5	$5,099	
Dual-unit advanced PC with CCS	1,300	28.5	$4,579	
Gas				
Advanced natural gas combined cycle	400	53.1	$1,003	1%

Notes: CCS = carbon capture and sequestration, PC = pulverized coal.

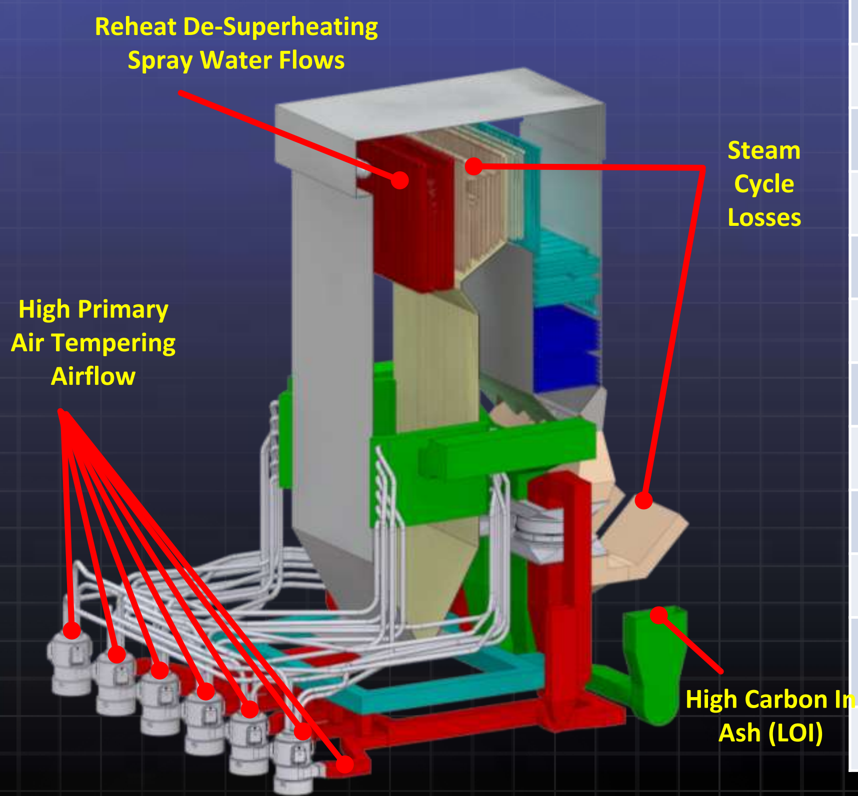
Coal-Fired Generation Cost and Performance Trend. *Sources: Power Magazine, May 2011. Article by Dale Probasco, managing director with Navigant's Energy Practice and Bob Ruhlman, associate director with Navigant's Energy Practice.*

Single-unit advanced PC option nearly double the average cost. Note: The cost of the coal option increased by 25% while the gas option rose by a meager 1%

Construction costs are one factor, fuel costs over the life of the plant will have more of an impact for our children's generation. Also natural gas is not likely to remain at $4.00 per million Btu's as demand doubles. Multiple fuels should be depended upon.

Stealth Opportunities

There is still room for Excellence in Operations and Maintenance!

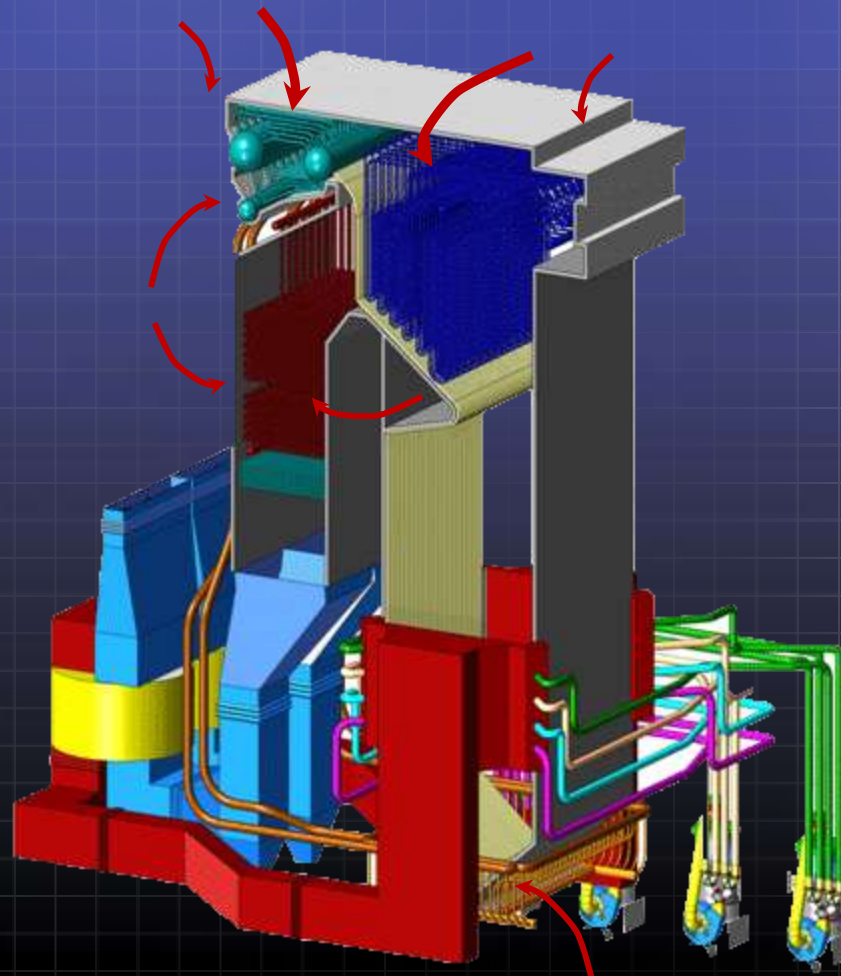


Variable	Potential Heat Rate Improvement (Btu/kWh)	Potential Annual Fuel Savings
Boiler & ductwork ambient air in-leakage	300	$819,000
Dry gas loss at the air heater exit	100	$273,000
Primary airflow	75[a]	$204,750
Steam temperature	75	$204,750
De-superheater spray water flow	50	$136,500
Coal spillage	25	$68,250
Unburned carbon in flyash	25[a]	$68,250
Unburned carbon in bottom ash	25	$68,250
Slagging and fouling	25[a]	$68,250
Cycle losses	25	$68,250
All others, including soot blowing and auxiliary power factors	25	$68,250
Total	**750**	**$2,047,500**

Note: a. Interactions between variables will impact meeting this estimate.

Air In-Leakage

- Penalties due to air in-leakage (up to 300 Btu's/kWh
- PTC-4.1 does not take into account. Thus, we call them "Stealth Losses"
- In addition to the thermal penalty, artificially high oxygen readings can have serious performance impacts on good combustion
- The air that leaks into the boiler setting, between penthouse and air heater inlet is useless for combustion, it is simply "tramp air"
- Bottom ash hopper seals are another source of Air Heater Bypass air
- Traditional Concerns of Air heater leakage and the penalties of high Air Heater Leakage

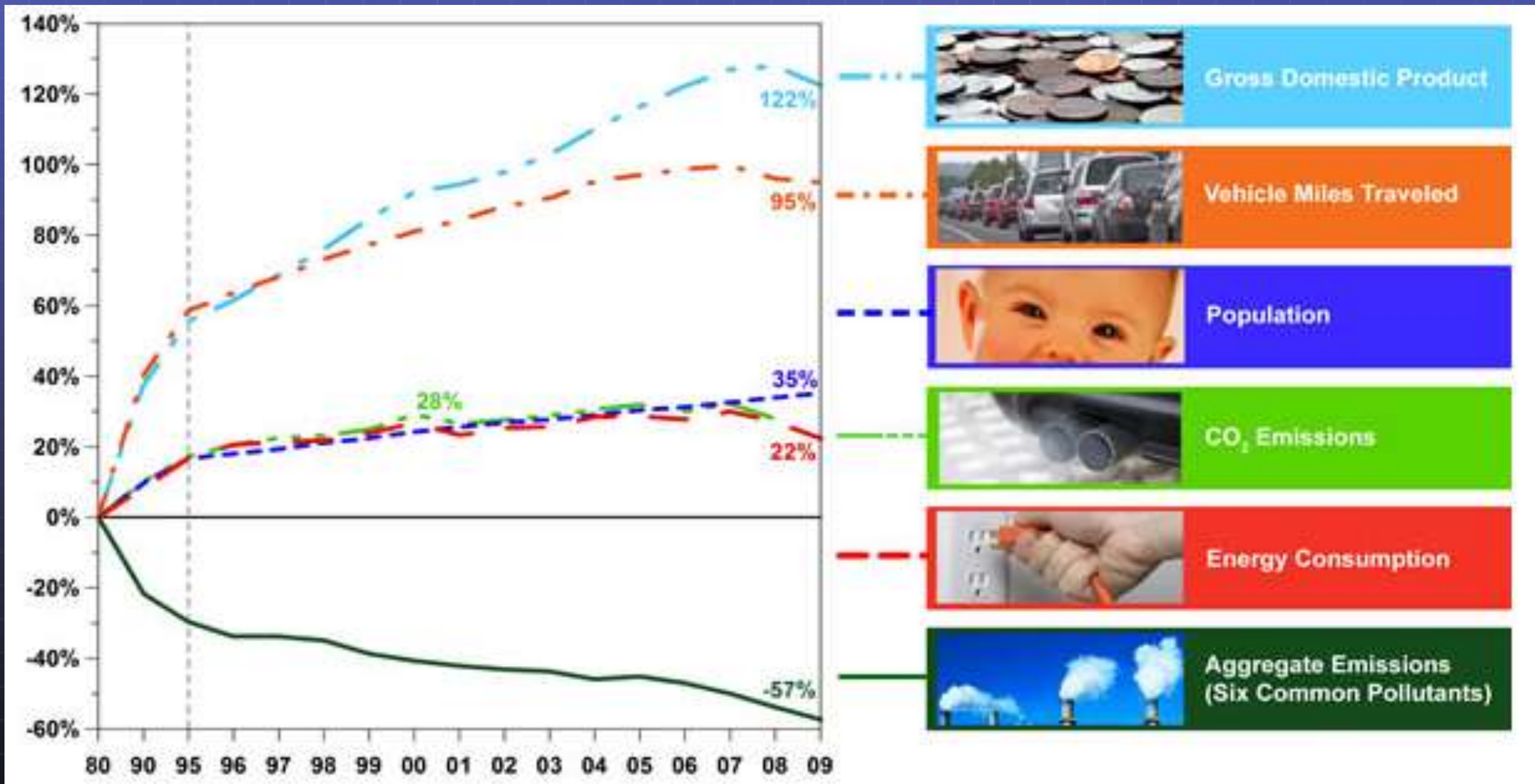


Operations at the Best Possible Efficiency is the Right Thing to do for Two Reasons: Environment Awareness and Cost of Generation

• Boiler air in-leakage	200 Btu/kWhr
• Airflow measurement optimization	50 Btu/kWhr
• Pulverizer performance optimization & fuel line balancing	100 Btu/kWhr
• Reducing pulverizer coal rejects	40 Btu/kWhr
• Reduced carbon in ash	50 Btu/kWhr
• Reduced desuperheating spray flows	50 Btu/kWhr

- Extra 50 MW @ $20/MWh translates to $2 million net power revenues
- 500 MW coal plant operating @ 80% capacity will reduce fuel consumption by 10,000 tons/yr.
- Payback on $5 million investment will take only 2 yrs

Comparison of Growth Areas and Emissions, 1980-2009



Stack emissions since 1970 have been reduced over 77% for the six major pollutants

Thank you very much

Dick Storm

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704-983-2040