CO2 Technology Update

Steve Moorman – Mgr Business Development
Advanced Technologies

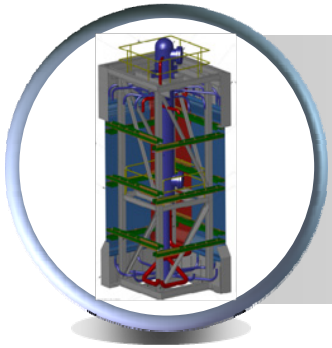
Advanced Technology Program Emphasis

Advanced Ultra-Supercritical

Confirm new designs, materials

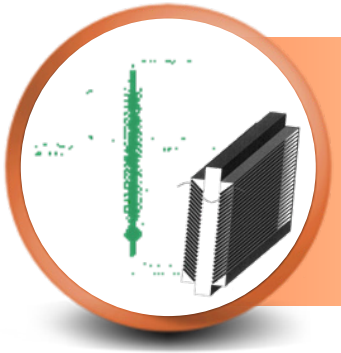
Oxy-Combustion

Get to the demo with DOE



Advanced Energy

Non-coal solutions – solar, biomass



Advanced Environmental

Move catalyst systems to demo

CO_2 Scrubbing

Lab to pilot to demonstration

Babcock & Wilcox Research Center Advanced Technology Development

Innovation with a vision for solutions

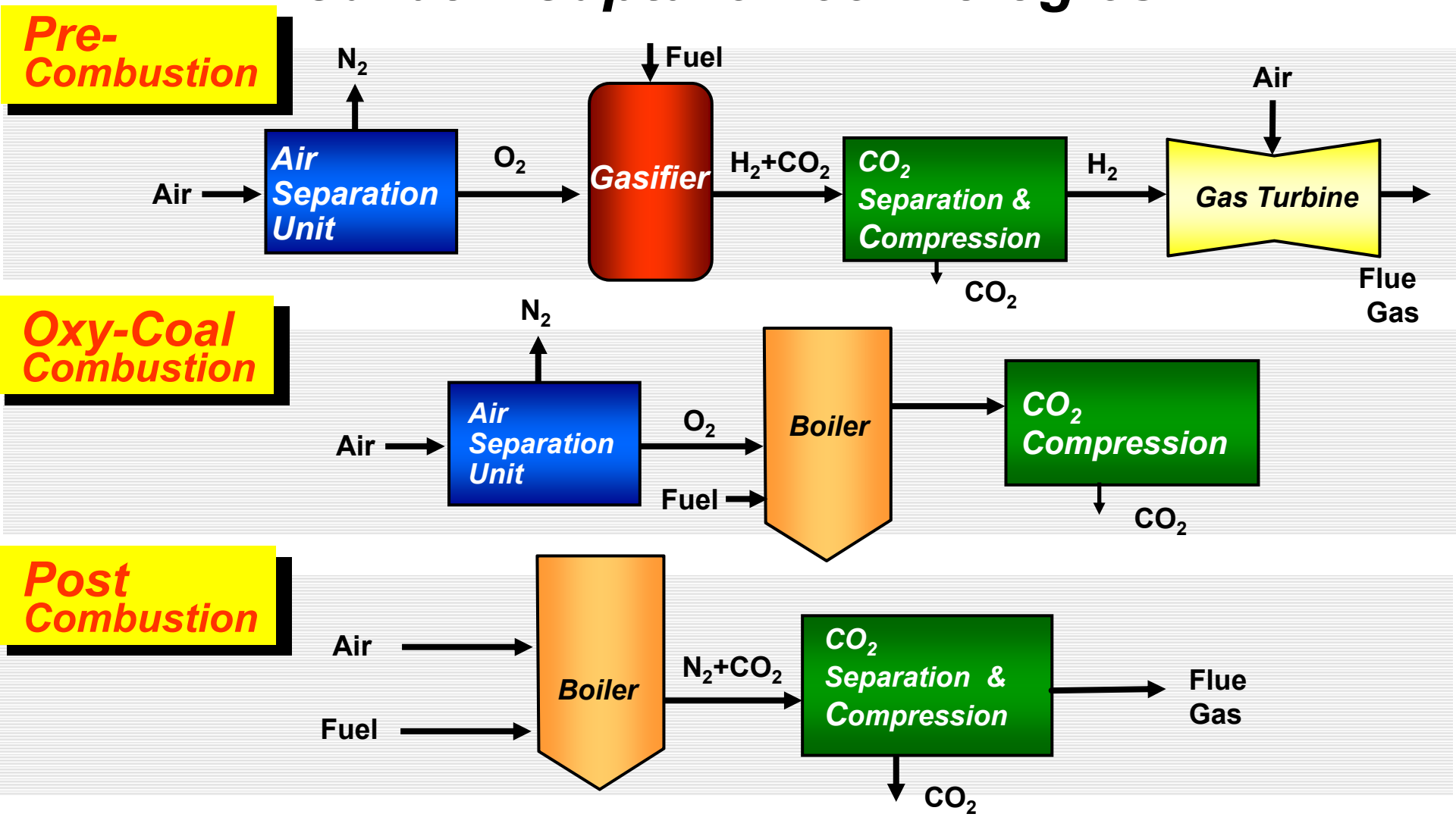
CCS Will Be Hard

- **Cap & Trade or Carbon Tax -- are all $$$$**
- **The path forward for Carbon Capture and Storage is of great interest to all of us – government, generators, suppliers, consumers**
- **Scale of CO2 capture is a huge – hundreds of millions of tons**

  A 600 MW PC Plant produces about 781,000 lbs/day of SO2 (@ 3% Sulfur)

  33,000,000 lbs/day of CO2 (@ 70 % Carbon)
- **How will we replace the lost capacity?**
- **Two components – "*capture*" and "*storage*" are both required but different paths, different players, different opportunities**
- **Technology indicates that the reductions are plausible, but an aggressive multi-dimensional response will be needed**
- **What will be the cost and will consumers ultimately be willing to pay??**

Carbon Capture Technologies

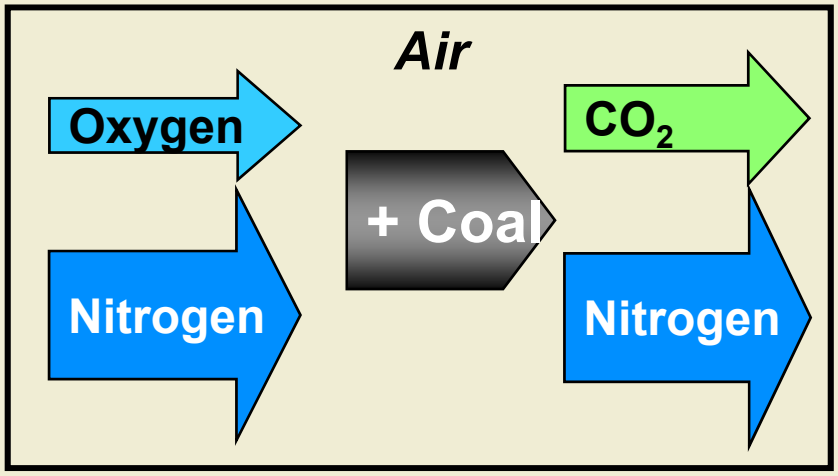


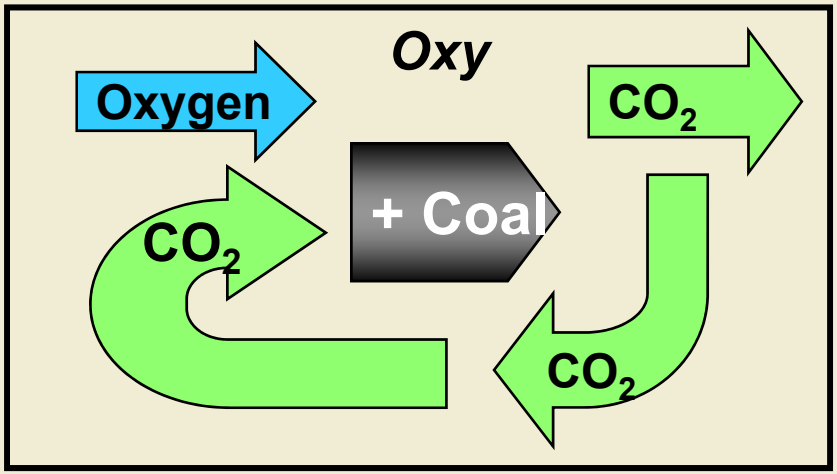
No obvious winner at this point

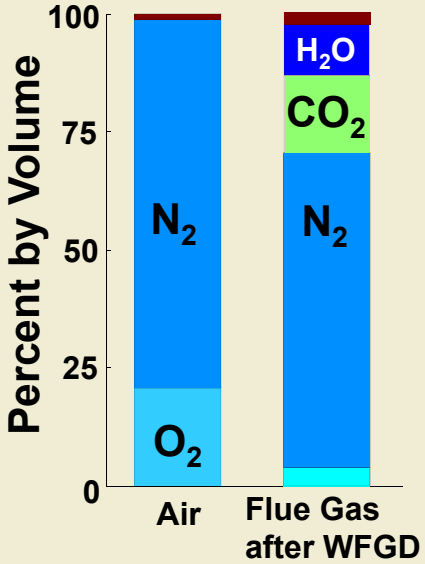
Oxy-Coal Combustion Principles

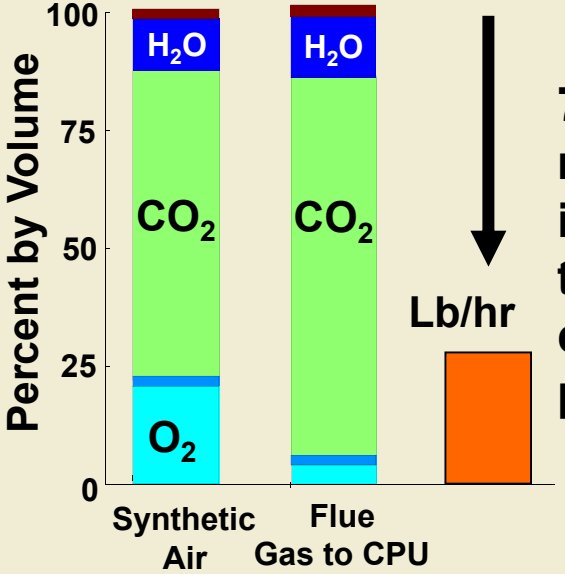
- Oxy-combustion is a means of replacing the nitrogen that comprises 80% of normal air with CO_2 by recycling flue gas from the combustion process. The subsequent increase in the CO_2 concentration in the flue gas facilitates its capture and storage.
  - Flue gas from coal combustion contains about 13% CO_2 making it difficult and costly to remove in a post-combustion scrubbing process
  - By concentrating the CO_2 up to 85% in the flue gas stream the CO_2 is more easily captured and compressed for storage
- Nearly pure oxygen from the Air Separation Unit is mixed with CO_2 from the flue gas to form "synthetic" air for the combustion process
- The CO_2 from the combustion process is cleaned and compressed in the Compression and Purification Unit prior to transporting via pipeline to the permanent storage location

Oxy-Coal Combustion Principles



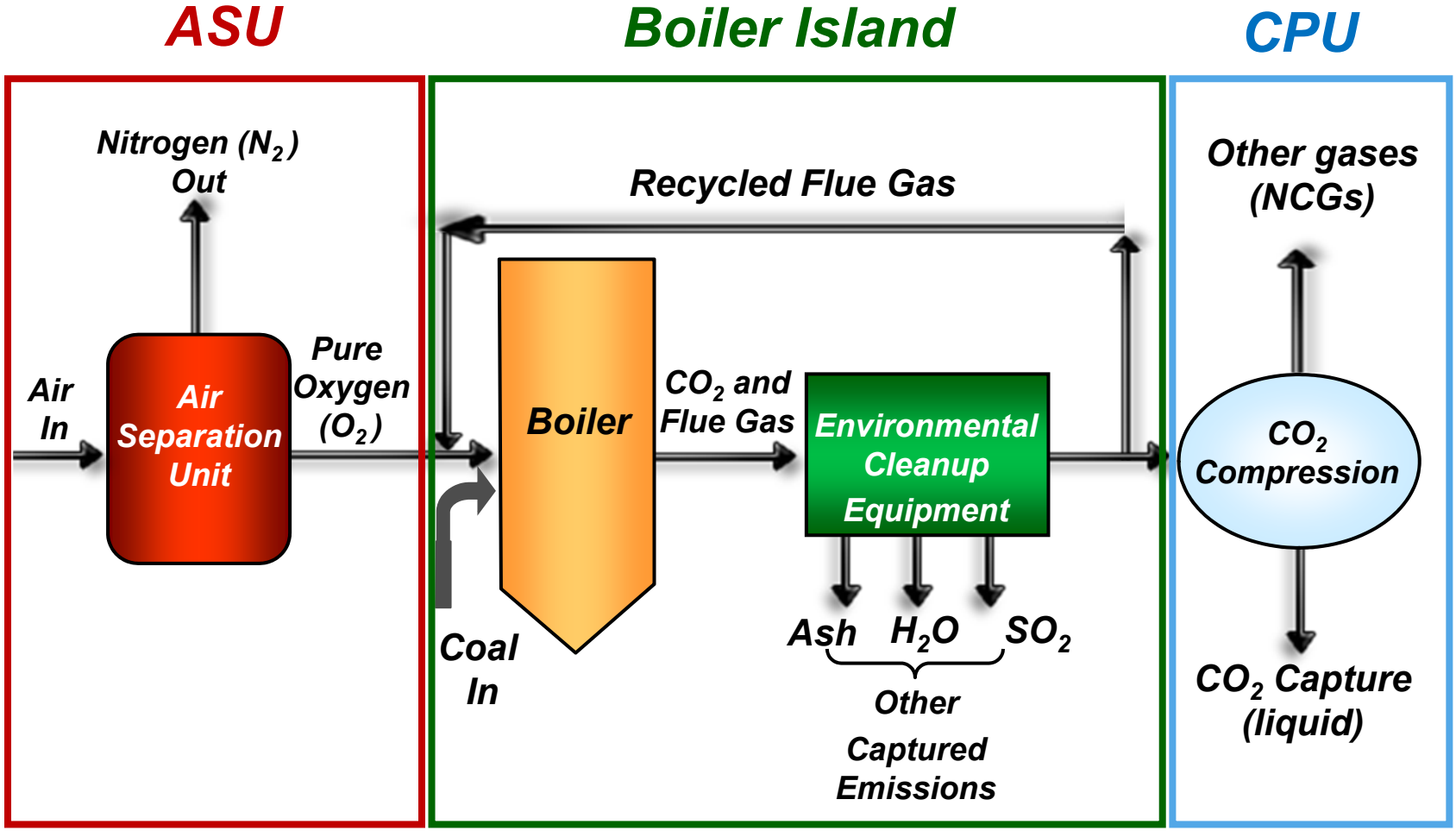




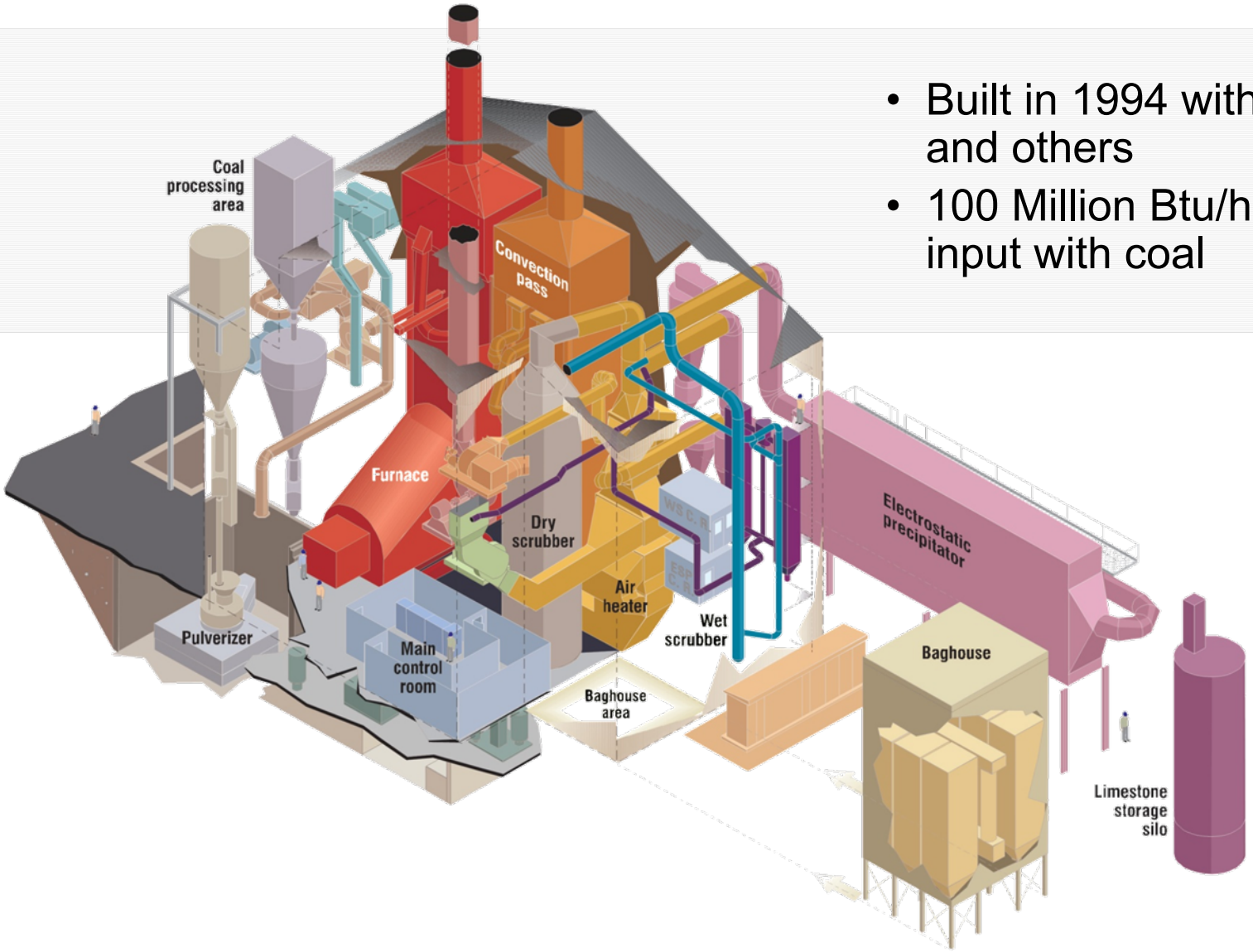


70- 80% reduction in flow rate to CO2 capture process

Oxy-Fuel Plant Configuration



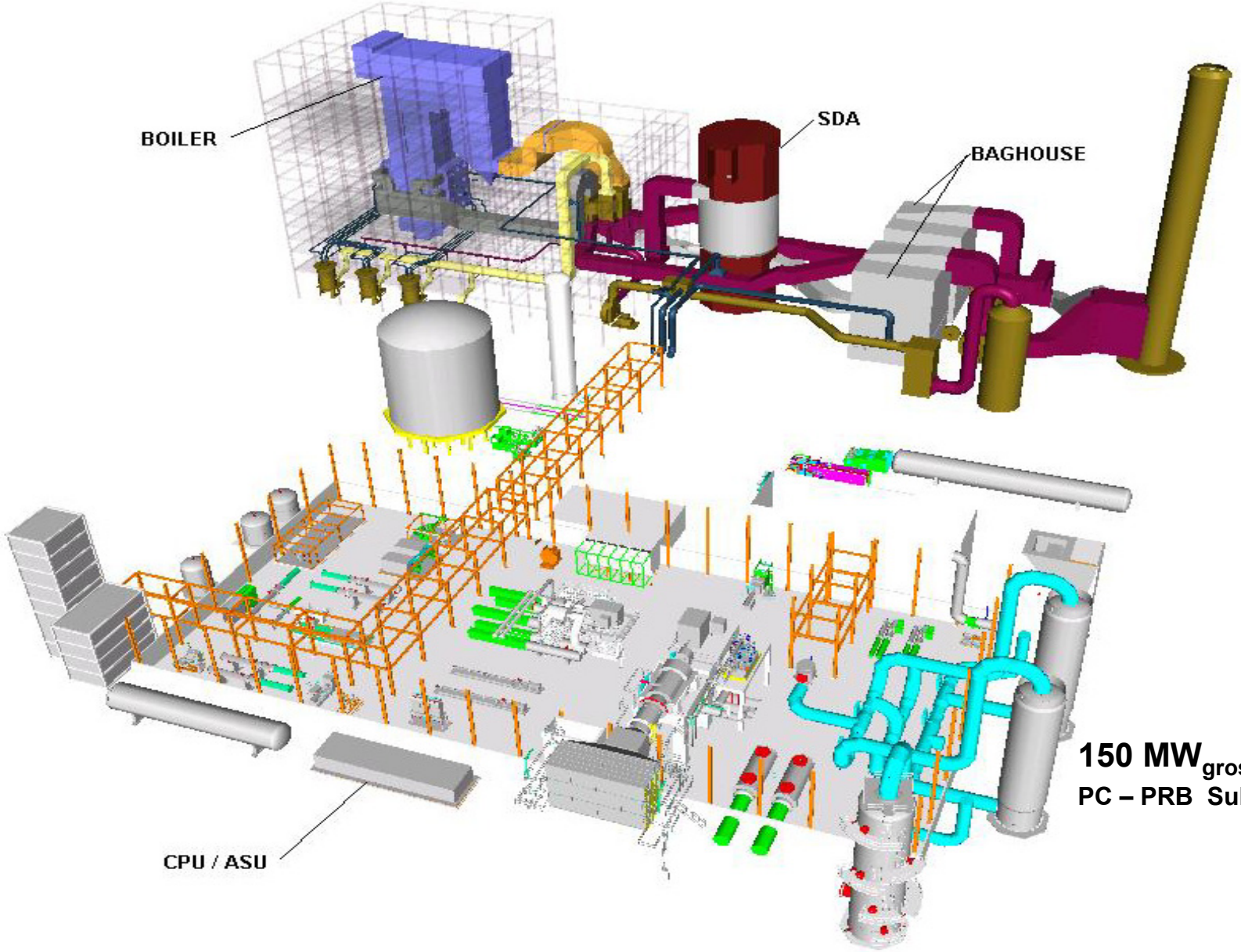
30 MW_{th} Test Facility located in Alliance, Ohio



- Built in 1994 with DOE and others
- 100 Million Btu/hr input with coal

Oxy-Coal Testing at CEDF Successfully Completed in 2008

Oxy Demo Plant Arrangement



150 MW_{gross} - 100 Mw_{net}

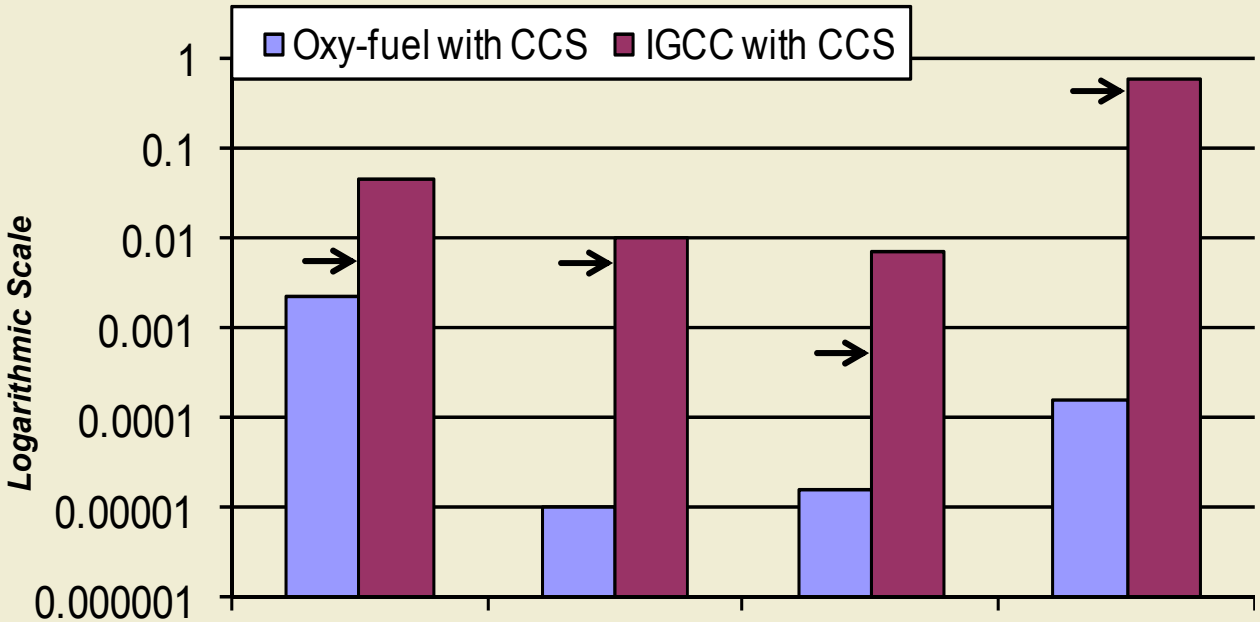
PC – PRB Subcritical Boiler

Project Objectives

- Establish technical and economic viability of a Near-Zero Emissions plant for pulverized coal-fired power (SO_2, NO_x, Hg and PM)
- Safely capture and permanently store large volumes of CO_2 in deep saline formations or EOR
- Build the knowledge to make informed CO_2 policy decisions for coal-based power plants
- Develop a public education program on transport and permanent underground storage of large volumes of CO_2
- Given coal is our nation's most abundant energy resource, demonstrate that coal can remain a long-term solution for reliable electric power generation

Environmental Performance of Oxy-Coal Near Zero Emission Plant (NZEP)

- **IGCC has been touted as best emissions performance**
- **Oxy with CCS is predicted to be lower by several orders of magnitude**



	NOx in lb/MBtu	SOx in lb/MBtu	Particulate in lb/Mbtu	Hg in lb/TBtu
Present reliable measurement limit (lb/Mbtu)	.005	.005	.0005	.4lb/Tbtu

Oxy-Coal Demonstration Plant

Project Schedule

- Selection 4th Qtr 2009
- Award – 3rd Qtr 2010
- NEPA Study – 2010 thru 2011
- Begin Matl Procurement – Late 2011
- Begin Erection – Mid 2012
- Startup – Late 2015
- Commercial – Early 2016
- Begin CO2 to EOR / Storage – Mid 2016
- Complete Demo – 2019

Almost 10 years to complete 1 demonstration!

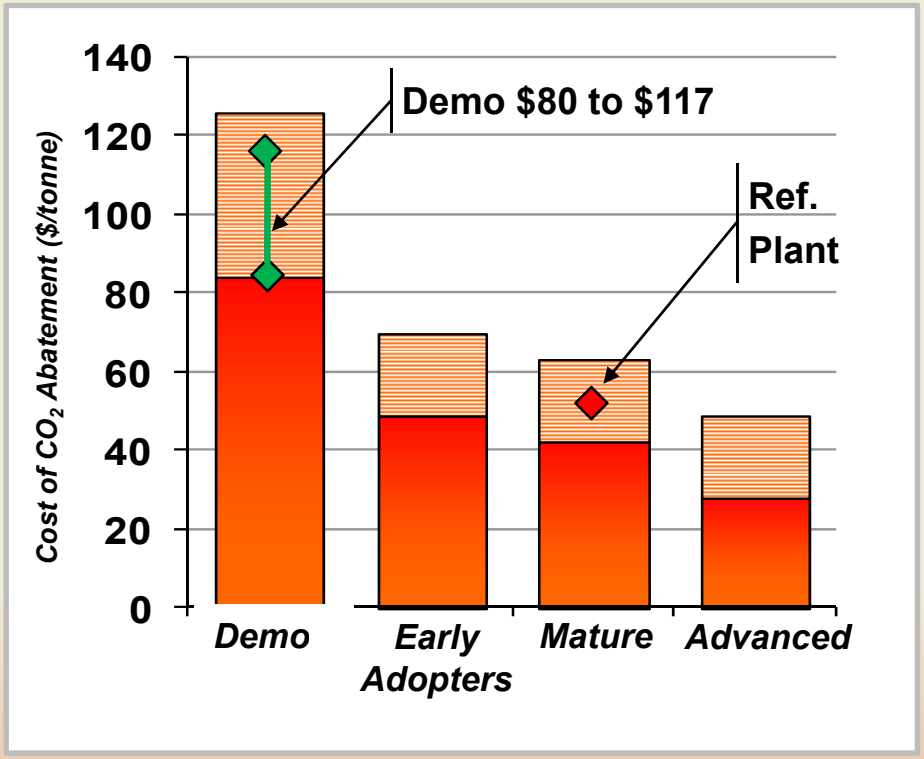
CO_2 Capture Cost: Effects of Learning

McKinsey and Company Study: "Assessing the Economics"

- Early plants to be small
- Focus to be on learning and not operating efficiency
- Benefits occur with scale
- Early commercial and mature plants will be larger

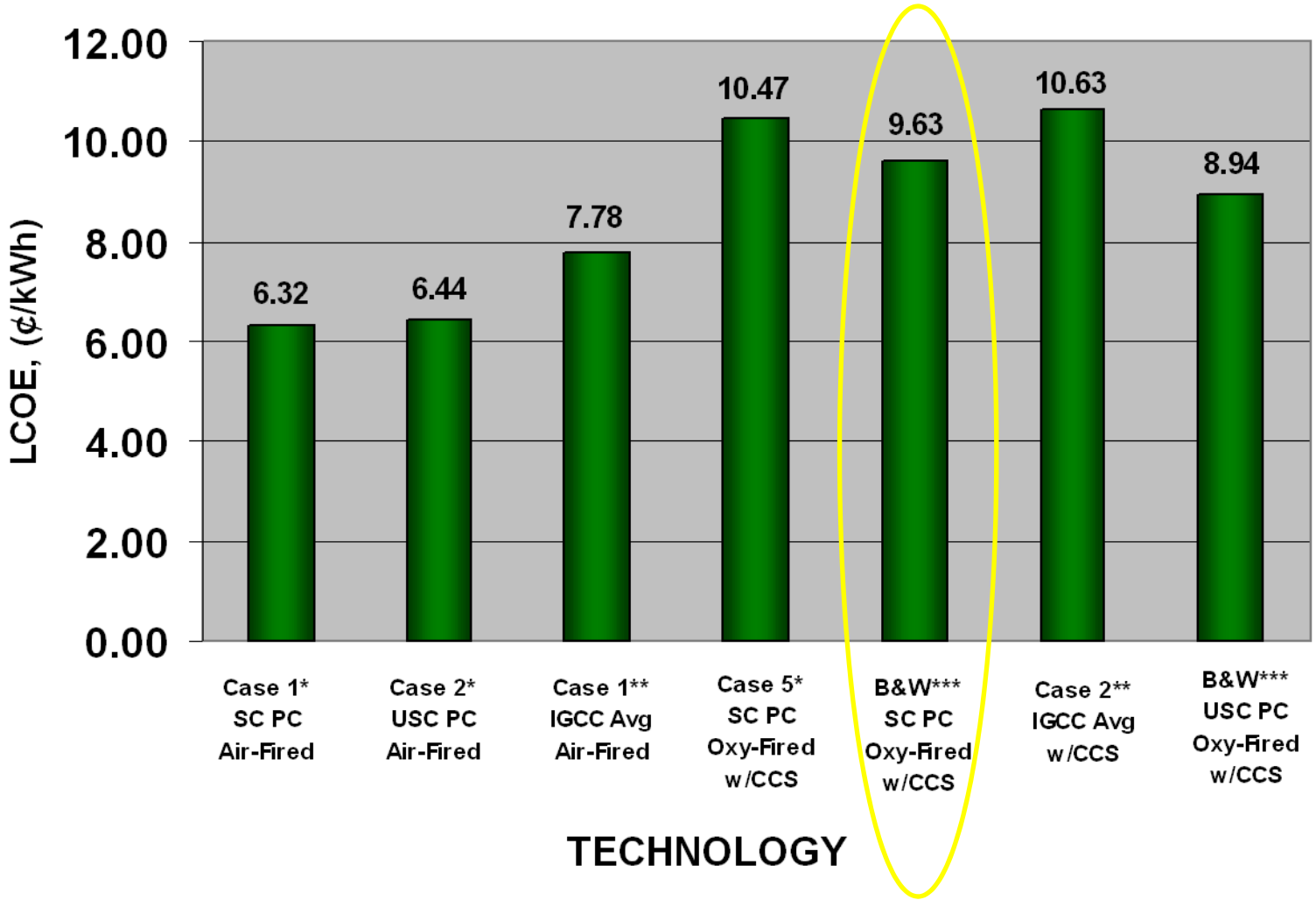
Oxy Plant Stacks Up Well

- Demo within range of expectations
- Reference Plant at ~ $50/ton
- What are people willing to pay?



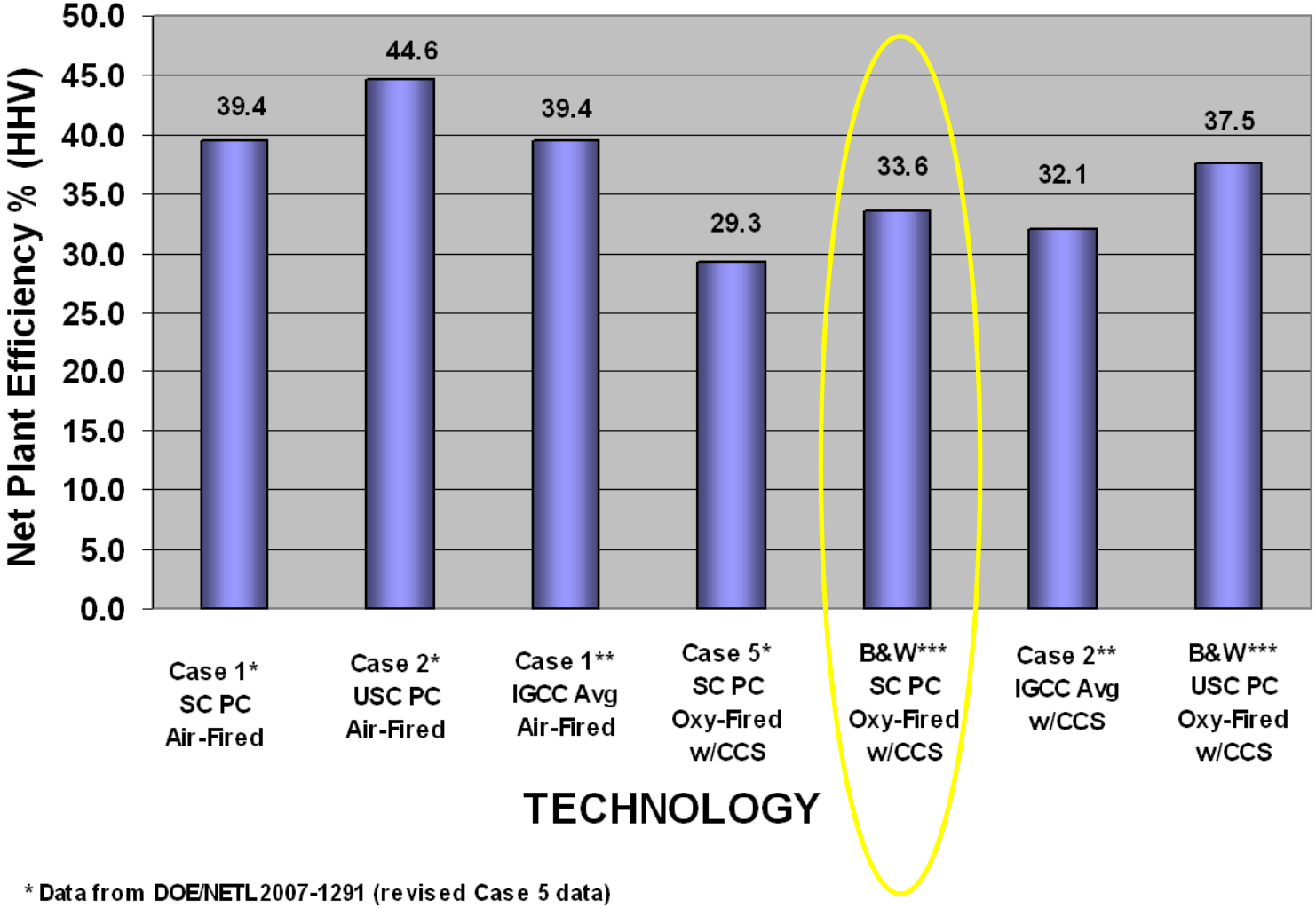
Source: McKinsey & Company *CCS: Assessing the Economics*, 9/22/08

Levelized Cost of Electricity Comparison



* Data from DOE/NETL 2007-1291 (revised Case 5 data)
** Data from DOE/NETL 2007-1281, averaged for IGCC as DOE did for DOE/NETL-1291
*** Data from B&W Integration Study 2008

Net Plant Efficiency Comparison



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How will CCS systems get into the existing fleet?

Technical issues

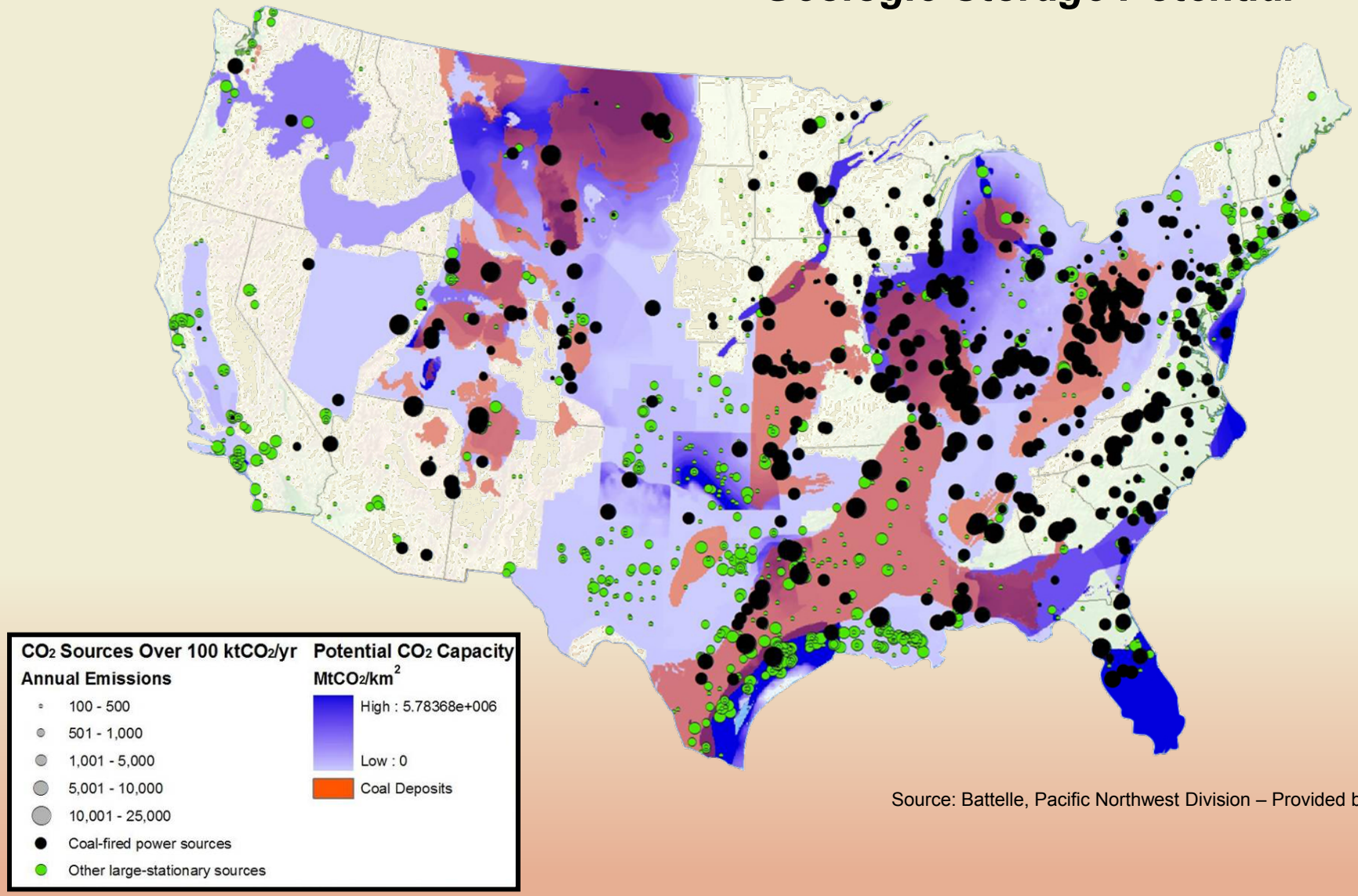
- **Space for CCS equipment – very large footprint for either CO2 Scrub or Oxy 4 – 6 acres for a ~ 500 Mw_{net} plant**
- **Loss of plant output - Steam for Scrub or Aux power for ASU / CPU ~ 25-35%**
- **Plant Performance changes**
  - **Ability to cycle, load swing will be minimized**
- **Plant capacity upgrades – how much could be recovered from a typical plant**
- **Water / wastewater treatment modifications potential net+ water balance**
- **Additional NOx and SOx reductions may be needed for CO2 purity**
- **ΔP increase to system resistance effects on:**
  - **Boiler, Fans, Flues**
- **Difficult to incorporate heat integration into existing plant processes**
- **Outage time required for changeover**

How will CCS systems get into the existing fleet?

Other issues

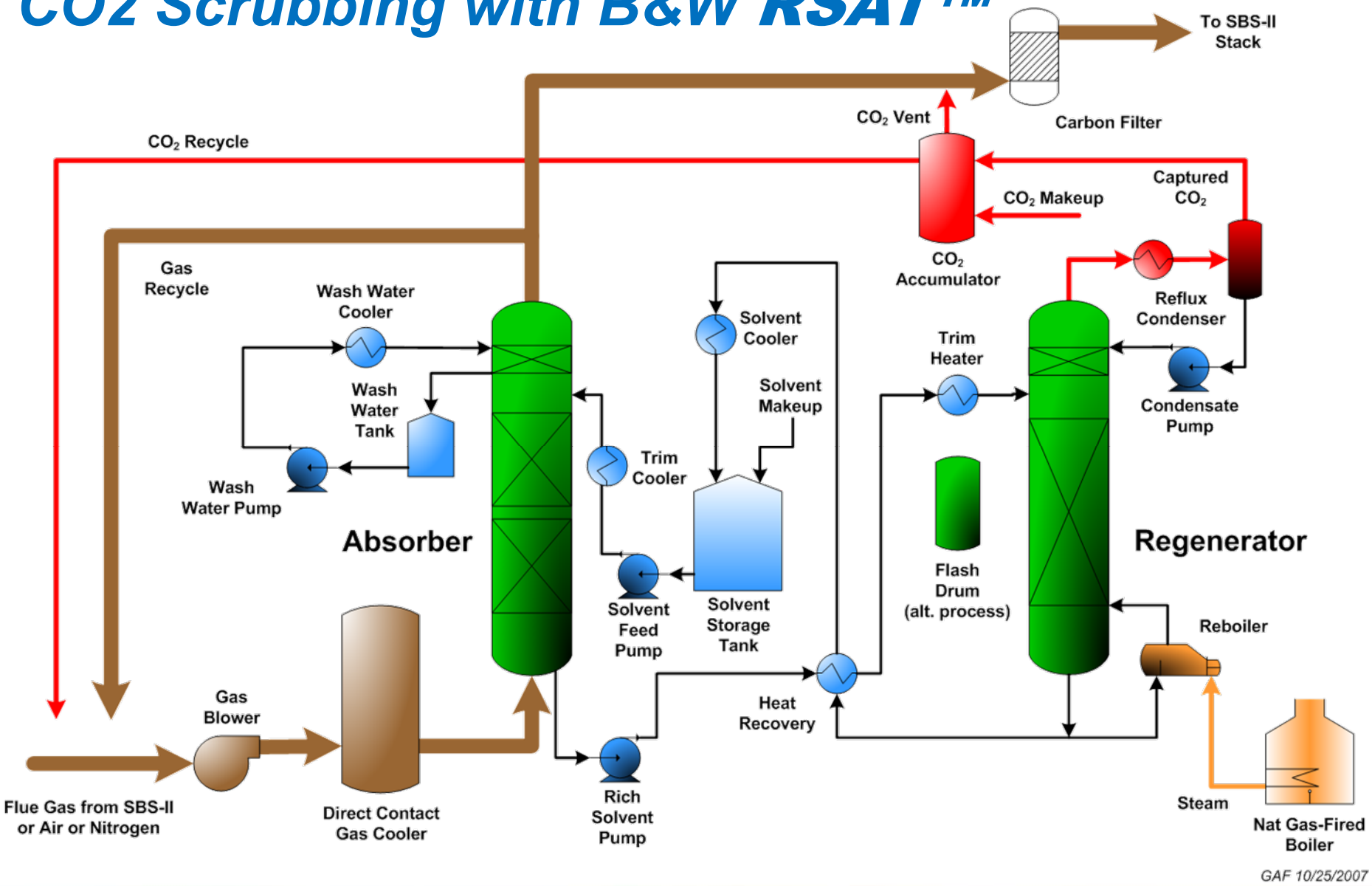
- How will CO_2 cap and trade compare to SO_2 C&T
- What will be the trigger price of CO_2 for projects to go forward
- Will partial capture be a consideration
- How will the permitting process be affected by NZE and FOAK status
- How will Aux power required for CCS be replaced in the system
- Can we assure early CCS units have the flexibility to incorporate future technology improvements
- Access to permanent storage, EOR opportunities, CO_2 pipelines
- What will consumers ultimately be willing to pay to affect climate change

Geologic Storage Potential



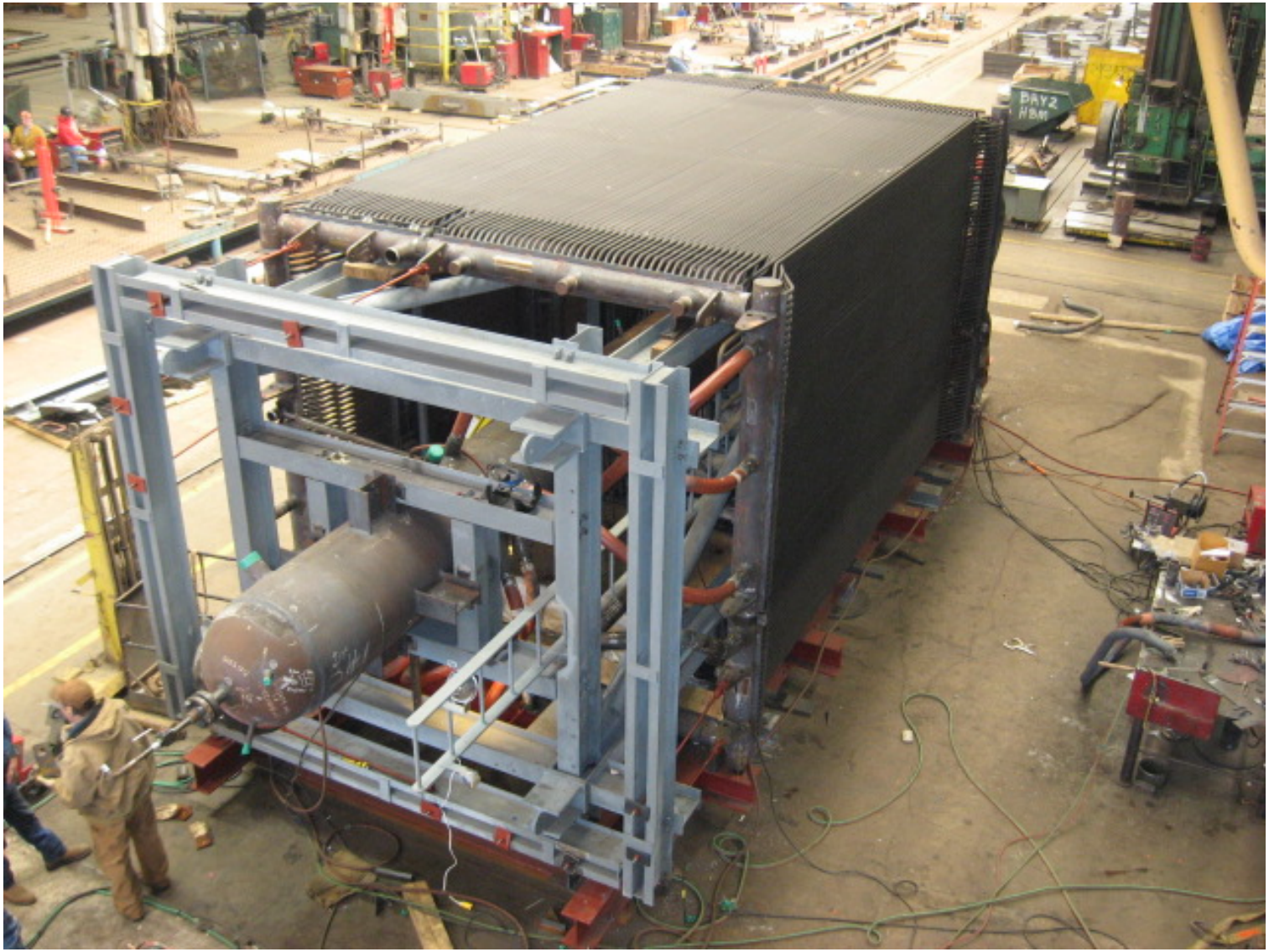
Source: Battelle, Pacific Northwest Division – Provided by Judd Virden

CO2 Scrubbing with B&W RSAT™



RSAT™

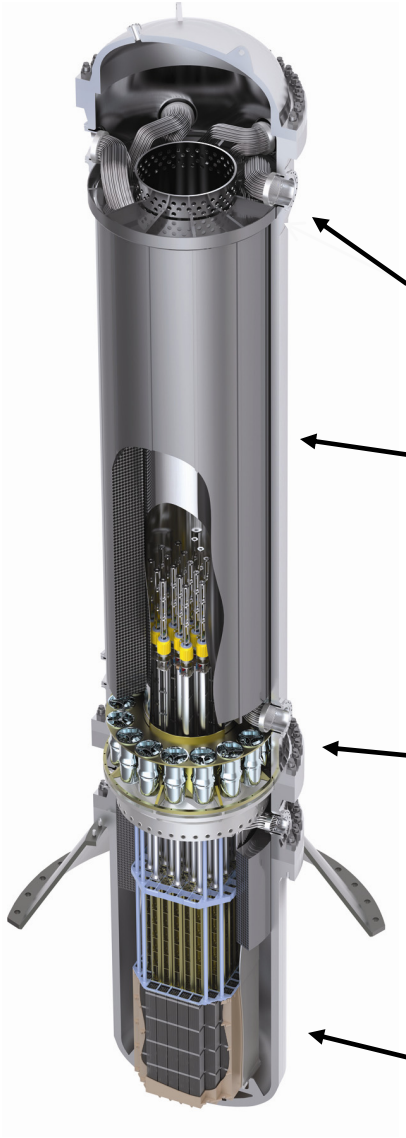
- Significant scale: 7 tonnes/day
- Absorber and Regenerator Columns – 2 ft diameter x 66 ft tall
- Can operate on boiler or synthetic flue gas

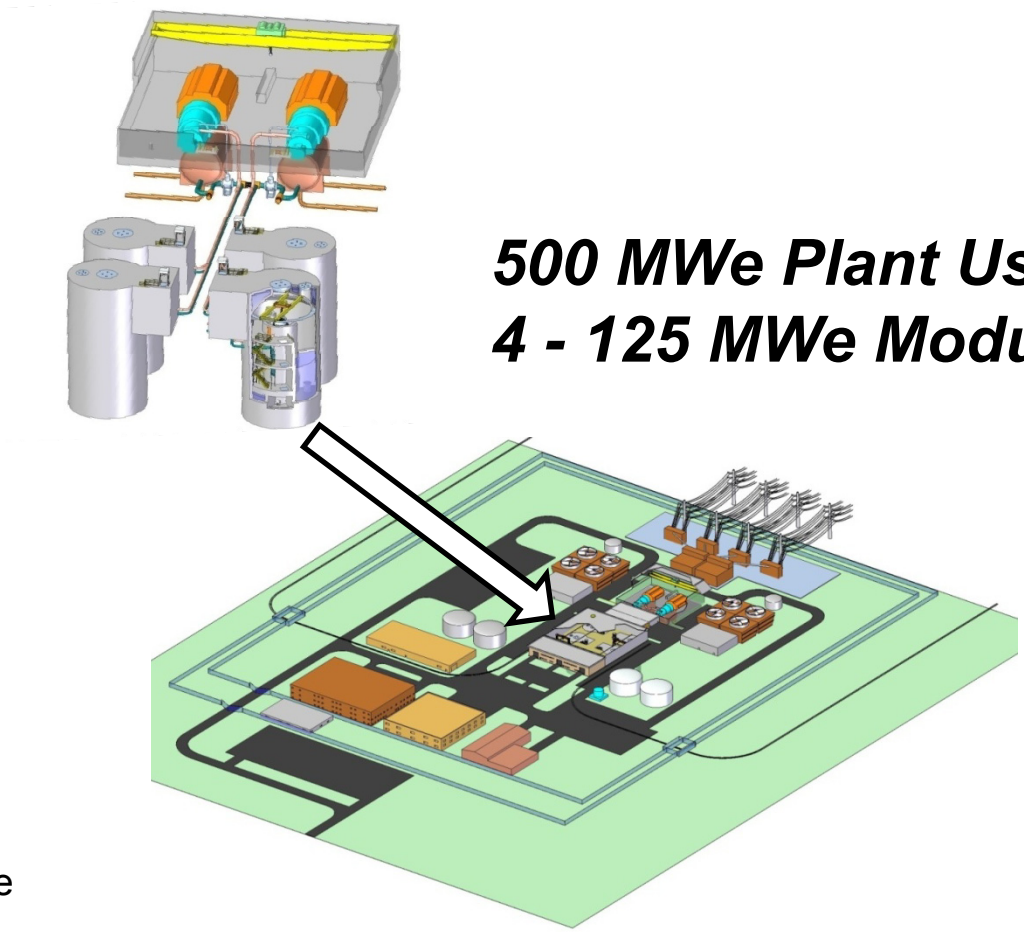


Concentrated Solar Power (Thermal)

2x10 MWt solar field

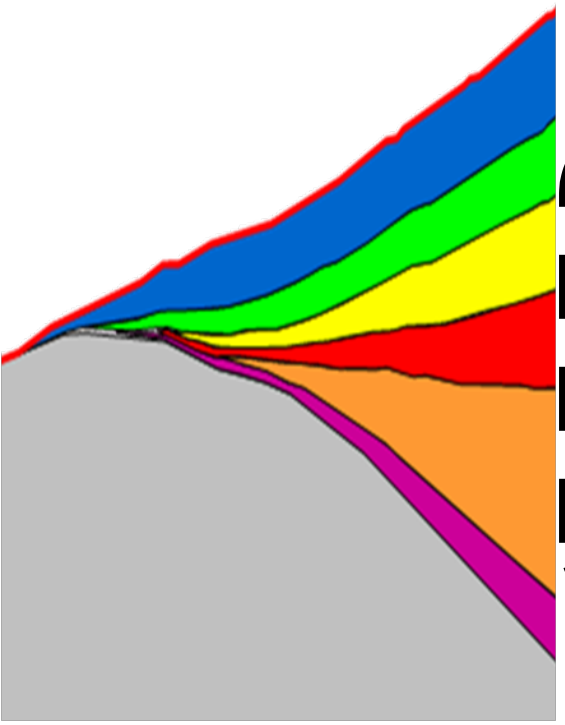
B&W Modular Reactor





500 MWe Plant Using 4 - 125 MWe Modules

B&W's Commitment to Clean Power



End-Use Efficiency

Renewables

- Biomass Power Plants
- Waste-to-Energy
- Concentrated Solar Thermal
- Biomass Gasification

Nuclear Generation

- Nuclear services / construction
- Nuclear steam generators
- Commercial nuclear component fabrication
- Government operations

Advanced Coal Generation

- High efficiency SCPC w/o CCS
- Ultra-supercritical boilers with CCS
- Advanced USCPC 1400F cycle
- Advanced low mass flux SCPC

Carbon Capture and Storage

- Oxy-coal retrofit application
- Oxy-coal new boiler application
- RSAT™ CO_2 scrubbers

PHEV / DER