POWERSPAN®
Clean Energy Technology

Field Testing and Independent Review of Post-Combustion CO_2 Capture Technology

Presented by Phil Boyle, President and COO, Powerspan Corp.

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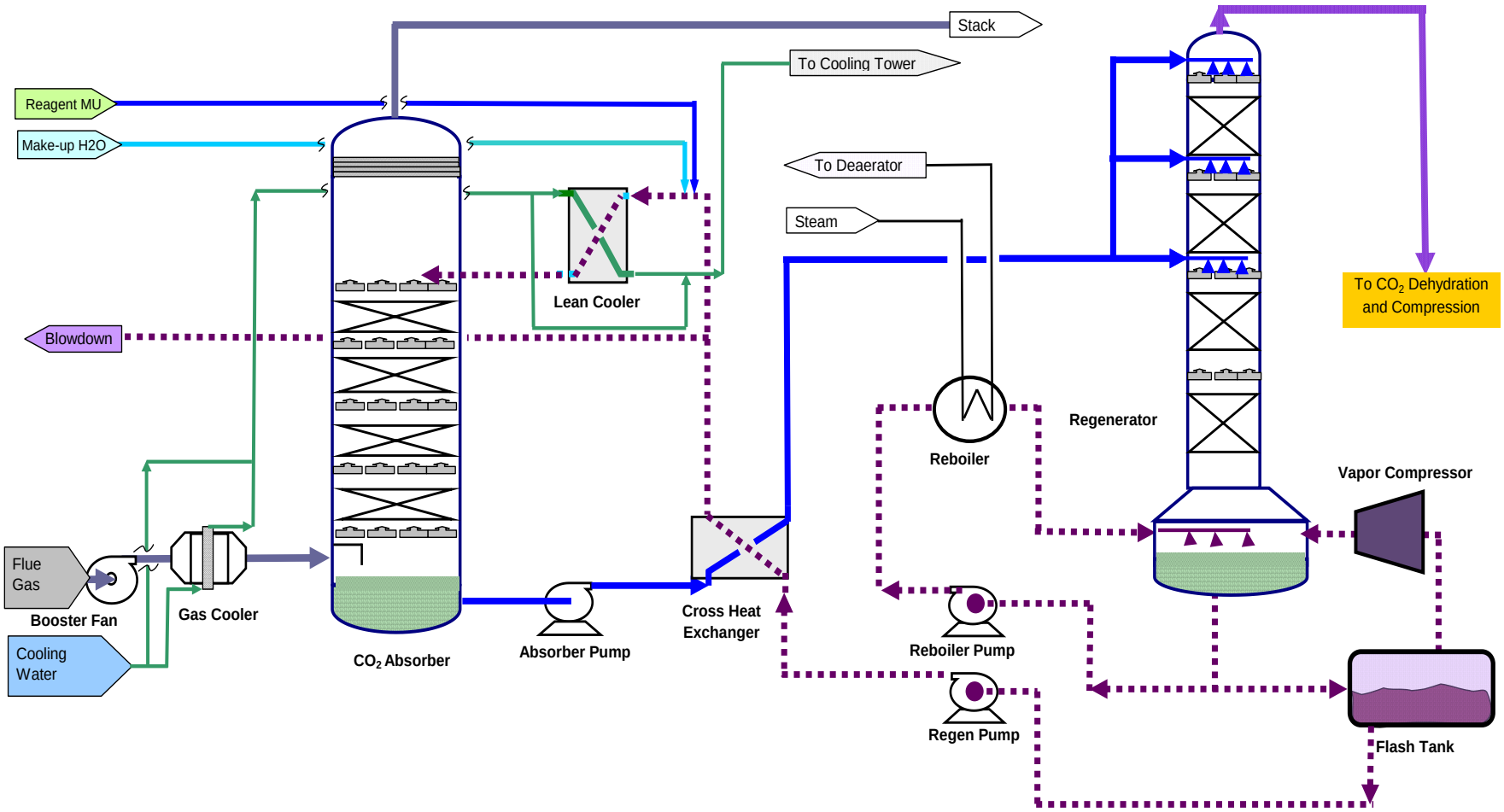
Description of ECO_2® Technology

- 90% CO_2 capture using absorption-regeneration process
- Packed-bed absorption tower, similar but smaller regeneration tower
- Uses proprietary solvent, but chemicals are readily available
- Solvent is stable from both thermal and oxidative degradation
- Tolerant of higher levels of SO_2 (40+ ppm); in many cases obviates need for a polishing scrubber
- Relatively low energy of regeneration – extraction steam heat less than 1000 BTU/lb of CO_2
- No interaction with Powerspan's SO_2 removal technology; can be installed after conventional SO_2 scrubbers

ECO_2 Process Flow Diagram

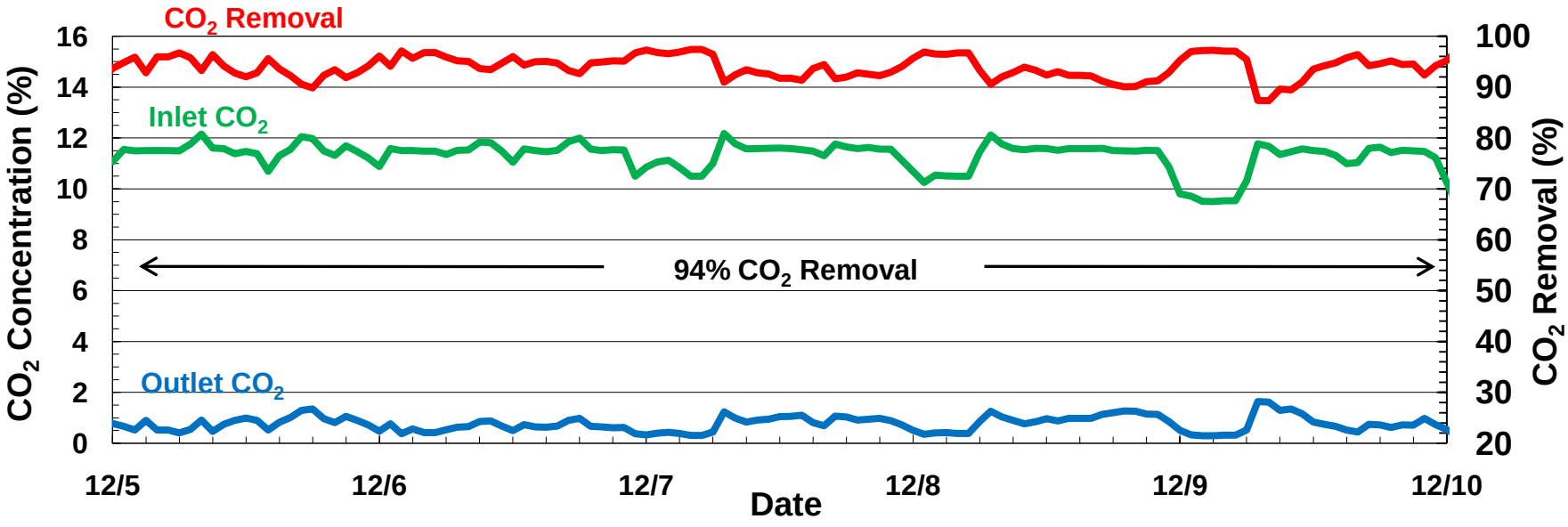


ECO_2 Pilot Plant

- At FirstEnergy's R.E. Burger Plant in Southeastern Ohio
- 1 MW capacity, 20 tons CO_2/day
- CO_2 capture >90% with 11-12% CO_2 in inlet gas
- Constructed using commercial equipment
- Designed to evaluate performance and economics for scale-up
- Demonstrates process performance and control under varying, real world plant operating conditions
- Initial flue gas flow – December 2008

ECO_2 Pilot Performance Test Results

- >90% CO_2 removal at full system flow
- Regeneration energy provided by extraction steam: 1,000 Btu/lb of CO_2
- Product gas meets Kinder-Morgan pipeline standards for concentration
  - O_2: 8 ppmv, H_2O: 16 ppmv, SO_2: <0.02 ppmv, H_2S: <0.5 ppmv
  - Hydrocarbons: <0.5%, N_2 <0.05%



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Background of Independent Assessment

- Independent review of Powerspan's ECO_2 carbon capture process
- Two-part study
  - Validate pilot design, operation, and performance
  - Assess commercial scale-up potential based on pilot results
- Selection of WorleyParsons
  - Worldwide experience in power, oil and gas, and chemical process industries
  - Supported USDOE NETL's Baseline Study of CO_2 capture technologies / costs
  - Commissioned by the Global CCS Institute to participate in strategic analysis of global status of CCS and CO_2 capture technologies

Approach to Pilot Assessment

- Study Objectives
  - Determine if the ECO_2 pilot is designed and constructed in such a way that it is a good representation of a large-scale ECO_2 unit (200 MW and higher)
  - Determine if the ECO_2 pilot is instrumented and operated in such a way as to produce reliable and meaningful results for the specification and design of a large-scale commercial unit
- Methodology
  - Visited, inspected, and observed operations of the ECO_2 pilot at FirstEnergy's R.E. Burger Plant in Ohio
  - Verified installation and operations per PFD, P&IDs, and operating procedures, including instrumentation calibrations and cross-checks
  - Counter-checked information on process and design using sources available in the public domain
  - Evaluated scale-up for the major equipment

Conclusions of Pilot Assessment

- Concluded that the ECO_2 pilot has demonstrated a reliable CO_2 capture process
- Verified that the pilot is constructed and operated as was intended
- Determined that the pilot is a good representation of the ECO_2 process
- Confirmed that the pilot data provide a sound basis for scale-up to commercial size units

Approach to Commercial Assessment

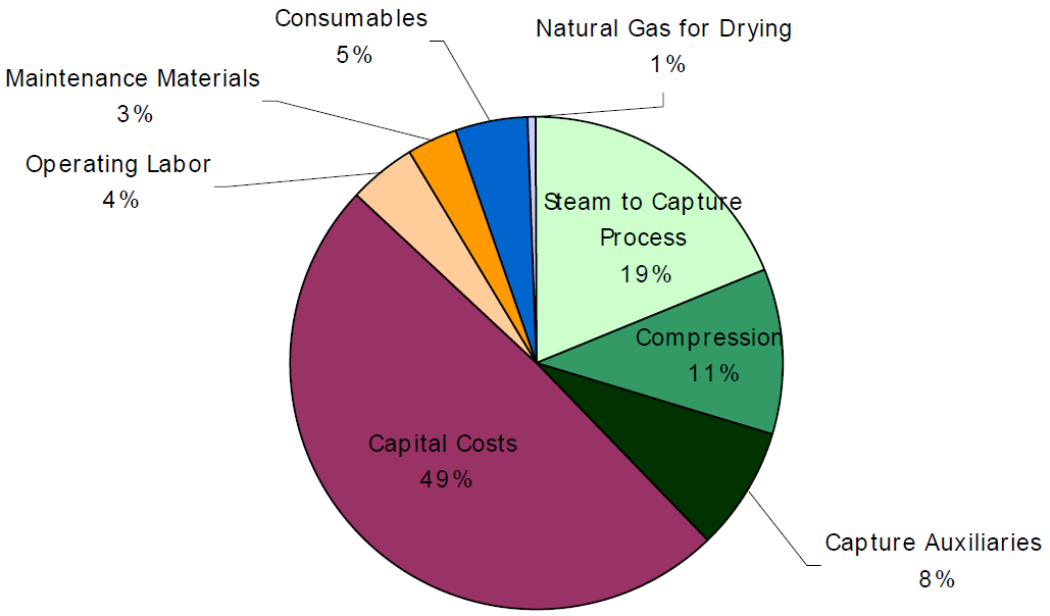
- Assess the performance and cost implications of scale-up and retrofit of the ECO_2 technology to commercial power plants (200 MW and greater)
- Selected 220 MW_{net} (234 MW_{gross}) with subcritical steam cycle
- CO_2 intensity of 1.14 tons of CO_2/MWh; 1.68 Mtons of CO_2/year
- Analyzed impact of ECO_2 process to the following plant systems:
  - Flue gas system
  - Steam and condensate system (using WorleyParsons in-house simulation models)
  - Circulating water cooling system
  - Water supply and treatment
  - Electrical system
  - Data acquisition and control
- Analyzed impact on maintenance and reliability

Conclusions of Commercial Assessment

- The ECO_2 technology is read for scale-up to 200+ MW units
- Economic analysis included:
  - Capital levelized over 20 years
  - Impact of added electrical load (33,470 kW, includes compression of CO_2 to 2200 psig) valued at $50/MWh
  - Impact of lost generation due to steam extraction (31,800 kW) valued at $50/MWh
  - Consumables
  - Maintenance and labor

Total Cost of CO_2 Captured: $36.61/ton of CO_2

(Selling Price of Electricity: $50.00/MWh)



Cost Drivers

- Capital cost contribution impacted by financing assumptions
- Use cost of power to evaluate lost generation and parasitic load increase (View as plant "selling" power to ECO_2 process)
- Value assigned to power has significant impact on $/ton result – 68% of operating cost is proportional to power cost
- Plant impact in terms of lost generation strongly affected by carbon intensity. Reference plant at 1.14 tons of CO_2/MWh. Many existing plants at 1.0 to 1.1 tons of CO_2/MWh. New SCPC may be as low as 0.89 tons of CO_2/MWh.
- The study's reference plant had reduced net output of 30%; Powerspan estimates this would be 18% for a USCPC unit at 0.77 tons of CO_2/MWh

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