Coal to Gas Conversion Advantages

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MHPS Product Lineup

Combined Cycle

Gas Turbines

Steam Turbines

Geothermal

Hydrogen Turbines

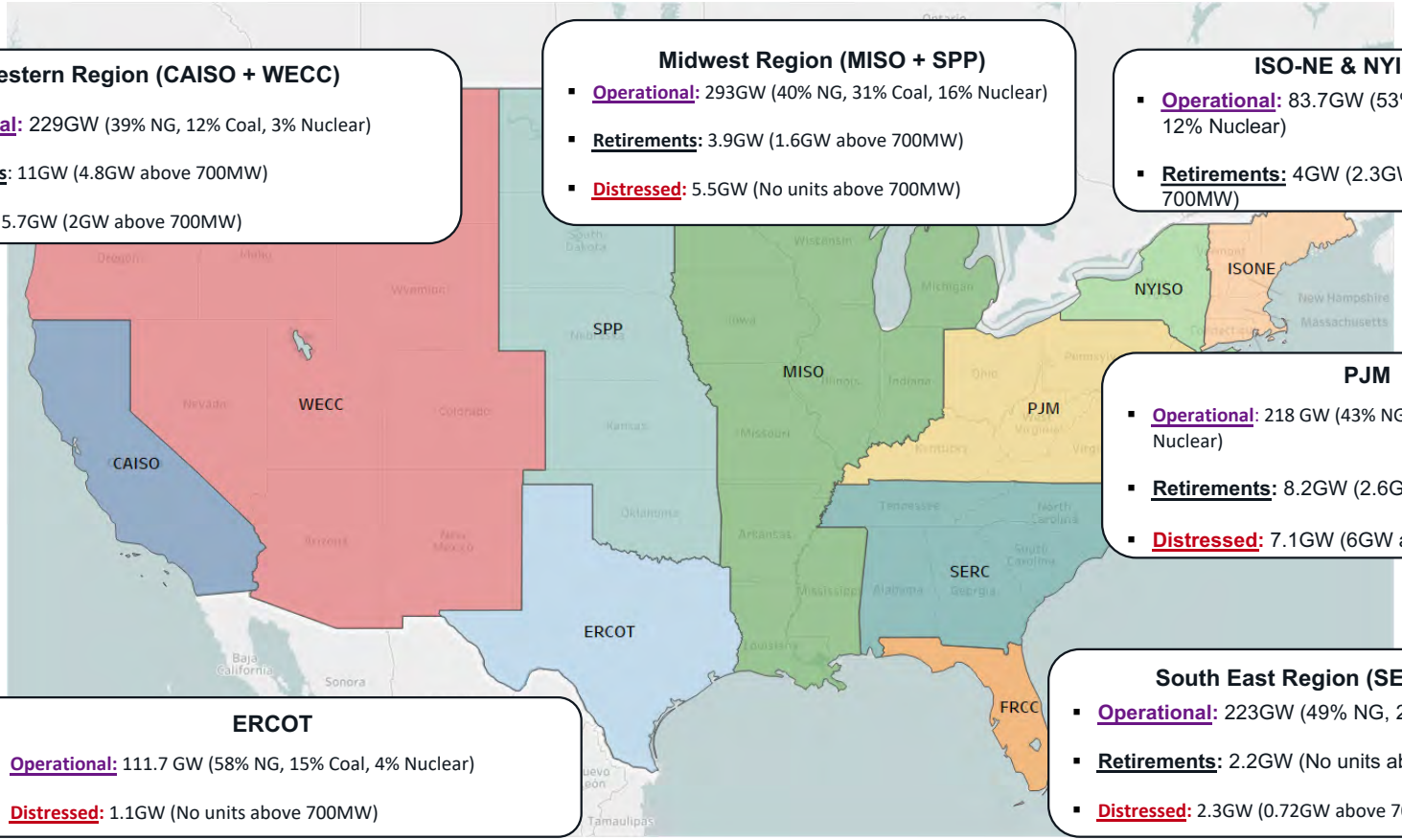
MHPS-TOMONI™ Digital Solutions

IGCC

AQCS

Fuel Conversions

Operating, Retirement, and Distressed Assets (2019-2023)



Western Region (CAISO + WECC)

- **Operational**: 229GW (39% NG, 12% Coal, 3% Nuclear)
- **Retirements**: 11GW (4.8GW above 700MW)
- **Distressed**: 5.7GW (2GW above 700MW)

Midwest Region (MISO + SPP)

- **Operational**: 293GW (40% NG, 31% Coal, 16% Nuclear)
- **Retirements**: 3.9GW (1.6GW above 700MW)
- **Distressed**: 5.5GW (No units above 700MW)

ISO-NE & NYISO

- **Operational**: 83.7GW (53% NG, 3% Coal, 12% Nuclear)
- **Retirements**: 4GW (2.3GW above 700MW)

PJM

- **Operational**: 218 GW (43% NG, 26% Coal, 16% Nuclear)
- **Retirements**: 8.2GW (2.6GW above 700MW)
- **Distressed**: 7.1GW (6GW above 700MW)

ERCOT

- **Operational**: 111.7 GW (58% NG, 15% Coal, 4% Nuclear)
- **Distressed**: 1.1GW (No units above 700MW)

South East Region (SERC + FRCC)

- **Operational**: 223GW (49% NG, 21% Coal, 14% Nuclear)
- **Retirements**: 2.2GW (No units above 700MW)
- **Distressed**: 2.3GW (0.72GW above 700MW)

Units faced with environmental challenges

- **Shut Down the Unit**
  - **Lowest Capital Cost Option**
  - **Eliminate all potential source of generation and potential capacity revenues and must incur de-commissioning cost (Replacement generation cost a possibility)**
- **Install New Combined Cycle**
  - **Minimize emmisions with an efficient generation source burning cheap natural gas**
  - **Very high capital cost ~ $1,250/kw++**
- **Re-power to Combined Cycle**
  - **Same benefits as Combined Cycle but re-using the Steam Turbine if possible**
  - **High Capital cost ~ $1,000/kw++**
- **Install Capital Air Quality Control Systems**
  - **Installing the latest AQCS allows unit to remain operational with most fuel flexibility**
  - **High Capital Costs: FF ~ $40/kw, DryFGD ~ $125/kw, SCR ~ $160/kw, with increased equipment to maintain and manpower**
- **Convert to Natural Gas**
  - **A Low cost option ($26 ~ $65/kw) that eliminates most all Hg, Particulate and Sulfur emissions**
  - **Gas Supply line has to be available to be cost effective and efficiency goes down slightly**

Natural Gas Conversion – Emissions Benefits

Emissions Improvements

- SO_2/SO_3 – none
- Mercury – none
- Particulate – none
- Effluent Wastewater – none
- NOx – reduced
- CO – reduced
- CO2 ~ 45% reduced

Air Quality Controls Avoided

- Flue Gas Desulphurization
- Dry Sorbent Injection
- Activated Carbon Injection
- Calcium Bromide
- Electrostatic Precipitator
- Pulse Jet Fabric Filter
- Selective Catalytic Reducer
- Selective Non-Catalytic Reducer

Due to Emissions reductions, Capital expenditures on AQCS are eliminated

Natural Gas Conversions – Equipment Savings

Reduced O&M Costs

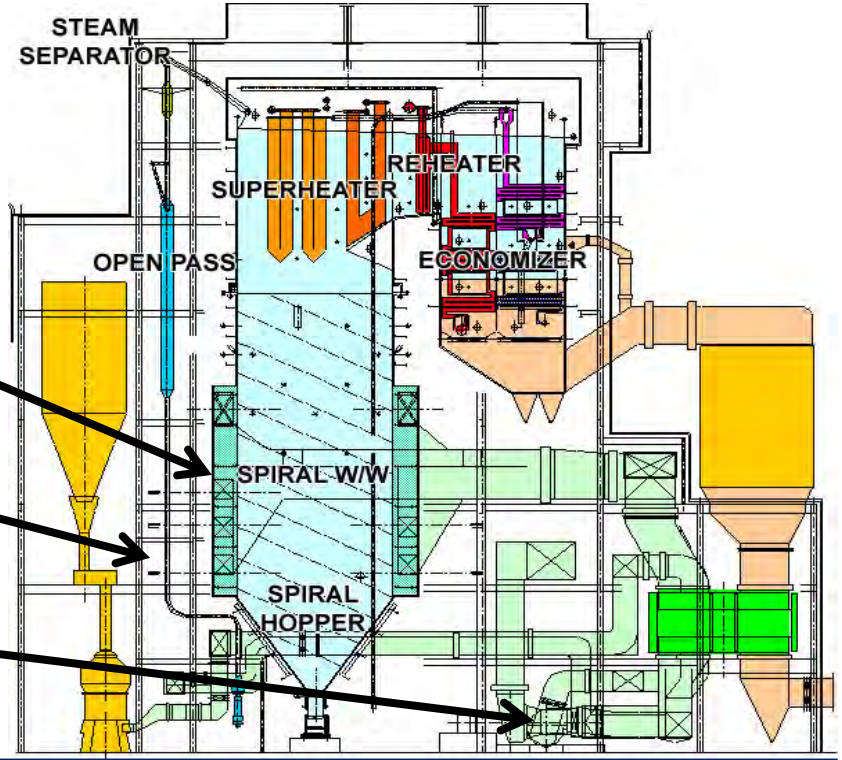
- Air Quality Controls (FGD, SCR, etc.)
- Coal Unloading, Storage & Conveying
- Pulverizer motors
- Primary Air Fans
- Ash Conveying, Sluicing & Disposal
- Sootblowing Equipment, Piping & Controls
- Dust Collection & Suppression
- Boiler Erosion/Corrosion

Cost Savings for Parasitic load, Maintenance and Personnel associated

Gas Conversion Technologies – Design Features

3 Main Components of Gas Conversion:

- Natural Gas Low NOx Burner modification of existing coal burner
- Natural Gas Piping and Control Valve Skids
- Flue Gas Recirculation (If Needed) to raise steam temperature and lower NOx emissions



Cost effectively maintain capacity with minimal modification
EPC Cost Range $30-65/kw

Boiler Capacity and Main Steam Temperature

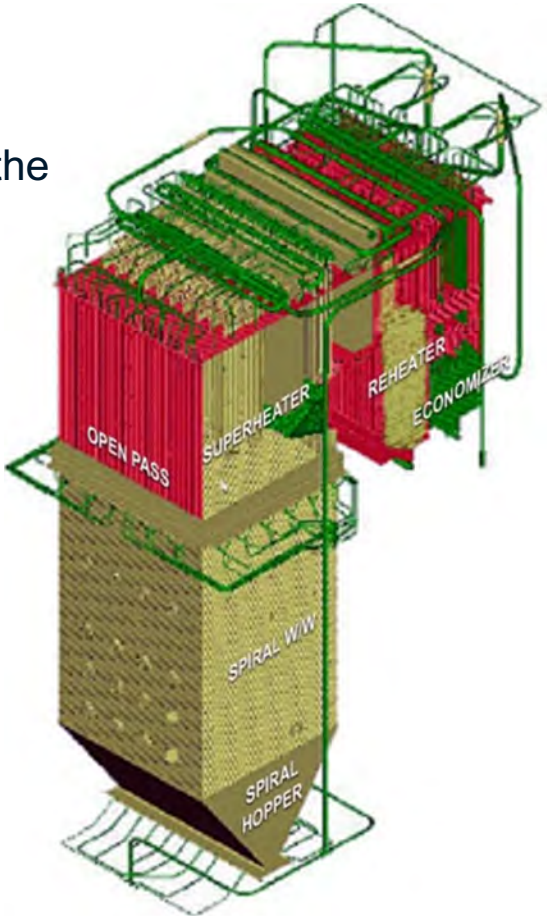
Boilers are sized for specific fuels:

- A Coal Boiler is much larger in size than a Gas Boiler of the same MW Capacity.
- When a Coal Boiler is converted to Gas, challenges are presented with reduced efficiency and elevated steam temperatures. (**due to lower emissivity (radiant) flame characteristic of gas vs. coal.**)
- **As a result, heat transfer is reduced in the furnace and increased in the conversion pass.**

To maintain Boiler Capacity, Firing Rate must be increased

Offsetting Steam Temperature effects can include:

- Decreasing Excess Air
- Adding Gas Recirculation
- Modifying SH/RH Surface



Low NOx Strategies

Reduce NOx/CO Emissions by:

- Utilizing the Latest Generation of Low NOx Burners
  - Multi-Lance Gas Canes (wall-fired)
  - Increase burners quantity to spread flame out (T-fired)
- Adding Over-Fire Air
- Utilize BOOS (Burner out of service)
- Air Heater By-pass
- Adding Gas Recirculation (FGR and IFGR) for NOx Control
- SNCR or SCR

NRG: New Castle Project Objectives

New Castle Units 3 and 4 are both 100 MW units with 12 burners.
Unit 5 is a 142 Net MW unit with 16 burners. 1950's vintage.
The objectives of the project was as follows:

- Achieve a NOx emission level of 0.15 lb/mmBtu firing on Natural Gas
- Supply and install Flue Gas Recirculation System (FGR)
- Maintain Full Capacity
- No Metals Upgrades
- Thermal Guarantees:
  - Main Steam Flow
  - Main Steam Temperature
  - Hot Re-Heat Temperature
  - Main Steam Pressure
  - Boiler Efficiency

MHPSA Gas Conversions - Schedule

New Castle Project	LNTP & Engineering Release	Dec.16, 2014		Pre-outage included installation of valve skids, gas piping, GR fans and ductwork.
	Mobilization & Pre-Outage	Nov.1, 2015		
	Gas Piping Delivery	Nov.27, 2015 – Dec.24, 2015		
	PRV/FCV Valve Skid Delivery	Dec. 2015 – Feb. 2016		
	GR Fan Delivery	Dec.15, 2016		
NC 3	Outage Tie-in	Mar.1 - 31, 2016	31 days	
	Commissioning	Apr.1 – 20, 2016	20 days	10 days ahead of schedule
NC 4	Outage Tie-in	Mar.15 – Apr.15, 2016	32 days	
	Commissioning	April 16 – May 5, 2016	20 days	10 days ahead of schedule
NC 5	Outage Tie-in	April 1 – 30, 2016	30 days	
	Commissioning	May 1 – 12, 2016	12 days	18 days ahead of schedule

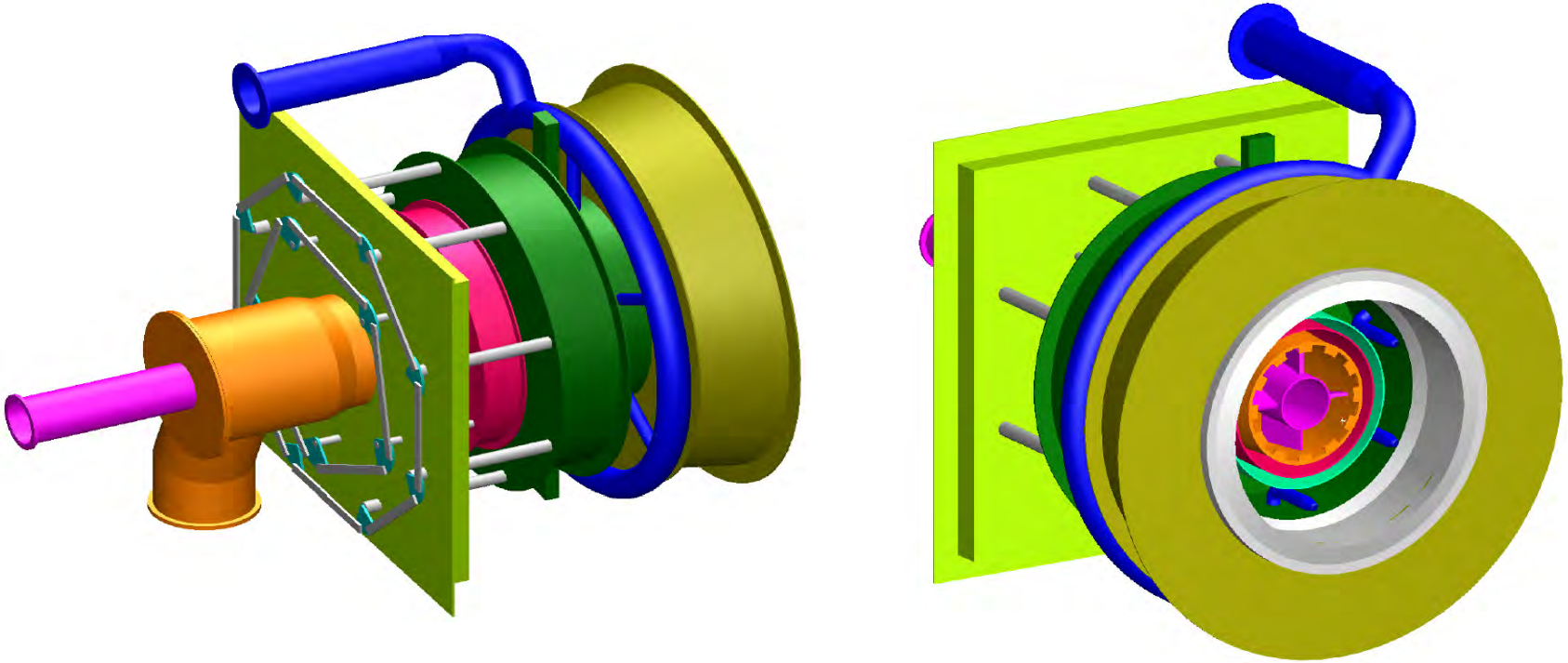
15 Months from LNTP to start of the first outage

New Castle Burner Front

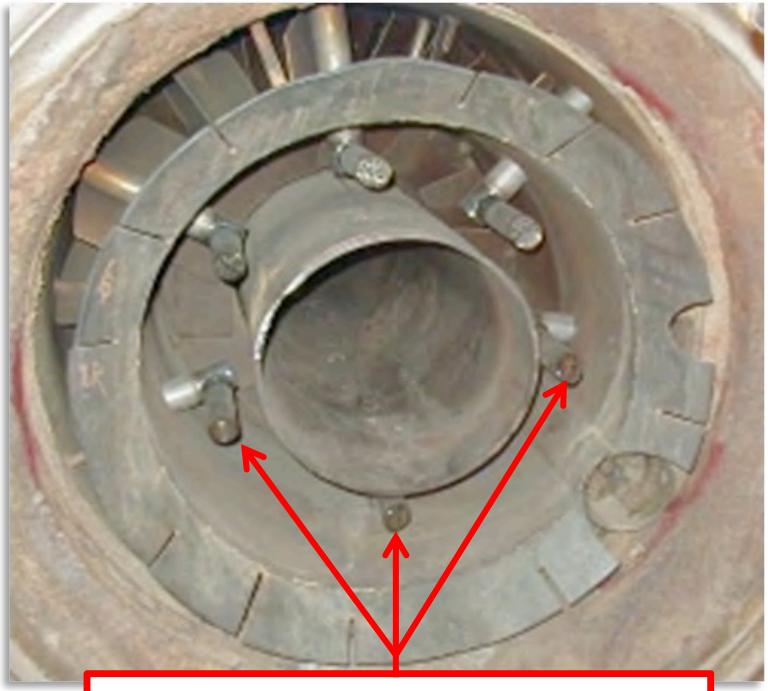
Existing Coal Burner

Coal Burner Retrofit with Full Load Gas Canes

Ring Header inside Windbox



Coal Burner Retrofit with Full Load Gas Canes

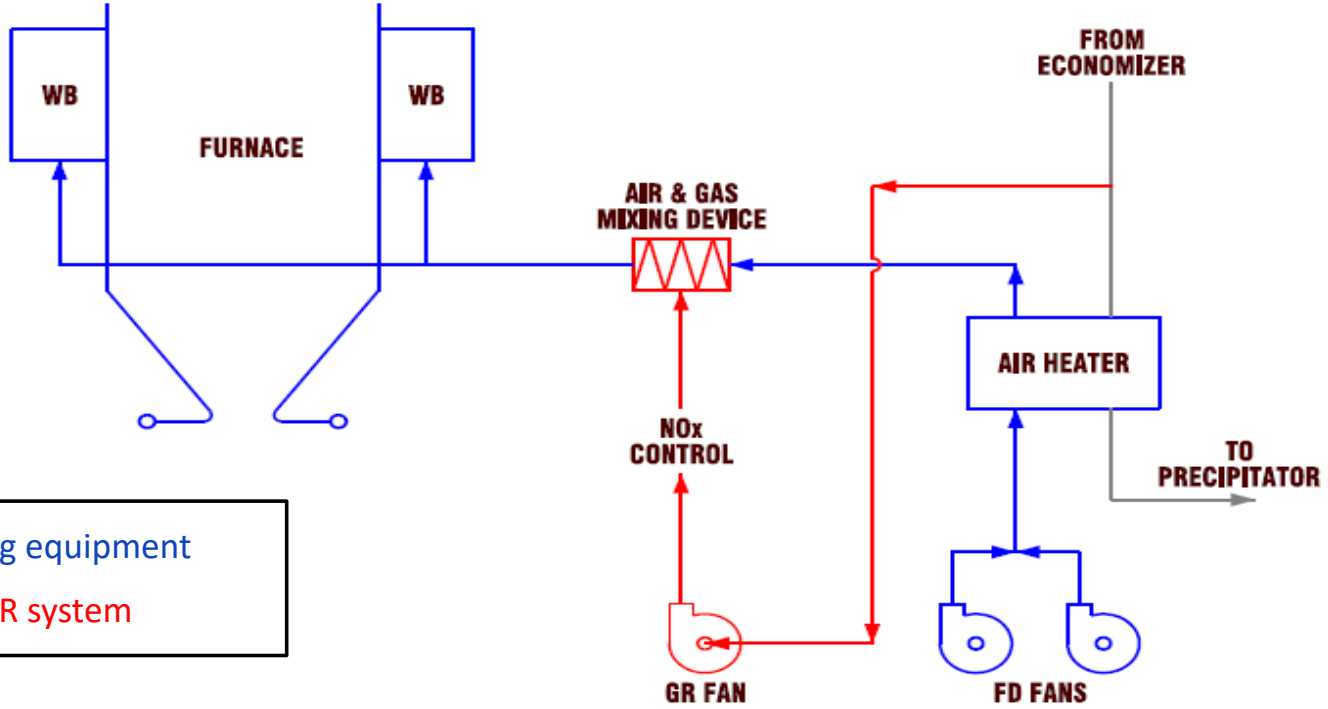


Gas Spuds Inserted into Burner

New Gas Spud

Minimal modification, dual-fired capability

Flue Gas Recirculation (FGR) – New Castle

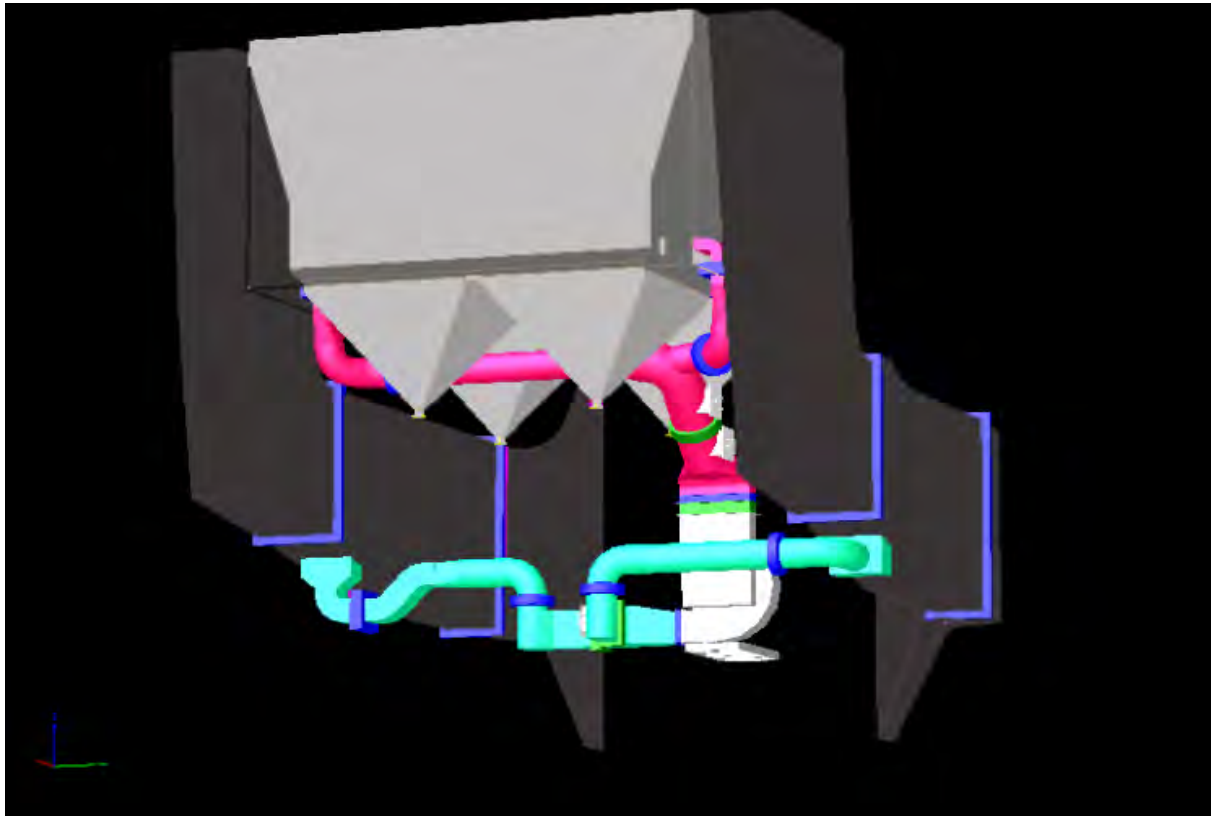


BLUE is existing equipment

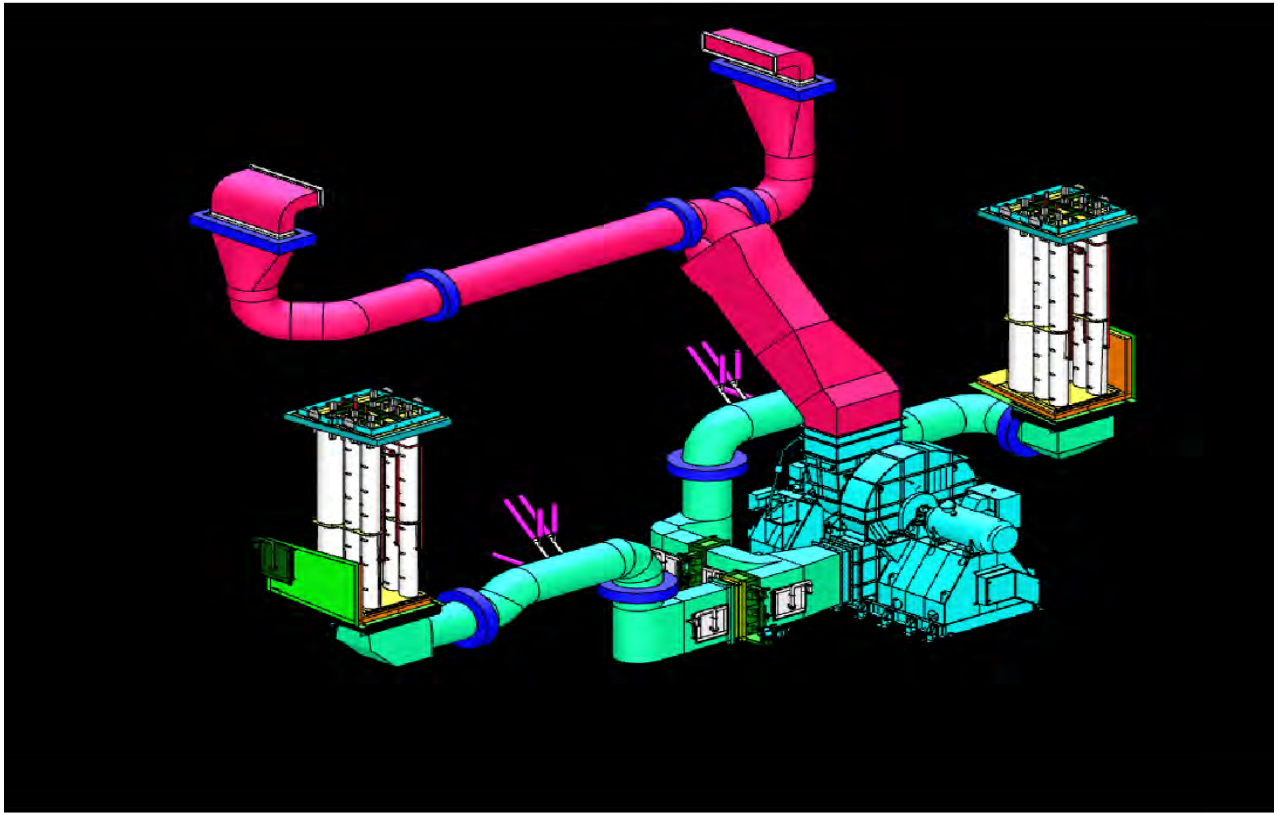
RED is new FGR system

FGR can meet stringent NO_x limitations and maximize boiler output

FGR Fan, Ductwork & Mixers for Customer New Castle 3&4



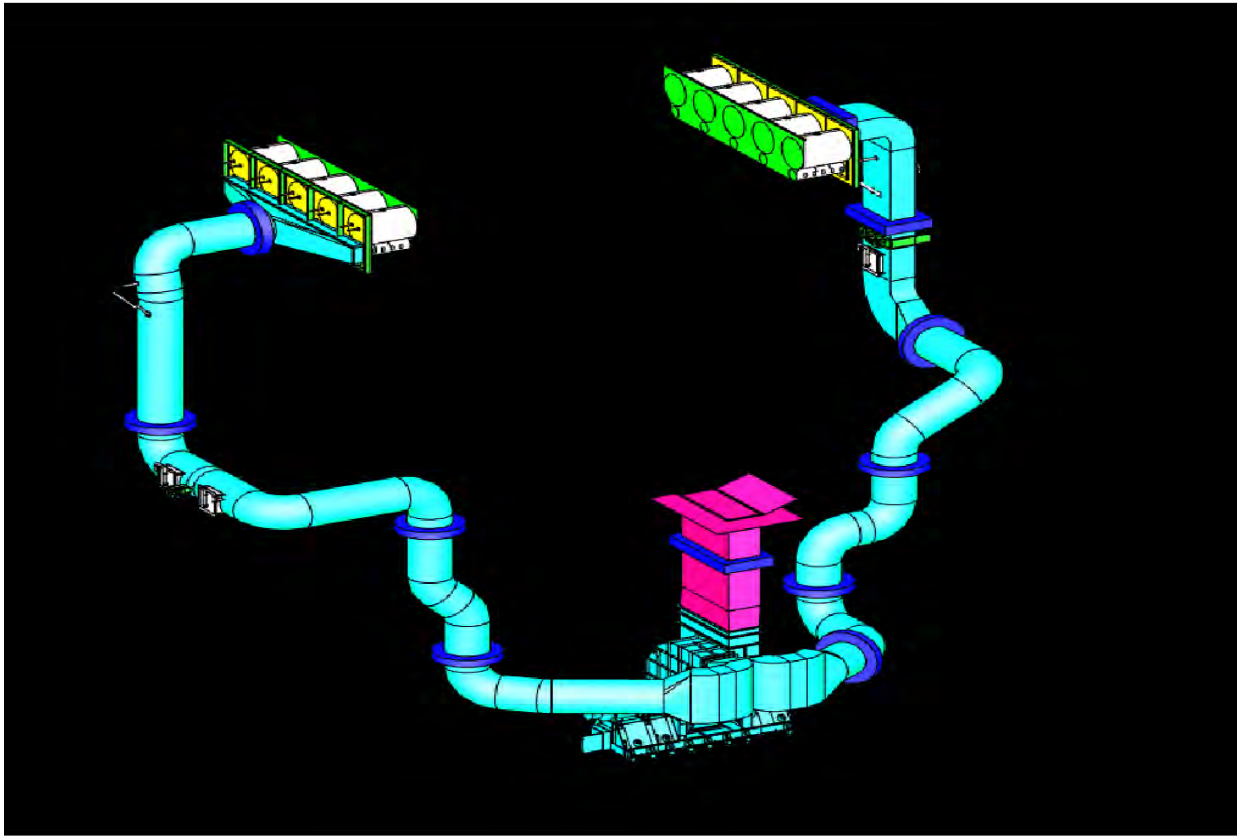
FGR Fan, Ductwork & Mixers for Customer New Castle 3&4



Flue Gas Recirculation Fan Installation for New Castle

Flue Gas Recirculation Ductwork Installation for New Castle

FGR Fan, Ductwork & Mixers for Customer New Castle 5



Gas Conversion Results

NRG	New Castle 3			New Castle 4			New Castle 5		
	Coal	Gas	Change	Coal	Gas	Change	Coal	Gas	Change
MW	92	95	↑3	91	94	↑3	142	149	↑7
Boiler Efficiency (%)*	86.70	83.78	↓2.92	86.20	84.22	↓1.98	87.14	84.69	↓2.43
SO_2 (lbs/mmBtu)	2.31	0	↓100%	2.23	0	↓100%	2.34	0	↓100%
Mercury (ppm)	0.12	0	↓100%	0.12	0	↓100%	0.12	0	↓100%
NOx (lbs/mmBtu)	0.35	0.09	↓74%	0.28	0.09	↓68%	0.47	0.10	↓78%
CO (ppm)	634	55	↓91%	2533	54	↓98%	430	48	↓89%
CO_2 (lbs/mmBtu)	205	127	↓38%	205	127	↓38%	205	127	↓38%

*Parasitic load savings (approximately 1-1.5%) not taken into account

18k Boilermaker hours
16k Pipefitter hours

Drastic emissions reductions with only minor efficiency loss

NRG: Joliet Station – Project Objectives

Joliet Units 7 & 8: 580 MW units with 32 Burners each. 1960's Vintage.

The objectives of the project was as follows:

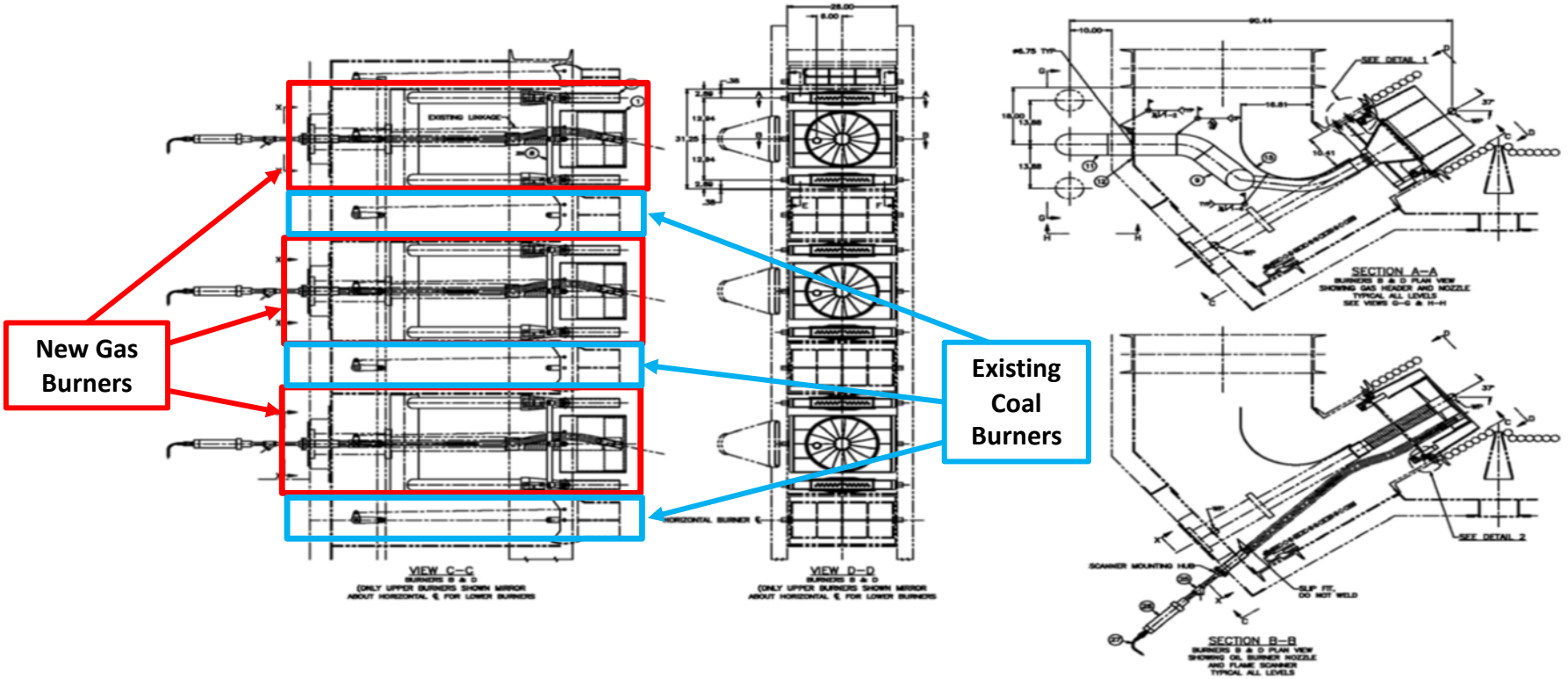
- Emissions guarantees
  - Achieve NOx, CO and VOC emissions at 5% Excess Oxygen across load conditions of 25% to 100%.
- Boiler Heat Input
- Maintain Full Capacity
- No Metals Upgrade

MHPSA Gas Conversions - Schedule

	Milestone/Activity	Schedule	Duration	Remarks
Joliet	Contract & Engineering Release	Mar.31, 2015		Pre-outage included scaffolding and installation of valve skids.
	Mobilization & Pre-Outage	Oct.1, 2015		
	Gas Piping Delivery	Dec.9, 2015 – Feb.2, 2016		
	PRV/FCV Valve Skid Delivery	Dec.16, 2015 – Feb.6, 2016		
J 7	Outage Tie-in	Mar.19 – Apr.30, 2016	43 days	Commissioning period for both units was extended due to Gas Supply difficulties.
	Commissioning	May 1 – 20, 2016	20 days	
J 8	Outage Tie-in	Mar.8 – May 6, 2016	60 days	Unit 8 outage was longer due to the Turbine Overhaul by others.
	Commissioning	May 7 – Jun.20, 2016	45 days	

Less than 12 months from LNTP to start of first outage

Burner Retrofit for T-fired Boilers

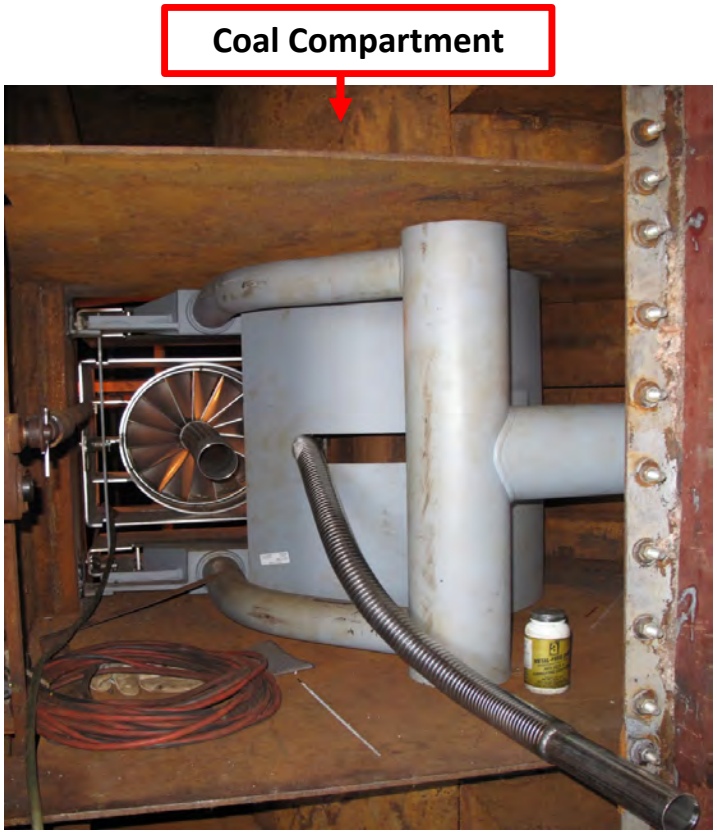


Coal Burner Retrofit for T-fired Boilers

New Gas Burners

Minimal modification, dual-fired capability

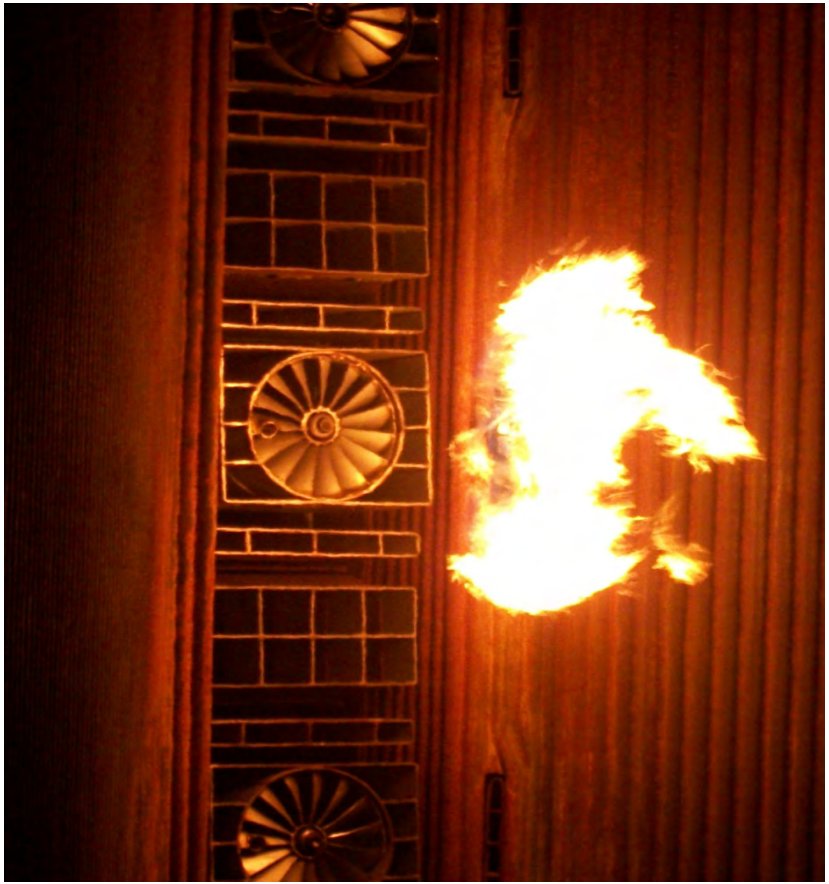
Coal Burner Retrofit for T-fired Boilers



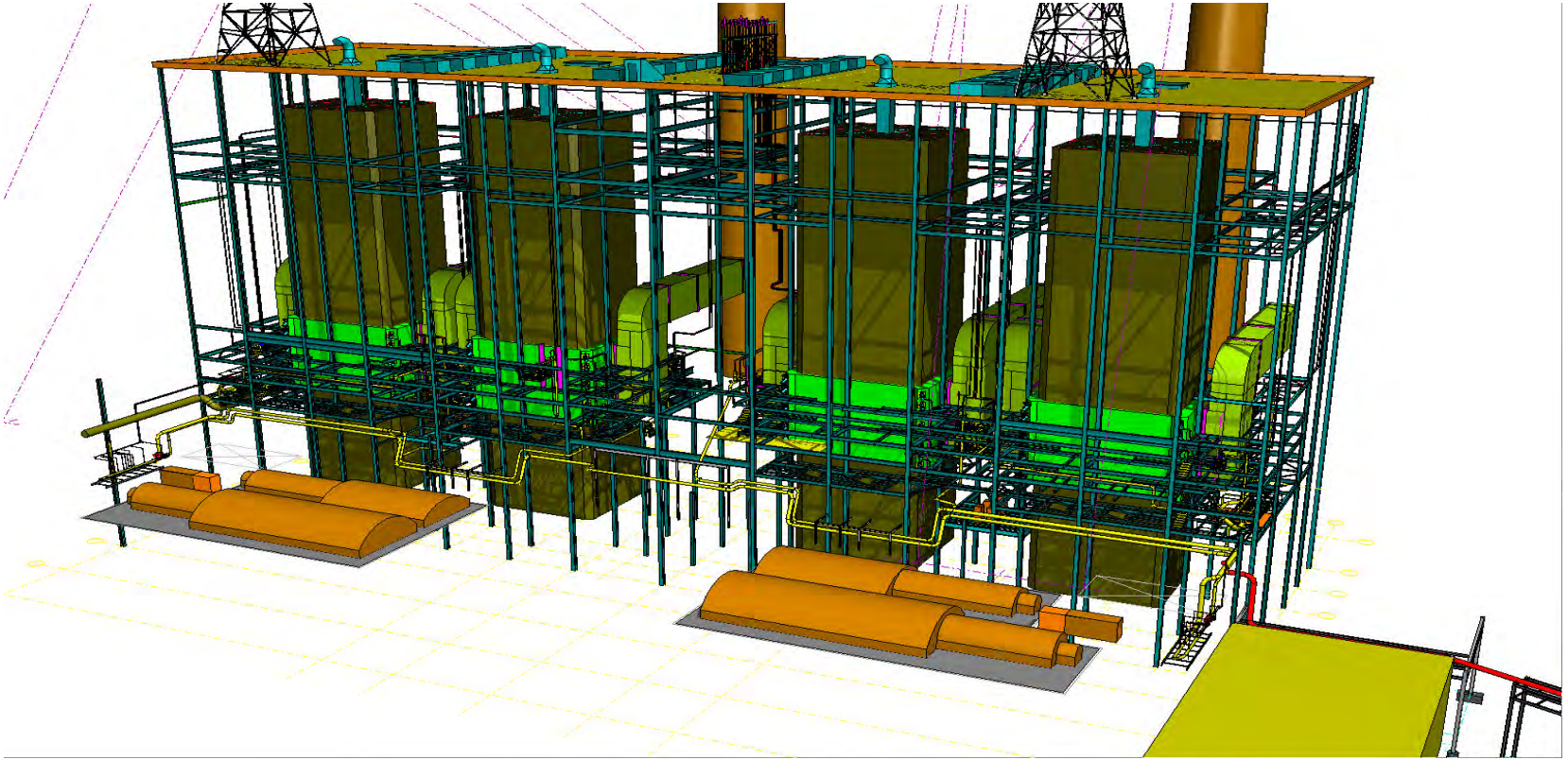
T-Fired Burner Components (Rear)

Windbox Cover Plate

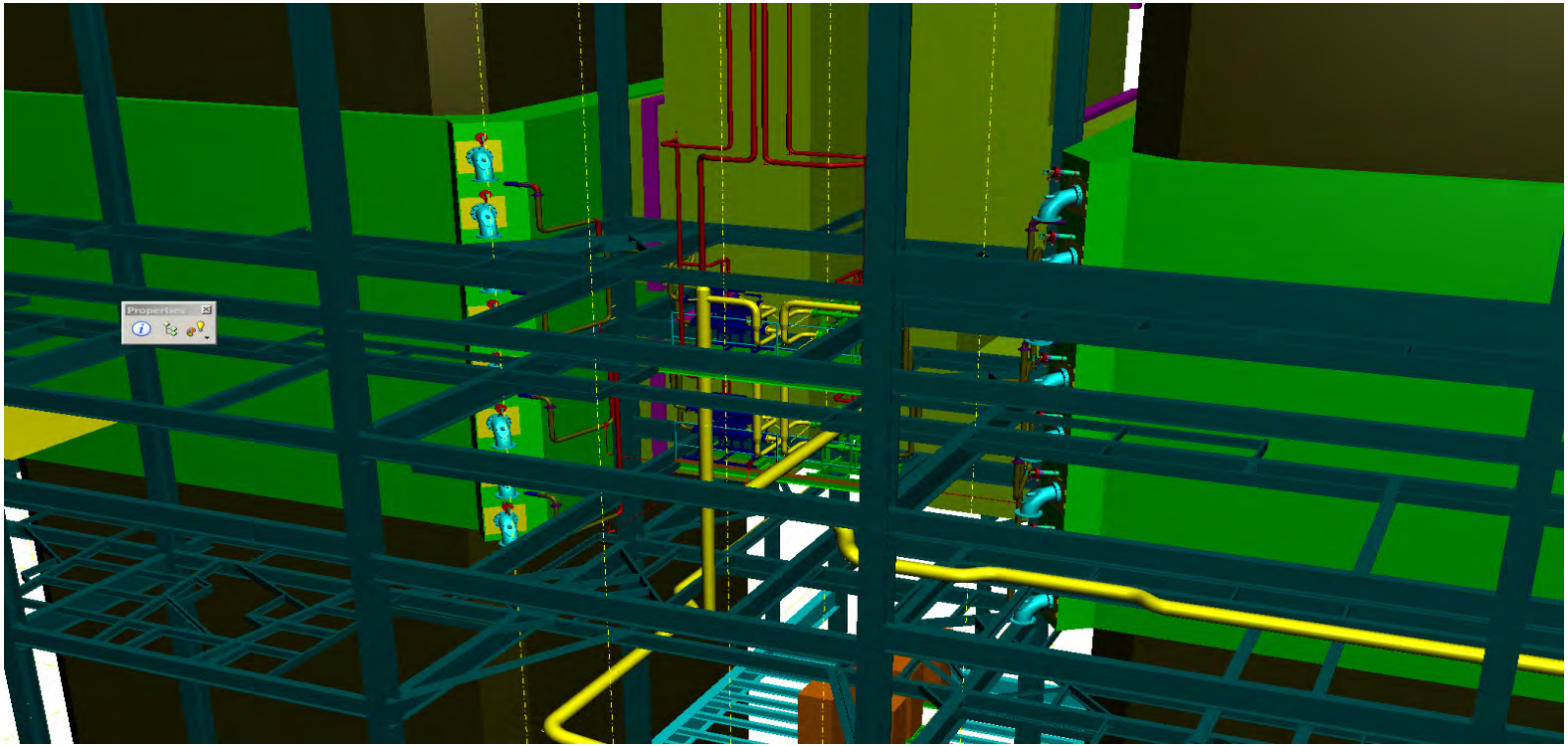
Burner Retrofit for T-fired Boilers



Boiler Overview with Gas Piping



Supply Piping between Furnaces



FCV/PRV Skid Installation for Joliet

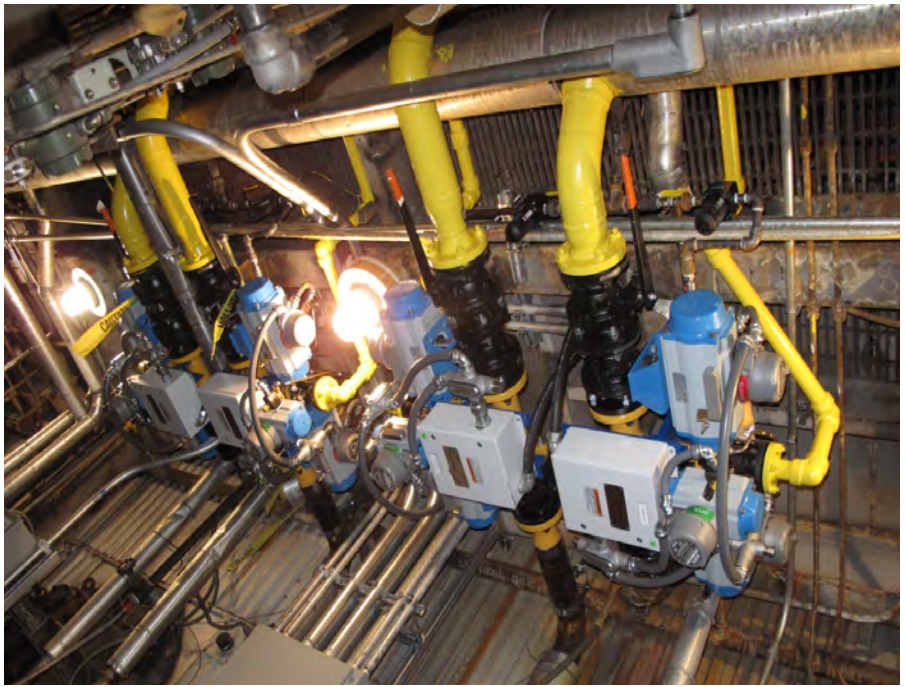
Natural Gas Piping Installation for Joliet

Scope of Supply - Natural Gas System

PRV/FCV Skid Example

Scope of Supply - Natural Gas System

Double Block & Bleed Valve Rack Examples



Gas Vent Piping

Gas Vent Piping

Gas Vent Piping

Gas Conversion Results

NRG	Joliet 7			Joliet 8		
	Coal	Gas	Change	Coal	Gas	Change
MW	525	561	↑36	525	566	↑41
Boiler Efficiency (%)*	85.14	83.80	↓1.24	85.19	83.95	↓1.24
SO_2 (lbs/mmBtu)	0.39	0	↓100%	0.40	0	↓100%
Mercury (ppm)	0.07	0	↓100%	0.07	0	↓100%
NOx (lbs/mmBtu)	0.10	0.07	↓30%	0.12	0.08	↓33%
CO (ppm)	1226	30	↓98%	1092	21	↓98%
CO_2 (lbs/MW)	1959	1122	↓43%	1959	1122	↓43%

*Parasitic load savings (approximately 1-1.5%) not taken into account

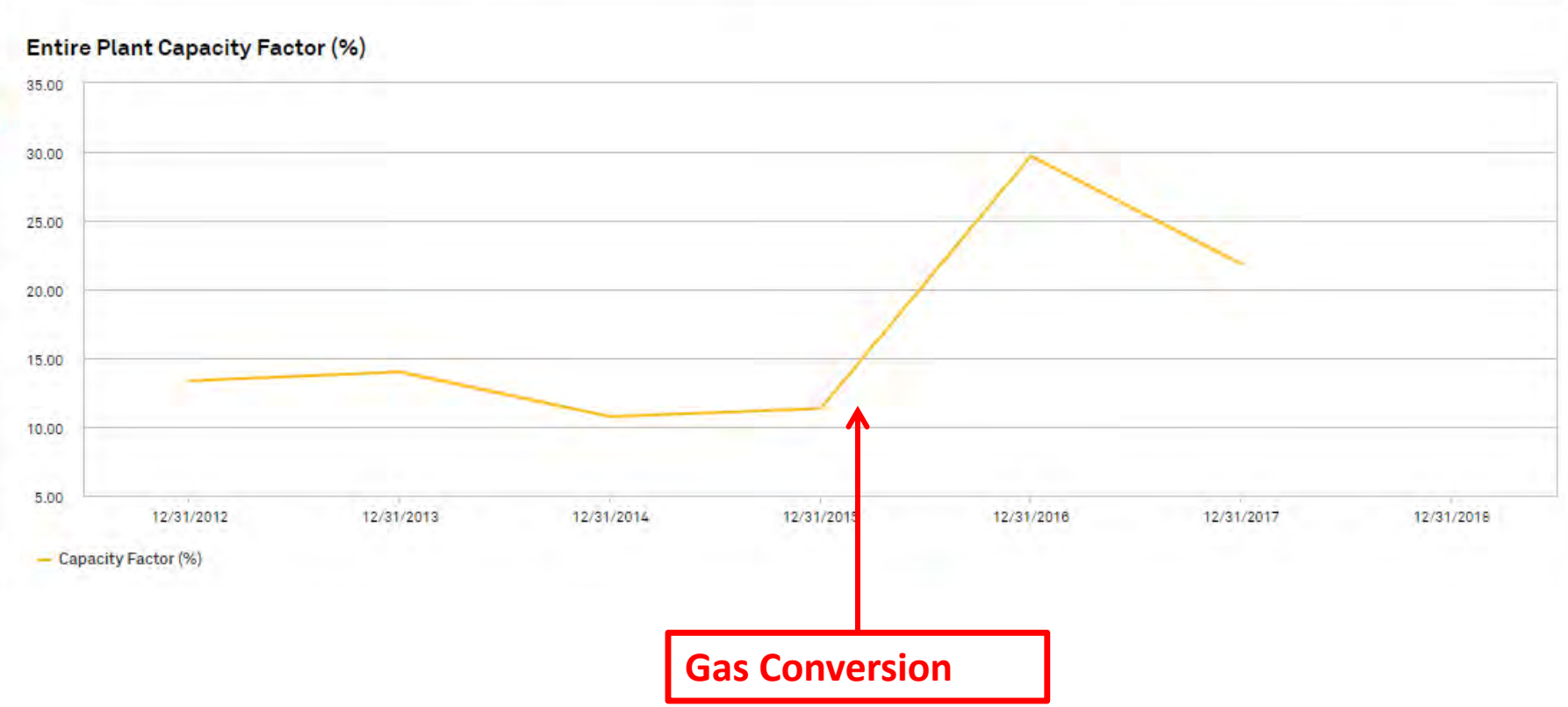
40k Boilermaker hours
64k Pipefitter hours

Drastic emissions reductions with virtually no net efficiency loss

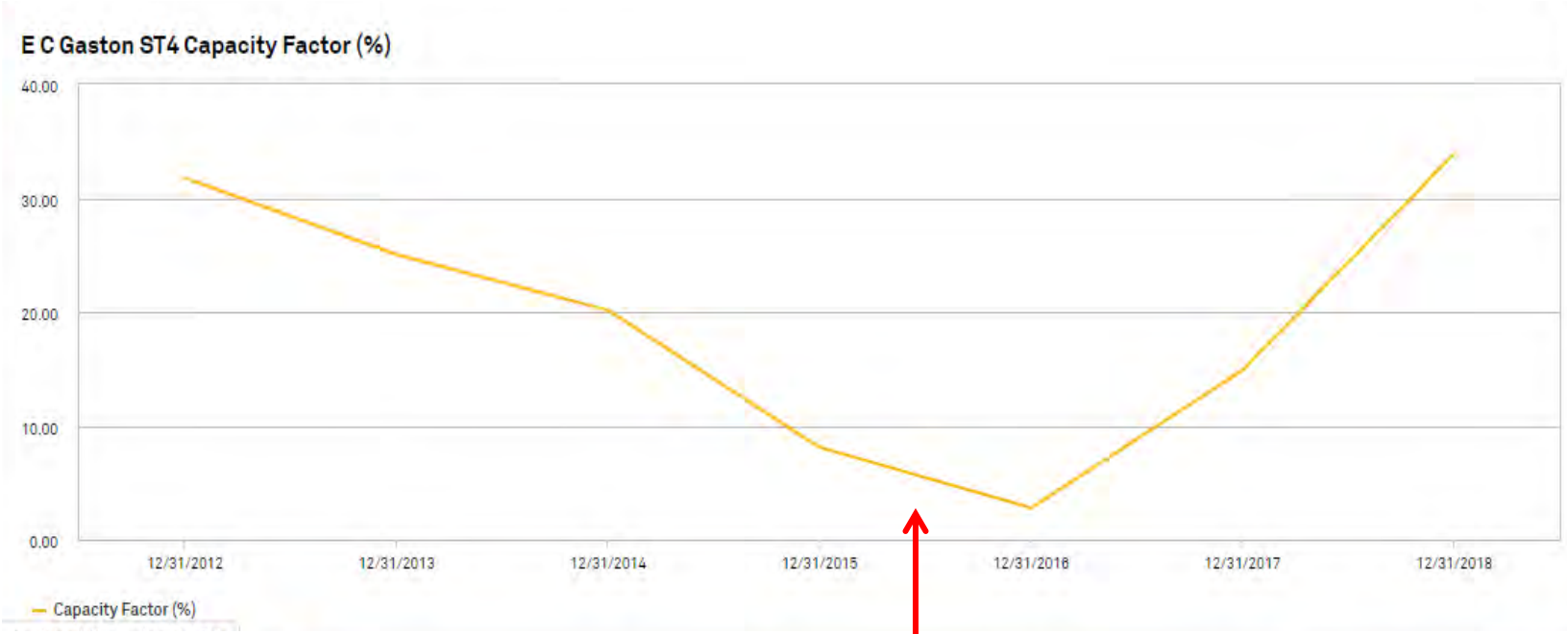
Gas Conversion Market Summary

Utility	Station	Boiler Firing Type	Unit	Total MWs
NRG	Joliet	Wall & Tangential	6 – 8	1680
PPL	Brunner Island	Tangential	1 – 3	1559
Southern Company	Gaston	Wall	1 – 4	1061
OG&E	Muskogee	Tangential	4 & 5	960
Southern Company	Yates	Tangential	6 & 7	807
IPL	Harding Street	Tangential	5 – 7	698
NRG	Big Cajun	Wall	2	626
NRG	Shawville	Wall & Tangential	1 – 4	626
Southern Company	Greene County	Wall	1 & 2	568
Nextera	Crist	Wall	6 & 7	550
AEP	Clinch River	Wall	1 & 2	475
NRG	New Castle	Wall	3 – 5	348
AEP	Big Sandy	Wall	1	281
DTE	Trenton Channel	Tangential	7 & 8	240
Duke	Lee	Tangential	3	175
TOTALS	16		35	~10,500

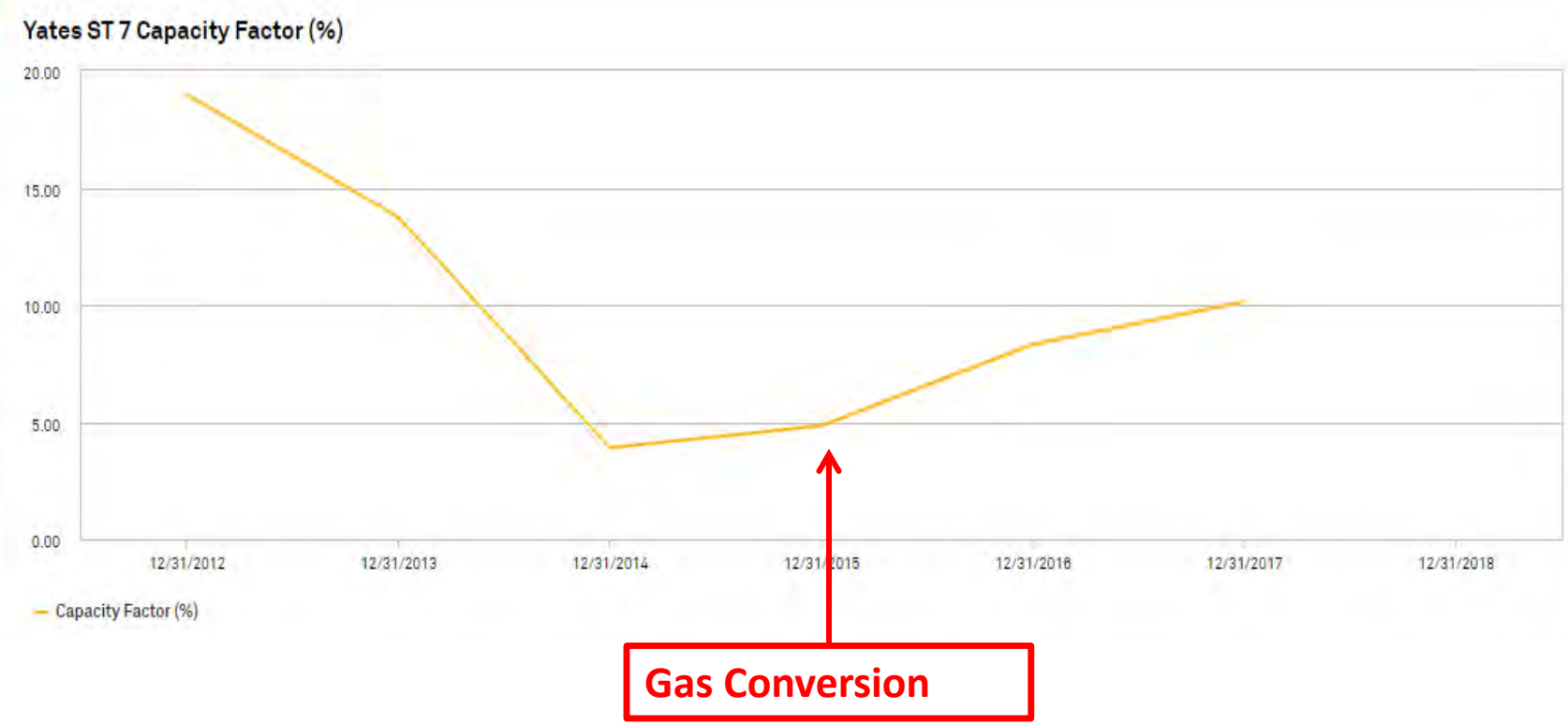
NRG - New Castle 3-5 (342MW)



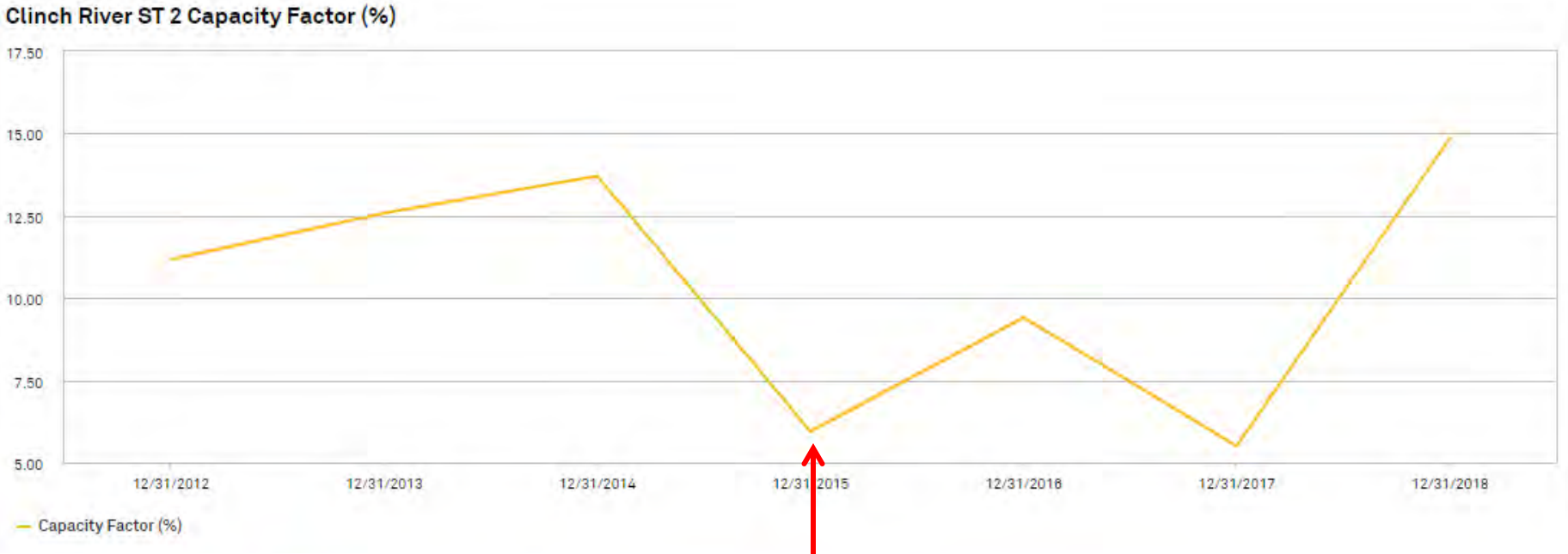
Southern Company - Gaston Plant # 4 (245 MW)



Southern Company – Yates #7 (404 MW)

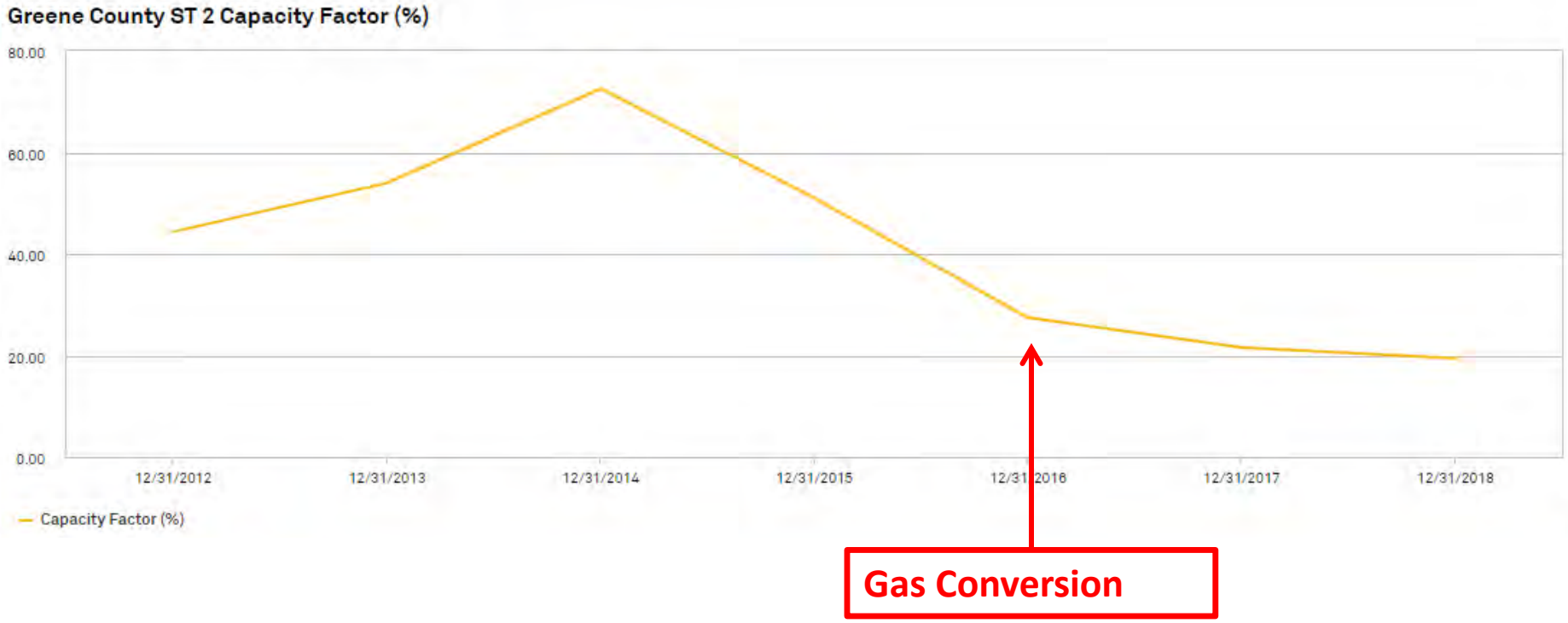


AEP – Clinch River #2 (238MW)

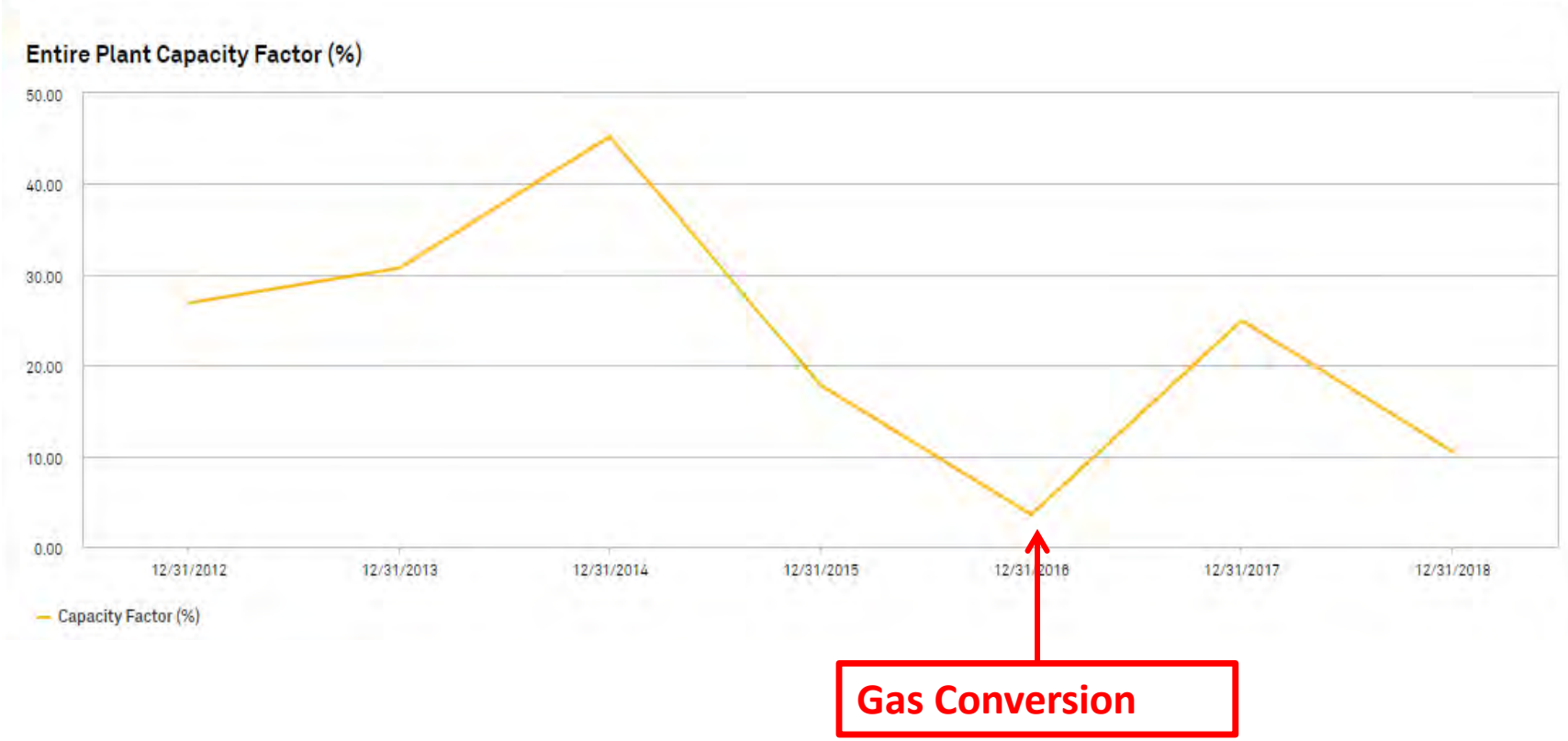


Gas Conversion

Southern Company – Greene #2 (299MW)



NRG – Shawville 1-4 (590MW)



Summary

- Drastically minimize or eliminate all air emissions
- Can maintain dual firing capability (oil and gas) at no additional cost
- Low capital investment cost of $30-65/kW USD
- Can maintain full capacity with minimal efficiency impact
- Can take advantage of lowest ever natural gas prices for fuel source (Up to 20% lower)
- Lower O&M costs, reduce manpower, and increase boiler reliability (55% less workers)

Burning clean natural gas is a low cost option for your existing coal unit

PSEG – Hudson Station (1020 MW)…….retired 2017

Power for a Brighter Future