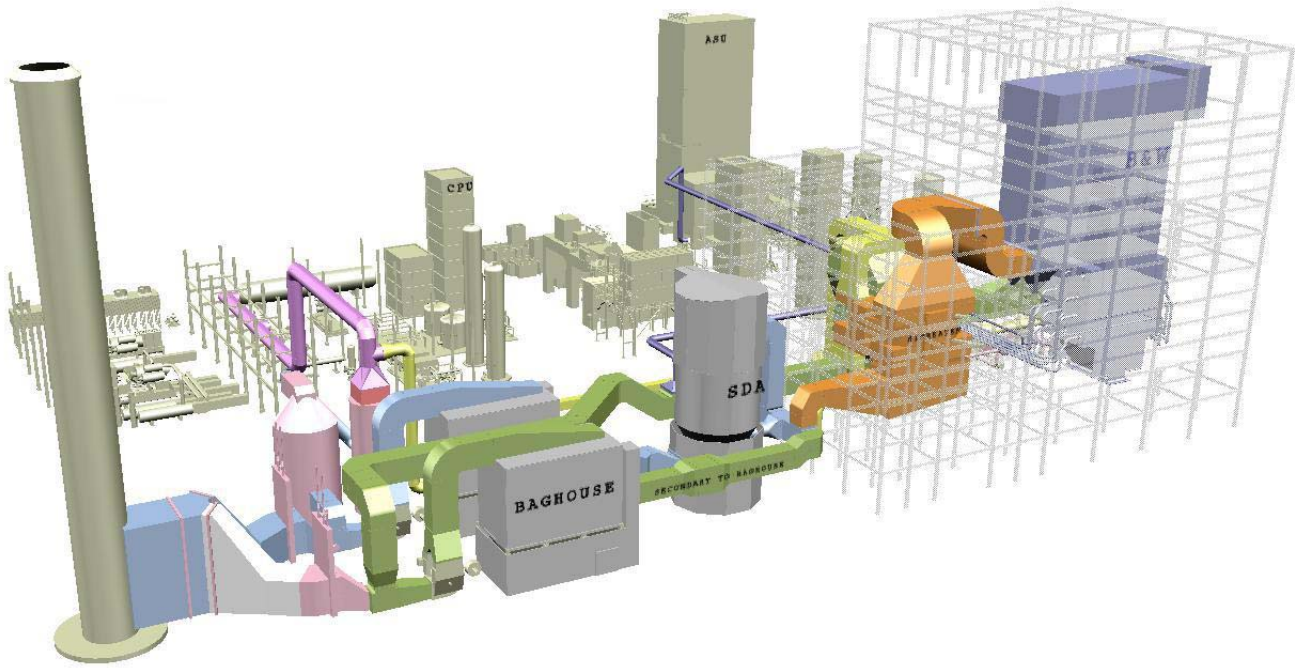
B&W and Black Hills Corporation: Oxy-Fuel Demonstration Project



Black Hills Corporation

B&W
thebabcock&wilcoxcompany

AIR LIQUIDE

Battelle
The Business of Innovation

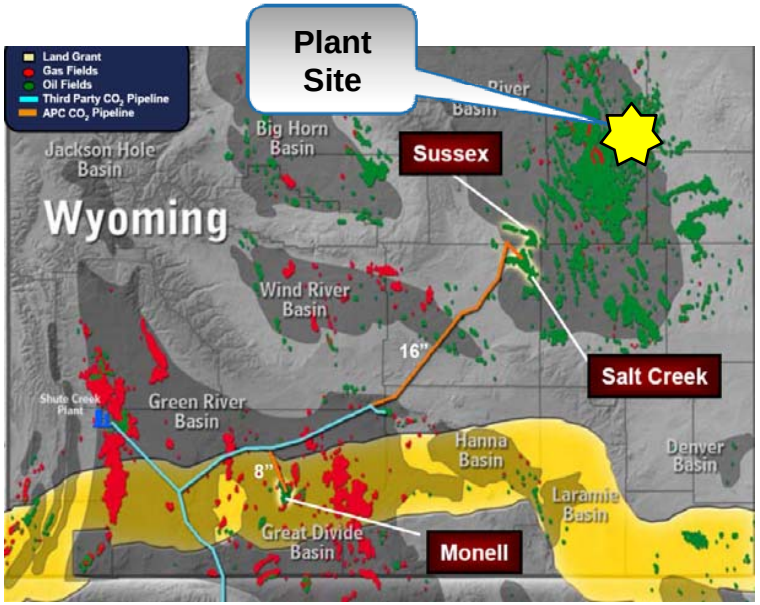
The first commercial scale CCS demonstration plant

Project Objectives

- **Establish technical and economic viability of a Near-Zero Emissions (SO_2, NO_x, Hg and PM) plant for pulverized coal-fired power with CO_2 capture**
- **Safely capture, compress and permanently store large volumes of CO_2 in deep saline/geologic formations or use for enhanced oil recovery**
- **Build knowledge to make informed CO_2 policy decisions for coal-based power plants**
- **Demonstrate long-term viability of coal for electric power generation, since coal is one of our nation's and Wyoming's most abundant natural resources**
- **Develop a public education program regarding transport and permanent underground storage of large volumes of CO_2**

B&W and Black Hills: Project Overview

- **100MWe Oxy-fuel pulverized coal greenfield plant located in Campbell County, Wyoming**
- **Application submitted to the DOE for CCPI-3**
- **Plant in-service by 2016**
- **Project Team:**
  - **Black Hills Corporation, host utility**
  - **The Babcock & Wilcox Company**
  - **Air Liquide Engineering and Construction**
  - **Battelle, Pacific Northwest Division**



Black Hills Demonstration Project

Milestone	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Selection	★										
Award		★									
Engineering	■	■	■								
NEPA and Permitting		■	■								
Procurement			■	■	■	■					
Installation				■	■	■	■	■	■		
Commissioning and Startup						■					
Test Period							■	■	■	■	
Monitoring										■	■

Oxy-Fuel Demonstration: Technology Readiness

- 5 MBtu/hr small pilot testing completed 2002
- 30 MWth large pilot test completed 2008
  - Burner designs, Process controls, Emissions
- Computer modeling and simulation validated
- Pulverized coal Oxy-combustion Power Plant study (DOE/NETL-2007/1291)
- Bottom-up Integration Study with ASU & CPU in 2008
- ASU efficiency optimization program completed in 2008
- CPU pilots in operation at Lacq and Callide (2008-2011)

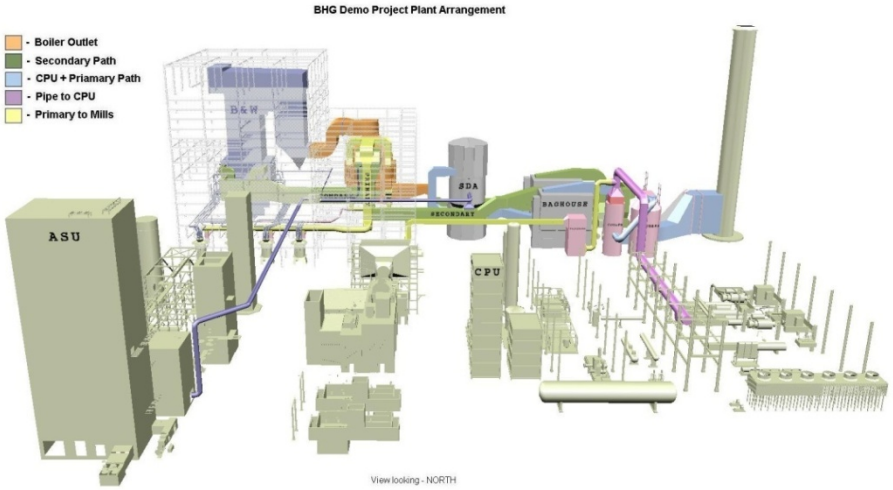
30 MWth Test Facility

CEDF Oxygen Supply System

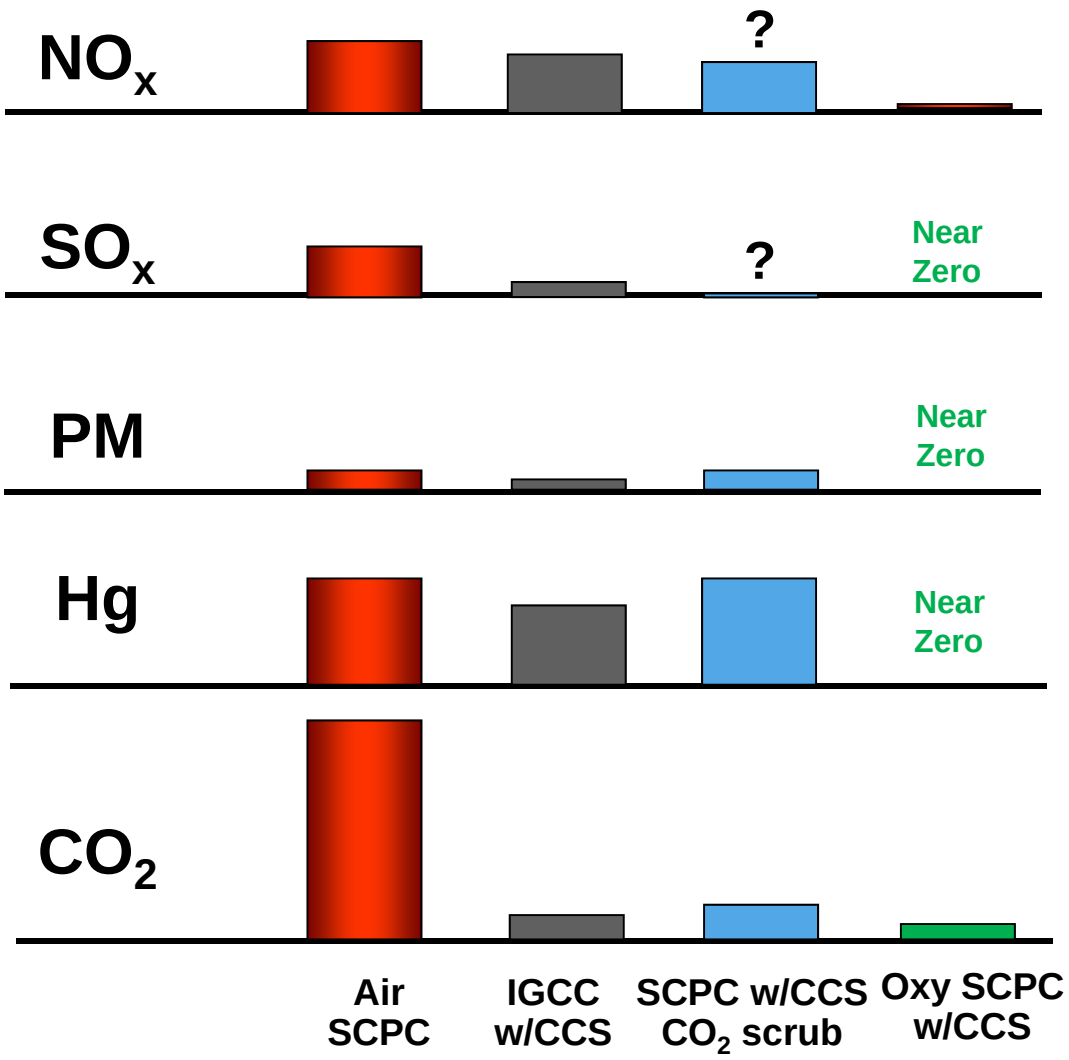
Oxy-combustion Flame

Project Scope and Technical Details

- Pulverized coal fueled boiler with 2400 PSI/1050F/1050F steam cycle
- Air Separation Unit (ASU)
- Compression and Purification Unit (CPU)
- 100 MWe net electric output
- Heat integration of ASU/CPU w/ steam cycle
- Near Zero Emissions Plant (NZEP)
  for SO_2, NO_x, PM and Hg
- Low raw water usage with dry cooling
- High altitude operation
- Zero Liquid Discharge (ZLD)
- Mine-mouth site using low-rank
  sub-bituminous Powder River Basin coal
- 1 million tons/yr CO_2 storage
- Use CO_2 for EOR or deep saline storage



Comparison of Plant Air Emissions

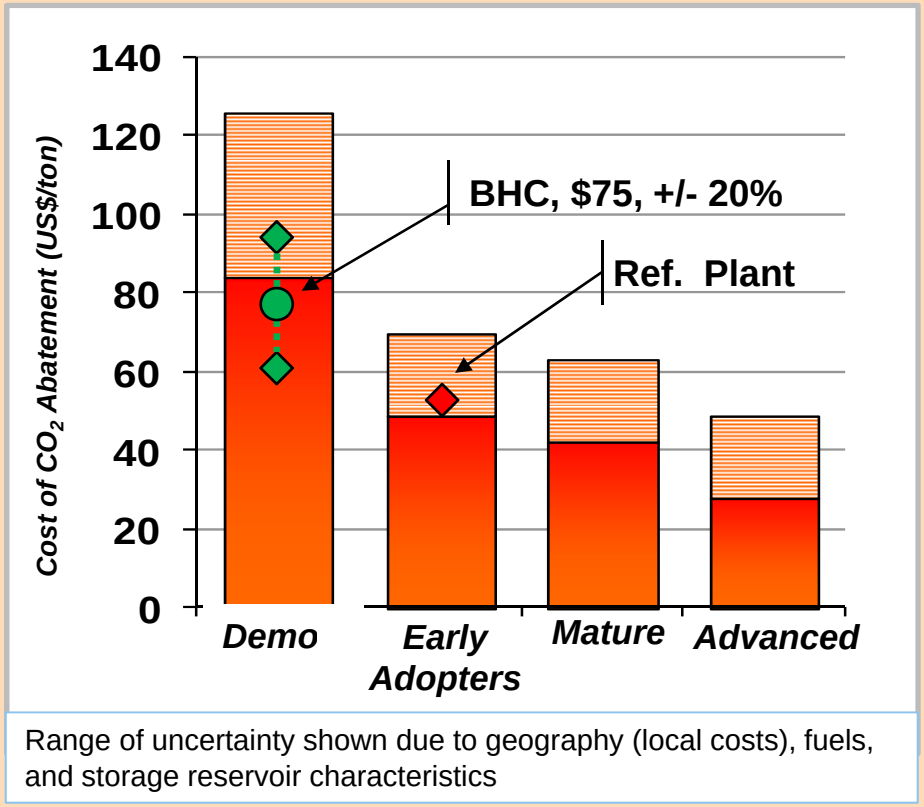


- Emissions from Oxy-Fuel Demonstration Plant will be well below practical measurement limits
- CO_2 scrubber SO_x and NO_x emissions depend on specific CO_2 capture solvent requirements
- Oxy SCPC emissions are well below IGCC and CO_2 Scrubbing

IGCC from DOE/NETL-2007/1281 Report

Learning from Demonstration

- **Early plants are typically small scale.**
- **Focus is on learning, not operating efficiency**
- **Economic and performance benefits occur with scale-up**
- **Early adopters enter at commercial scale and cost**
- **Maturity and larger plant size will continue to reduce costs**



Range of uncertainty shown due to geography (local costs), fuels, and storage reservoir characteristics

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