NATIONAL ENERGY TECHNOLOGY LABORATORY

2011 Pittsburgh Coal Conference

Circulating Fluidized Bed Combustion as a Near-Term CO_2 Mitigation Strategy

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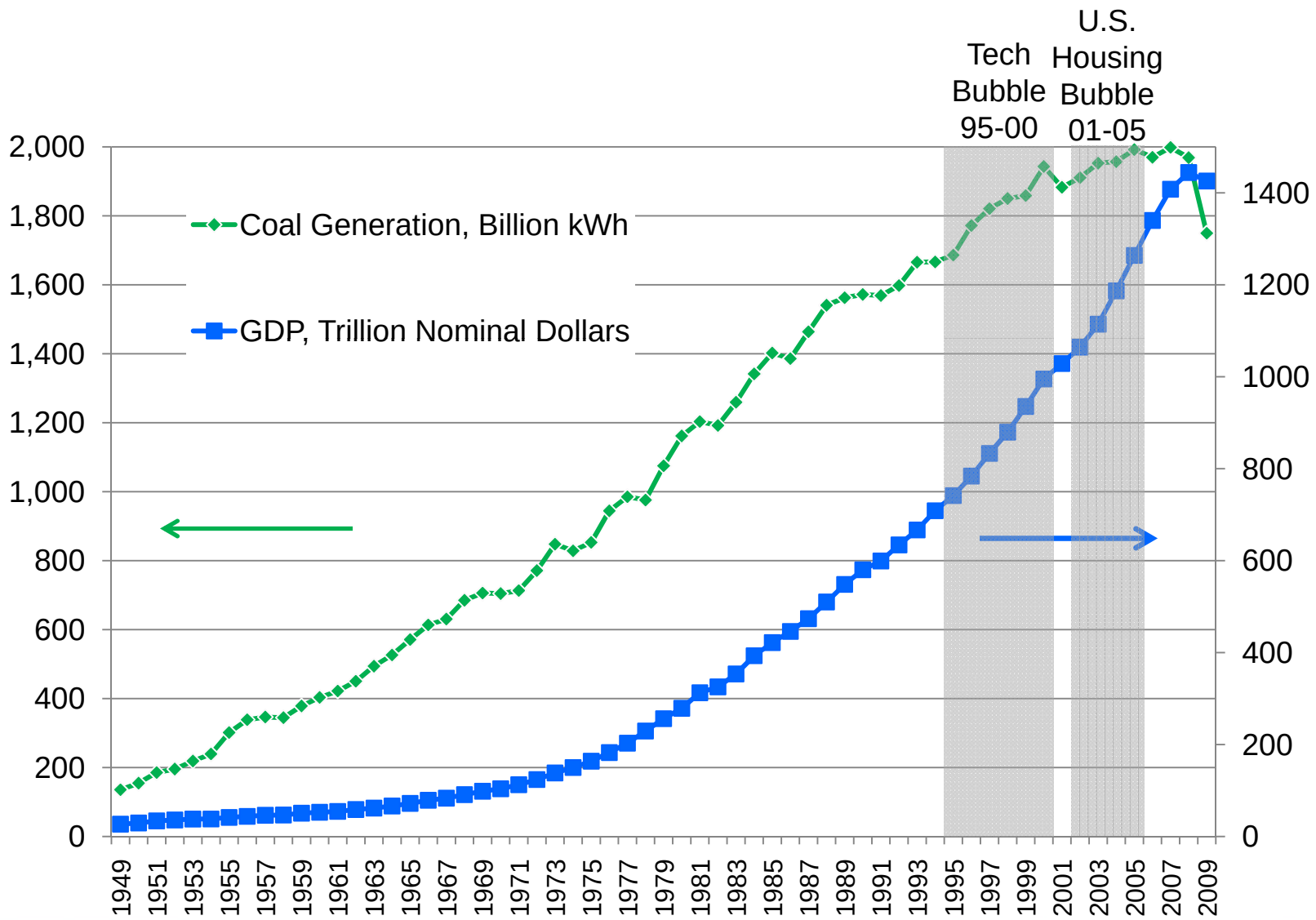
U.S. DEPARTMENT OF ENERGY

Overview

- **Inexpensive coal power has helped fuel America's industrial growth since 1950, and needs to play a key role in the current recovery**
- **Circulating Fluidized Beds (CFB) are a coal technology that can compete in the current regulatory climate**
  - Single best performing source for Hg is CFB
- **The fuel-flexibility of a CFB allows for co-feeding biomass, which can help reduce CO_2 emissions in the near-term**
- **Building CO_2 capture-ready CFB's can help ease integration of full scale CCUS in the long-term**

Energy Consumption and U.S. GDP

U.S. Economic Prosperity Strongly Linked to Coal Generation



American Prosperity: Past, Present and Future

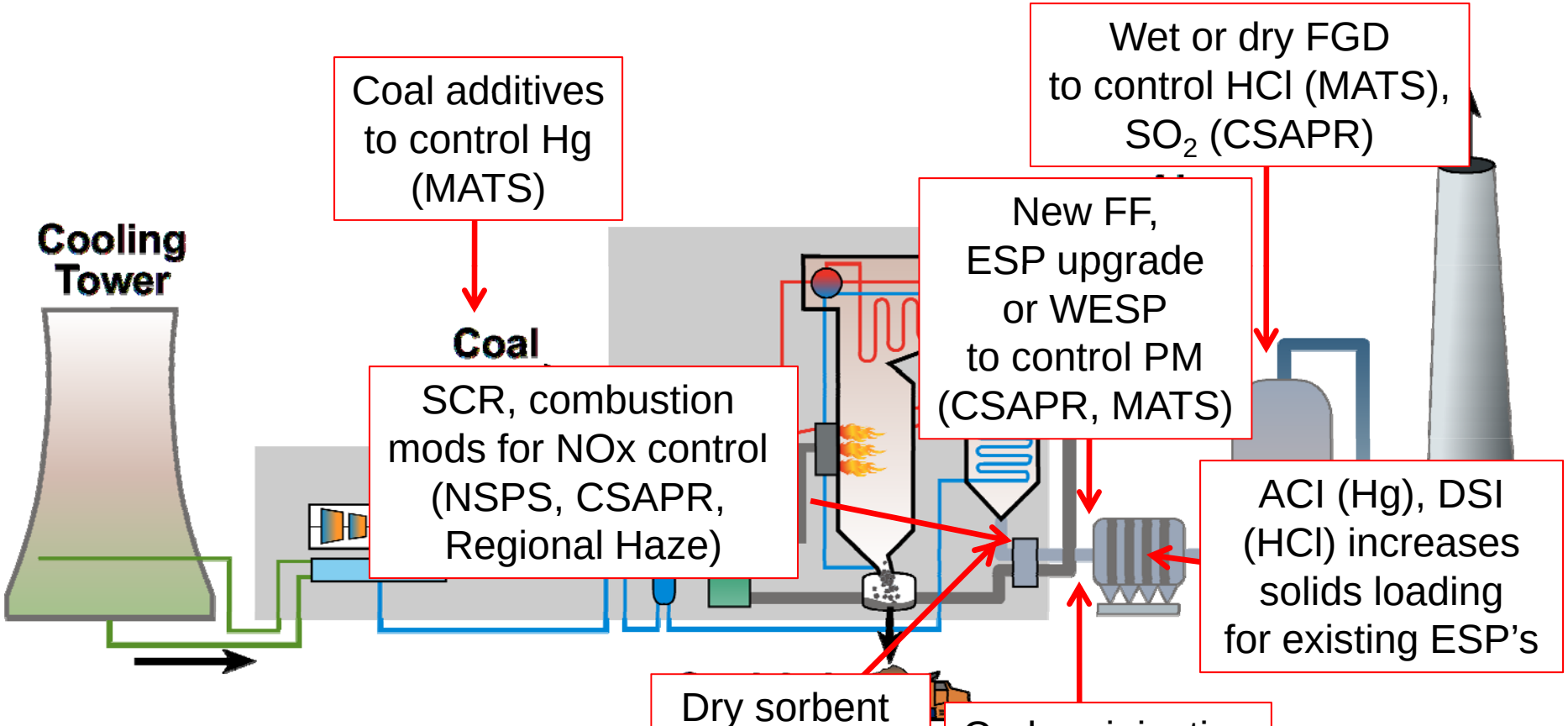
Coal power was the backbone of growth since 1950 and needs to play a critical role in current recovery

- ***"If we want a robust, growing economy, we need a robust, growing manufacturing sector."* – President Obama at a speech in Pittsburgh, June 24, 2011**
- **Coal plants of America's future need to:**
  1. Meet stringent air quality rules in the near term
  2. Be built with future installation of CCUS[1] in mind (capture ready) to deal with gradual tightening of CO_2 emissions

1. CCUS – Carbon Capture, Utilization, and Storage

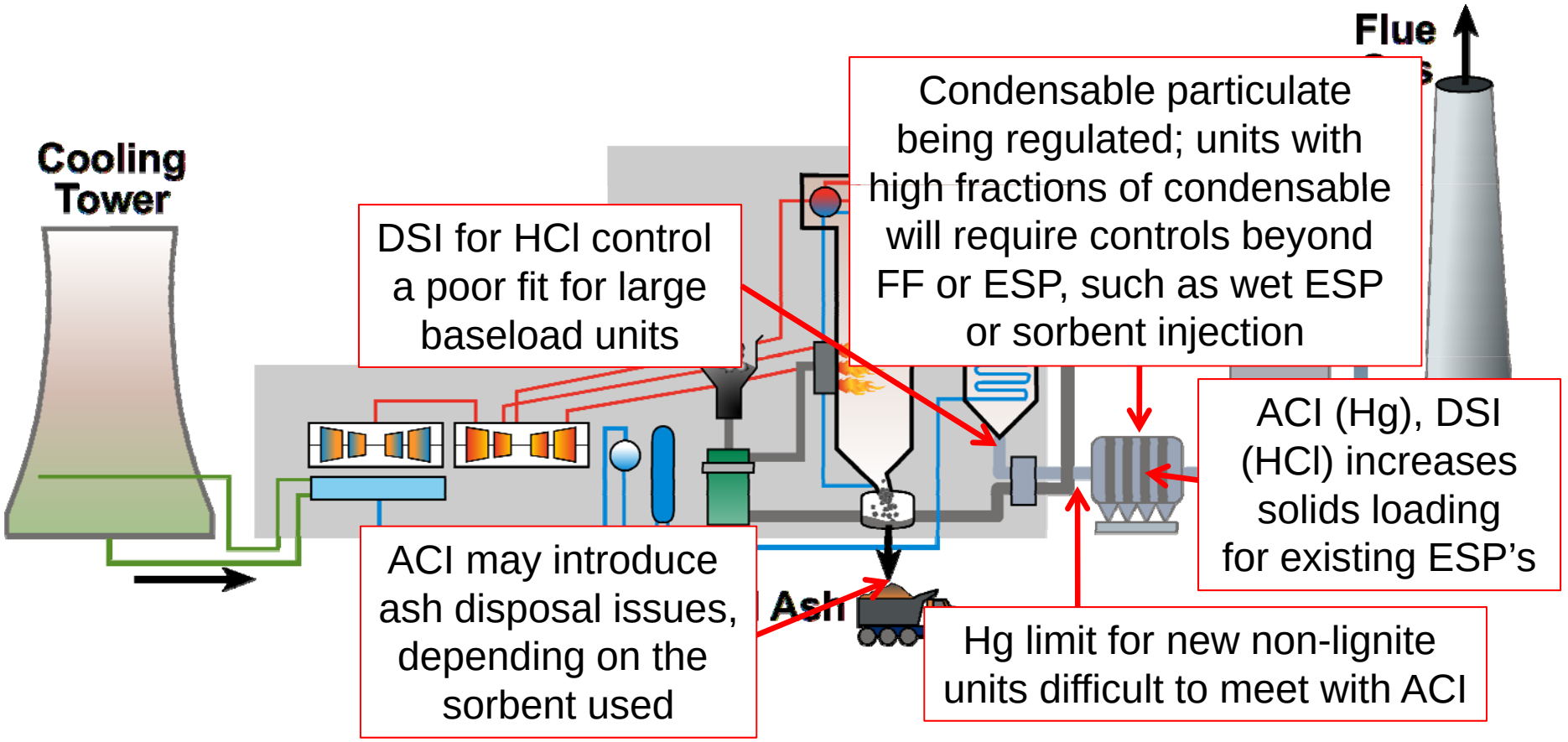
Pulverized Coal Power Plant

Air Quality Regulations: Compliance



Pulverized Coal Power Plant

Air Quality Regulations: Key Issues



Greenhouse Gas New Source Performance Standard

What will the GHG NSPS look like?

- **Initially, efficiency improvements/best practices likely to suffice**
  - *"PSD and Title V Permitting Guidance for Greenhouse Gases,"* EPA, March 2011 identifies efficiency improvements as an acceptable CO_2 mitigation strategy
  - Examples: Increased air heater, condenser surface area; improvements in turbine performance
- **Eventually, CCUS expected to become Best Available Control Technology**
- **Focus of CCUS RD&D includes facilitation of *"widespread cost-effective deployment after 2020*"***
- **Solution: CO_2 capture-ready circulating fluidized beds, *that can co-feed biomass***

*"Report of the Interagency Task Force on Carbon Capture and Storage," August 2010

Case Study: Recently Permitted Coal Units

Consider the emission control systems on recently permitted units…

	Nameplate Capacity (MW)	Technology	SO_2 Control	NOx	Particulate
Prairie State Supercritical	2 x 800	Pulverized Coal	Wet FGD	SCR/Low NOx Burner	ESP, Wet ESP
Trimble County Supercritical	834	Pulverized Coal	Wet FGD	SCR/Low NOx Burner	Baghouse, Wet ESP
Longview Supercritical	808	Circulating Fluidized Bed	Wet FGD	SCR	Baghouse, Wet ESP

Case Study: Recently Permitted Coal Units

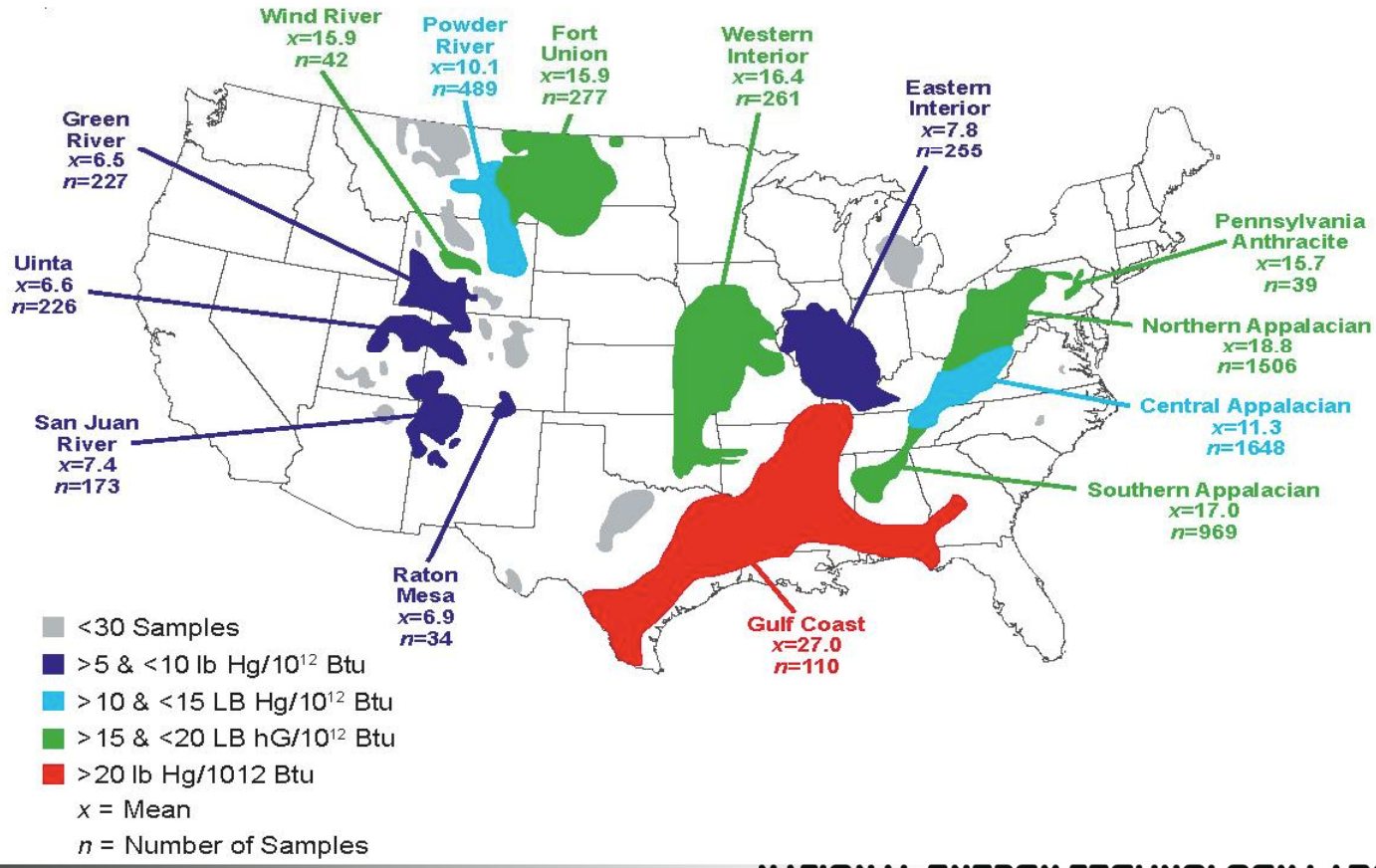
Based strictly on their air quality permits, would recent new units meet proposed air quality standards?

	EPA Limit	Prairie State Permit	***Prairie State in Compliance?***	Trimble County Permit	***Trimble County in Compliance?***	Longview Permit	***Longview in Compliance?***
NO_X	1.2 lb/MWh (NO_X+CO)	0.07 lb/MMBtu	**Close** (permitted level ~1.46 lb (NO_X+CO)/MWh)	0.7 lb/MMBtu	**No** (permitted level ~6.12 lb (NO_X+CO)/MWh)	0.065 Lb/MMBtu	**Close** (permitted level ~1.35 lb (NO_X+CO)/MWh)
PM	0.05 lb/MWh	0.035 lb/MMBtu	**No** (permitted level ~0.27 lb PM/MWh)	0.018 lb/MMBtu	**No** (permitted level ~0.14 lb PM/MWh)	0.018 Lb/MMBtu	**No** (permitted level ~0.14 lb PM/MWh)
SO_2	1 lb/MWh or 97% removal	0.182 lb/MMBtu	**No** (permitted level ~1.4 lb SO_2/MWh)	0.84 lb/MMBtu	**No** (permitted level ~6.6 lb SO_2/MWh)	0.095 Lb/MMBtu	**Yes** (permitted level ~0.73 lb SO_2/MWh)
HCl	0.30 lb/GWh	0.0032 lb/MMBtu	**No** (permitted level ~24.7 lb HCl/GWh)	9 tons/year	**No** (permitted level ~3.8 lb HCl/GWh)	10^{-5} Lb/MMBtu	**Yes** (permitted level ~0.08 lb HCl/MWh)
Hg	0.0002 lb/GWh	95% removal	N/A	0.000013 lb/MWh	**No** (permitted level ~0.14 lb Hg/GWh)	N/A	N/A
CO	1.2 lb/MWh (NO_X+CO)	0.12 lb/MMBtu	**Close** (permitted level ~1.46 lb (NO_X+CO)/MWh)	0.078 lb/MMBtu	**No** (permitted level ~6.12 lb (NO_X+CO)/MWh)	0.11 Lb/MMBtu	**Close** (permitted level ~1.35 lb (NO_X+CO)/MWh)

Proposed Mercury Limits for New Units

New non-lignite units will require 99%+ Hg removal to be in compliance

- **Coal with higher Hg content could become unmarketable**
- **CFB's could continue to make use of abundant coal supplies with higher Hg content**



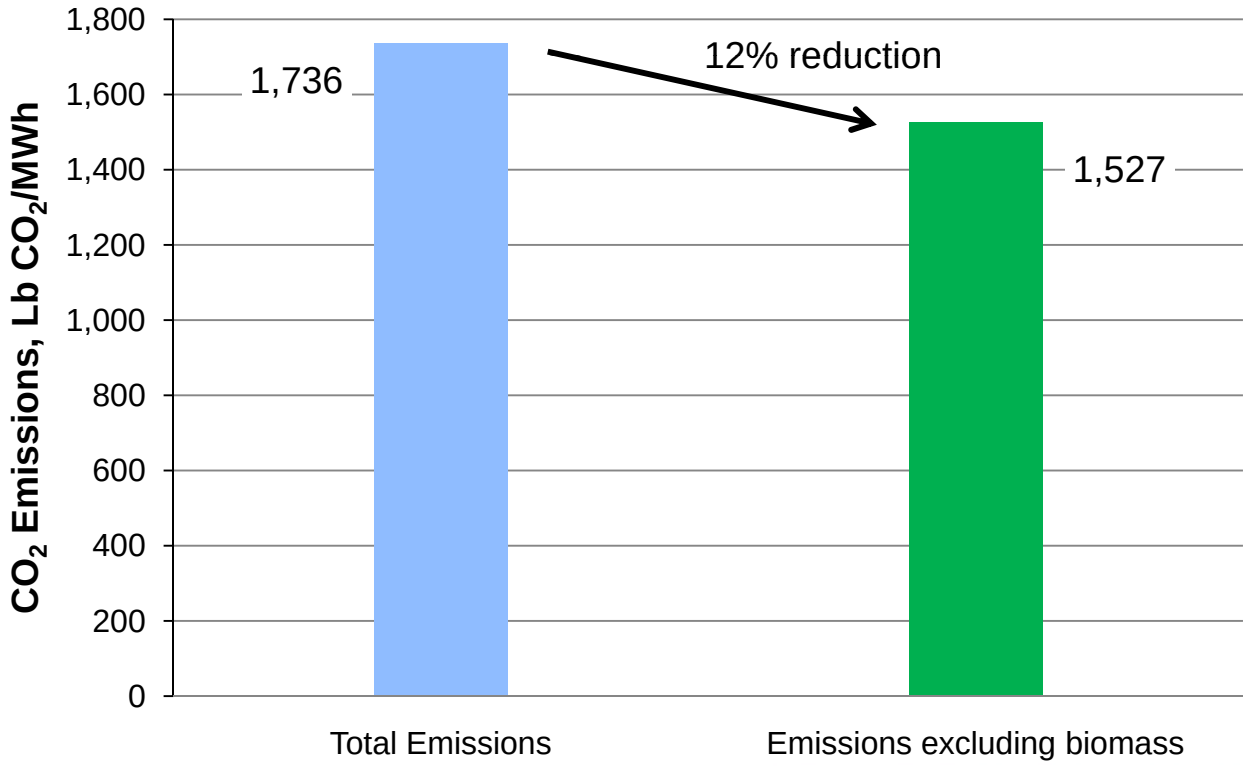
"Mercury in U.S. Coal – Abundance, Distribution, and Modes of Occurrence," USGS, 2001

Why Biomass?

- **Biomass *(including wood waste, switchgrass, hybrid poplar)* is considered a carbon-neutral fuel**
  - For every pound of CO_2 resulting from biomass combustion, one pound of CO_2 scrubbed from atmosphere during plant growth
- **As of July 2011, CO_2 emissions resulting from combustion of biomass exempt (for 3 years) from EPA Title V permitting requirements**
  - Suit filed against EPA challenging this
- **Reason to believe that biomass co-firing will be an acceptable CO_2 mitigation strategy for GHG NSPS**
  - 2011 TVA Clean Air Act Settlement: New Source Review violations resulting in civil penalty, CAA compliance, obligation to address 92% of coal-fired fleet with SCR, FGD, retirement, or biomass repowering

Why Biomass?

- Assume:
  - i. 25% biomass / 75% coal fed (by weight)
  - ii. Biomass 4,200 Btu/lb; Coal 11,700 Btu/lb
  - iii. 0.26 Lb C/Lb biomass; 0.64 Lb C/Lb biomass
  - iv. 40% efficient process
  - v. Biomass C-neutral, therefore is NOT included in emissions of CO_2



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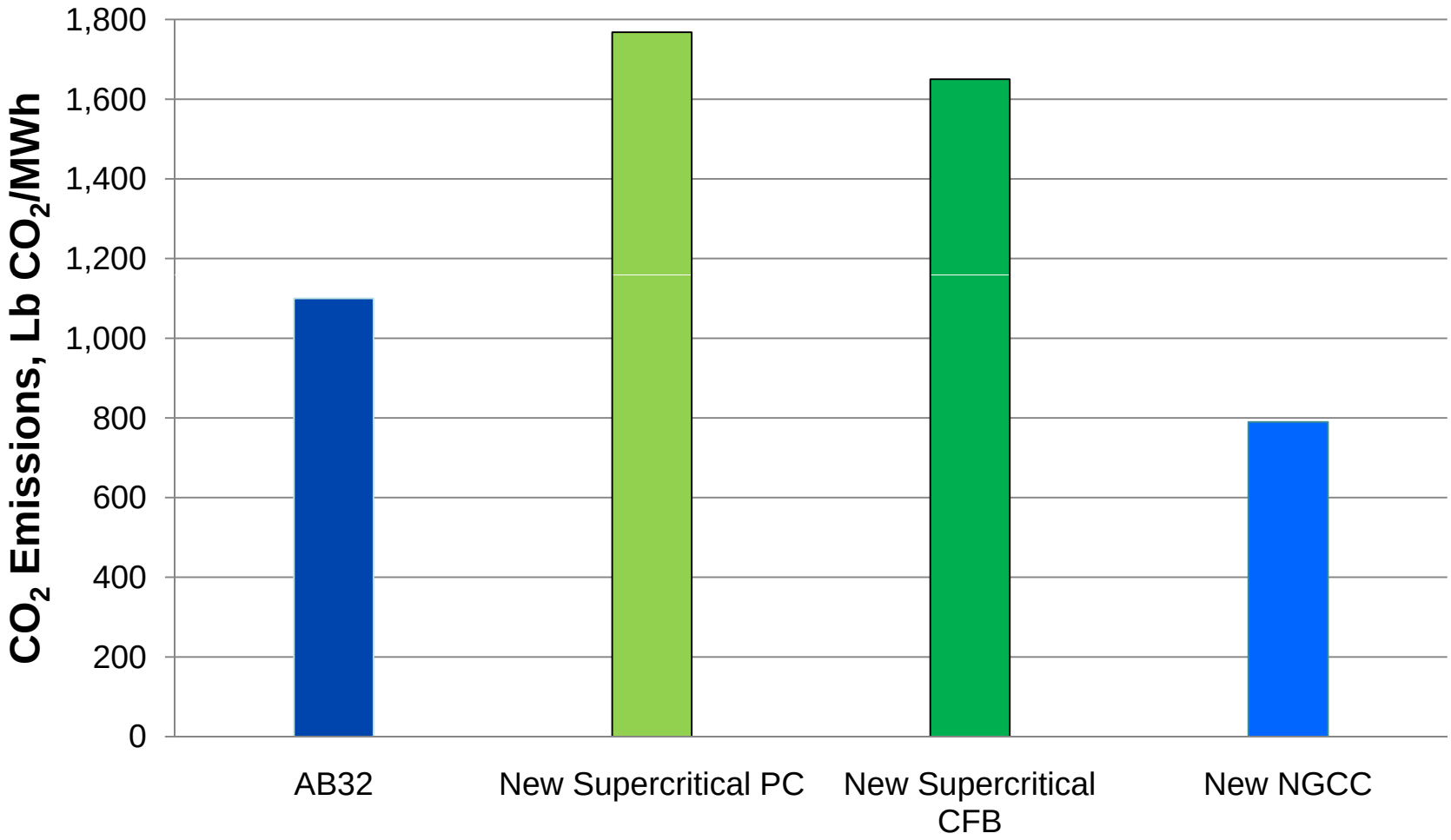
Why Biomass in a CFB?

- **CFB can burn low quality, opportunity fuels such as biomass**
  - Combustion of high fouling and slagging fuels due to low bed temperature
  - Rapid heating of fuel due to bed mass, long residence time allows for combustion of low Btu fuels
  - High degree of fuel flexibility with CFB
- **Ability to co-fire biomass (reducing CO_2 in the short-term), along with low NO_x, SO_2, and Hg emissions, make CFB an ideal technology for near-term builds**

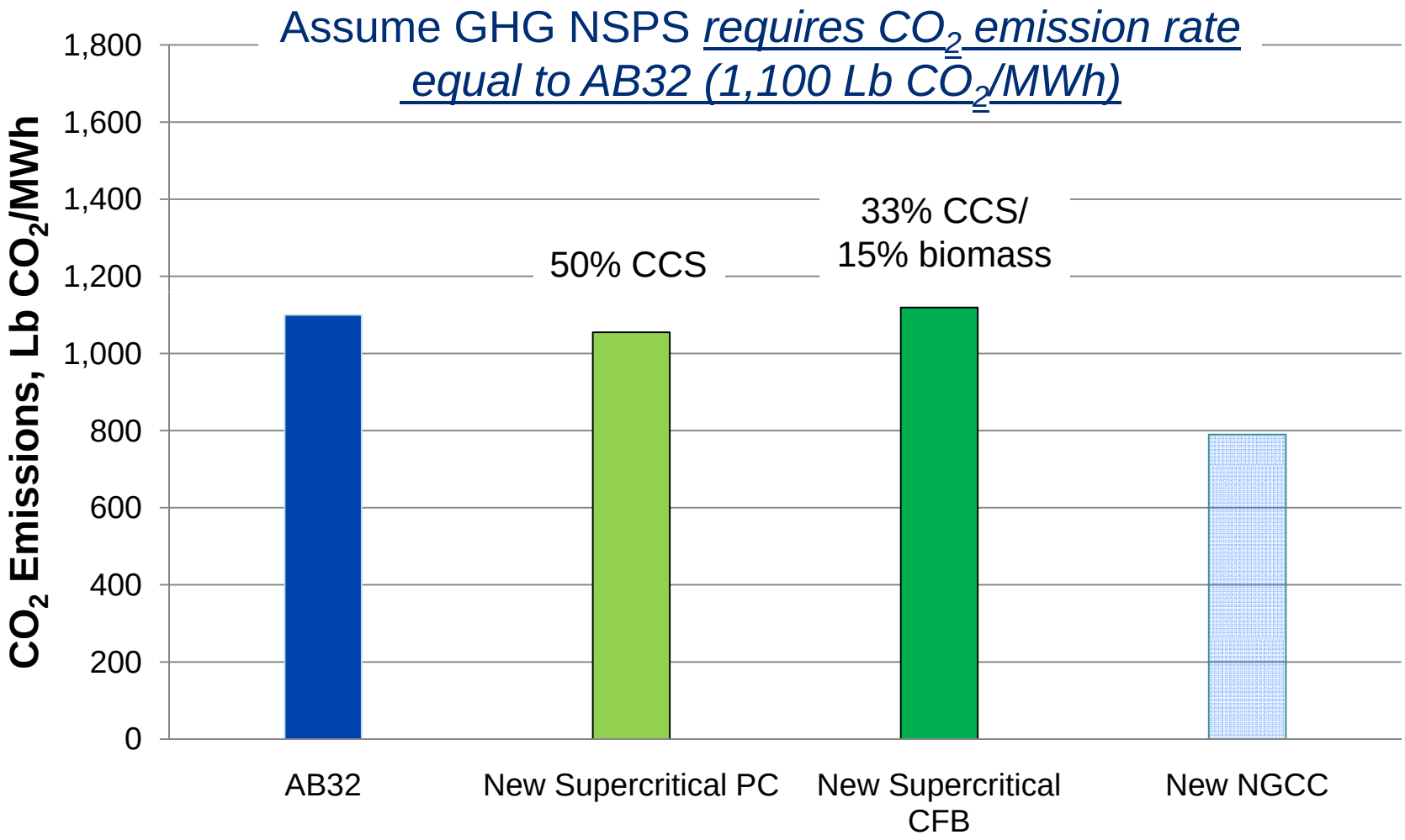
Future Considerations for Carbon Mitigation

- **CO_2 emission limits will become increasingly more stringent**
  - NSPS reviewed every 5 years, every new project results in more stringent obligations for next project
- **Build CFB's with future installation of CCUS in mind**
  - Access to CO_2 storage and utilization opportunities (transportation pipeline, EOR site and saline storage)
- **Existing units built with CO_2 capture in mind can more easily integrate it in the future**
  - Available real estate for capture equipment
  - Turbine considerations (steam extraction ports at correct pressure)

Fossil Power CO_2 Emission Rates



Fossil Power CO_2 Emission Rates



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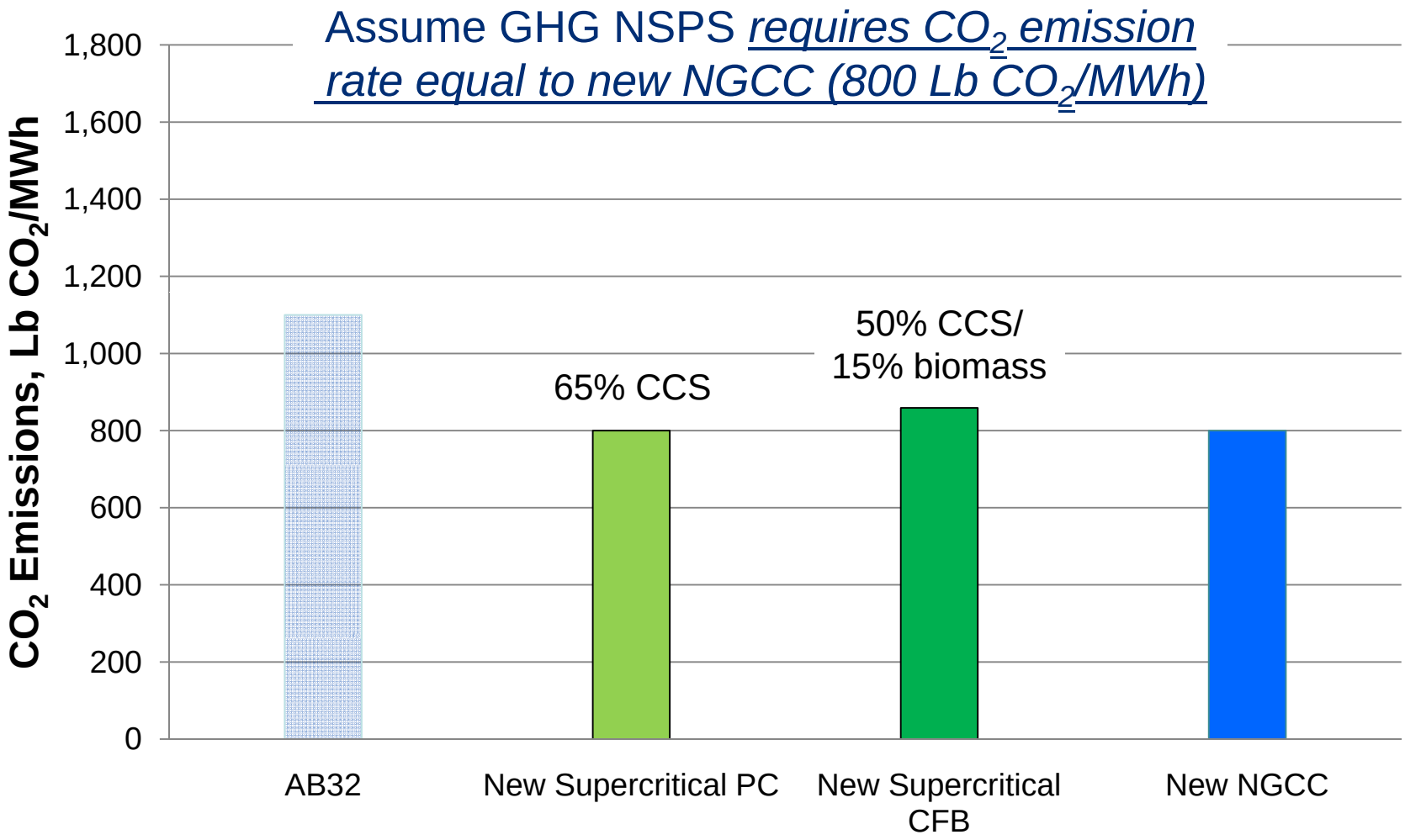

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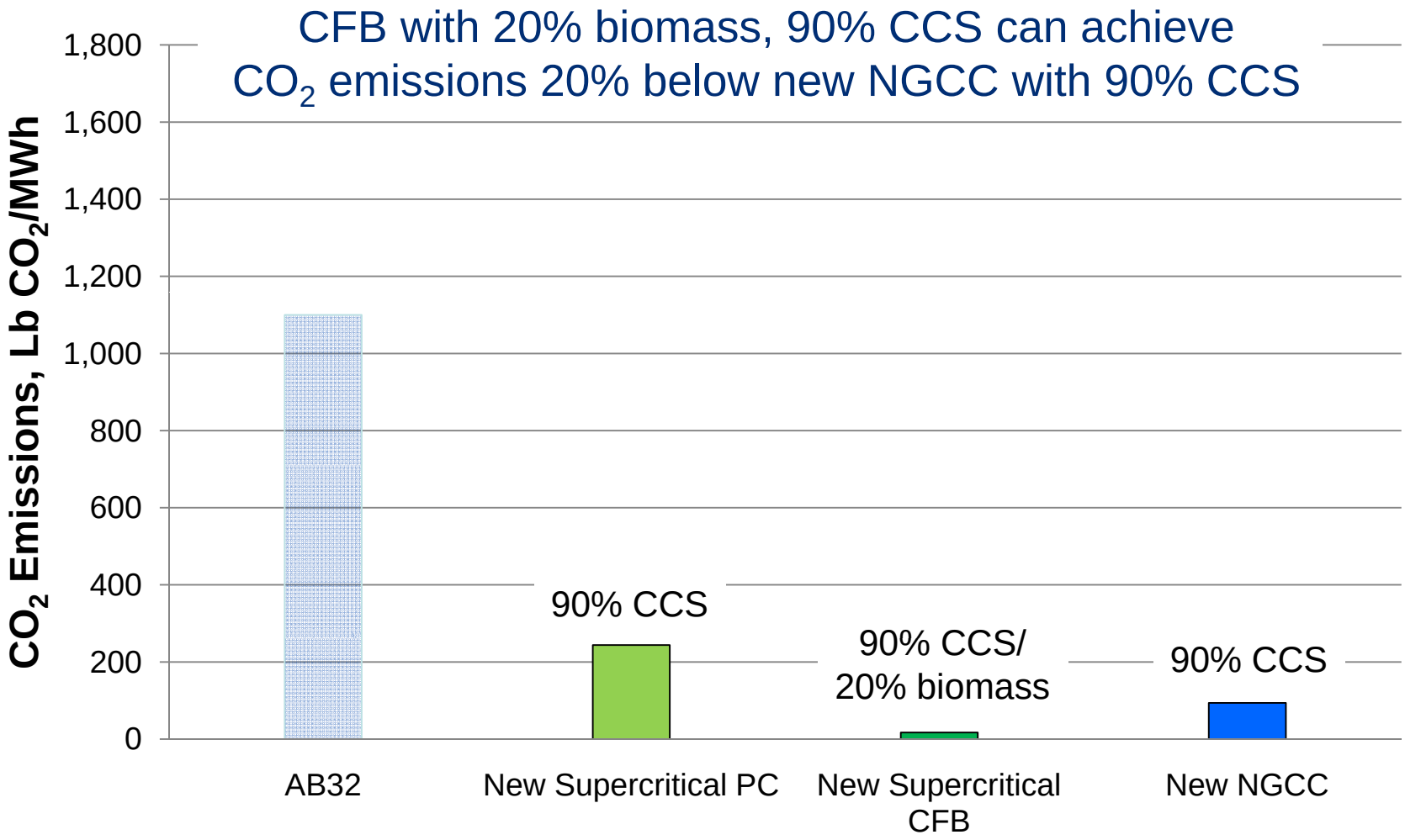

Parting Shots…

- **Current regulatory climate requires ultra-low emissions, which CFB's are in a unique position to accommodate**
- **As CO_2 emission limits become more stringent, fuel-flexibility of CFB can help achieve near-to-mid term reductions by co-firing biomass**
- **Building CFB's with future installation of CCUS in mind (CO_2 capture-ready) can help ease process integration when full-scale capture is required**
- **By co-firing biomass ***and*** capturing CO_2 emissions, GHG footprint for CFB can be even lower than new NGCC with capture**