CARBON MANAGEMENT TECHNOLOGY CONFERENCE

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CO_2 Capture Using Advanced Carbon Sorbents

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Overview

- Process Overview
- Experimental Results
- Economic Analysis
- Future Development Plans
- Conclusions and Summary
- Acknowledgements
- Questions

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Process Description

- Adsorption of CO_2 from flue gas on a selective and high capacity carbon sorbent.
- Ability to achieve rapid adsorption and desorption rates (no solid state diffusion limit).
- Minimize thermal energy requirements
- Ability to desorb as pure CO_2.
- A cascading reactor geometry integrating the adsorber and stripper in a single vertical column
  - Provides a low pressure drop for gas flow and minimize physical handling of the sorbent.

Merits of the Sorbent – Chemical Properties

- High CO_2 capacity:
  - The sorbent has a high capacity for CO_2 adsorption (20 wt% at 1 atm CO_2) and good selectivity for CO_2 over other flue gas components.
- Rapid adsorption and desorption rates:
  - The adsorption of CO_2 occurs on the micropores of the sorbent with very low activation energy (<5 kJ/mole), allowing rapid cycling of the sorbent.
- Low heat of adsorption and desorption:
  - The relatively low heats (28 kJ/mole) indicate that this process has a low heat demand for regeneration and low cooling requirements.
- High oxidation resistance and hydrothermal stability:
  - Carbon does not oxidize under the operating conditions.
  - Direct heating with steam can be used for CO_2 desorption.

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Merits of the Sorbent – Physical Properties

- Mechanical robustness for long lifetime:
  - Hard and attrition resistant; Unusually tough for a high surface area (1600 m^2/g) porous solid.
  - ASTM Test D-5757: Attrition resistance very high: Weight loss <0.01%/hour
- Spherical morphology of the sorbent granules:
  - The spherical nature of the sorbent granules (100 to 300 μm in diameter) allows a smooth flow on an inclined surface, like a ball bearing.
  - This free-flowing, liquid-like characteristic allows the use of commercially available structural packing as the gas-solid contacting device.
- Low heat capacity:
  - The low heat capacity of the sorbent (1 J/g/K) and low density (1 kg/m^3) minimizes the thermal energy needed to heat the sorbent to the regeneration temperature.
- High thermal conductivity:
  - The thermal conductivity of 0.8 w/m-K enables rapid thermal equilibrium between the surface and interior.

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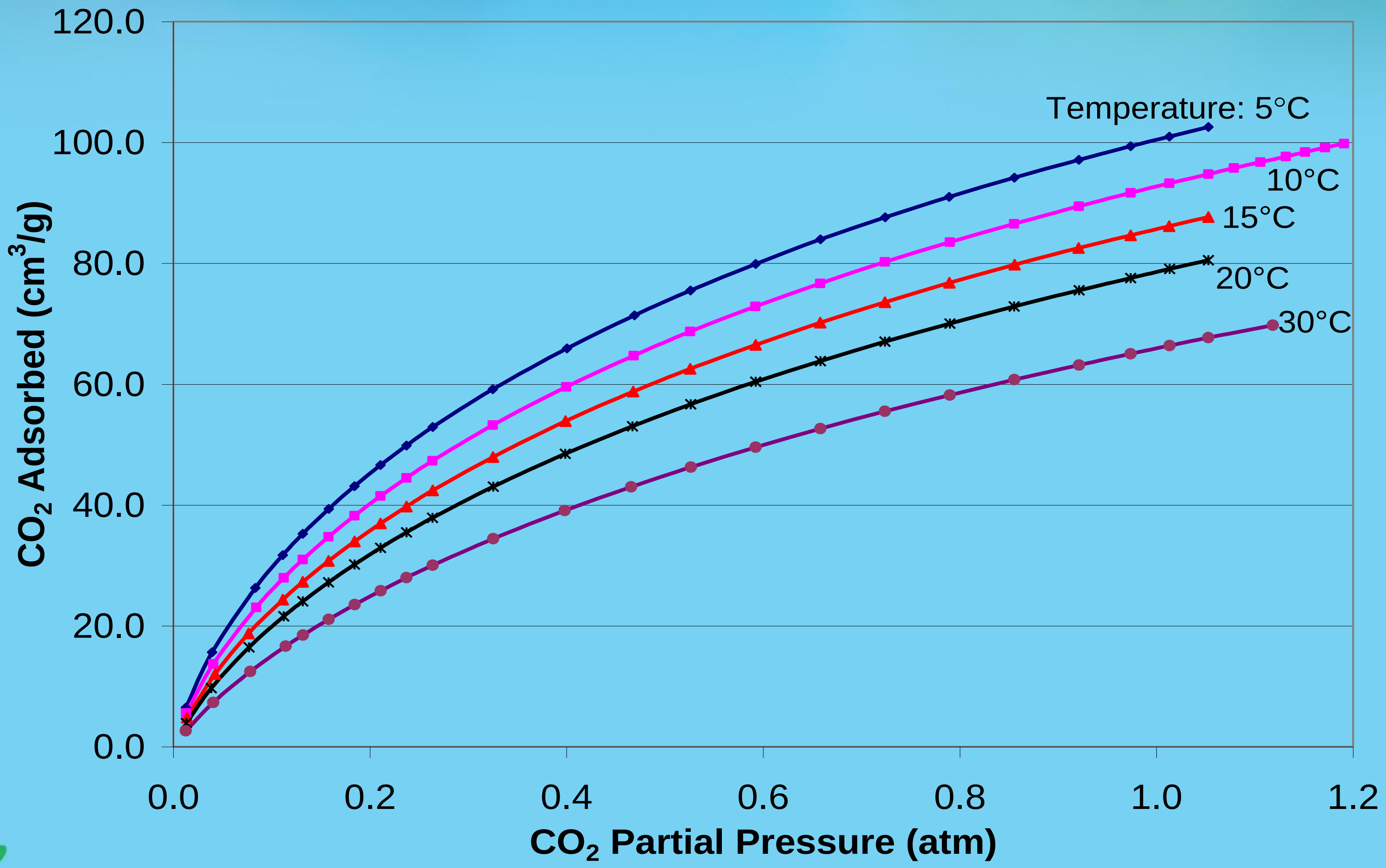
CO_2 Adsorption Isotherms



100 cm3/g = 20 wt% CO_2

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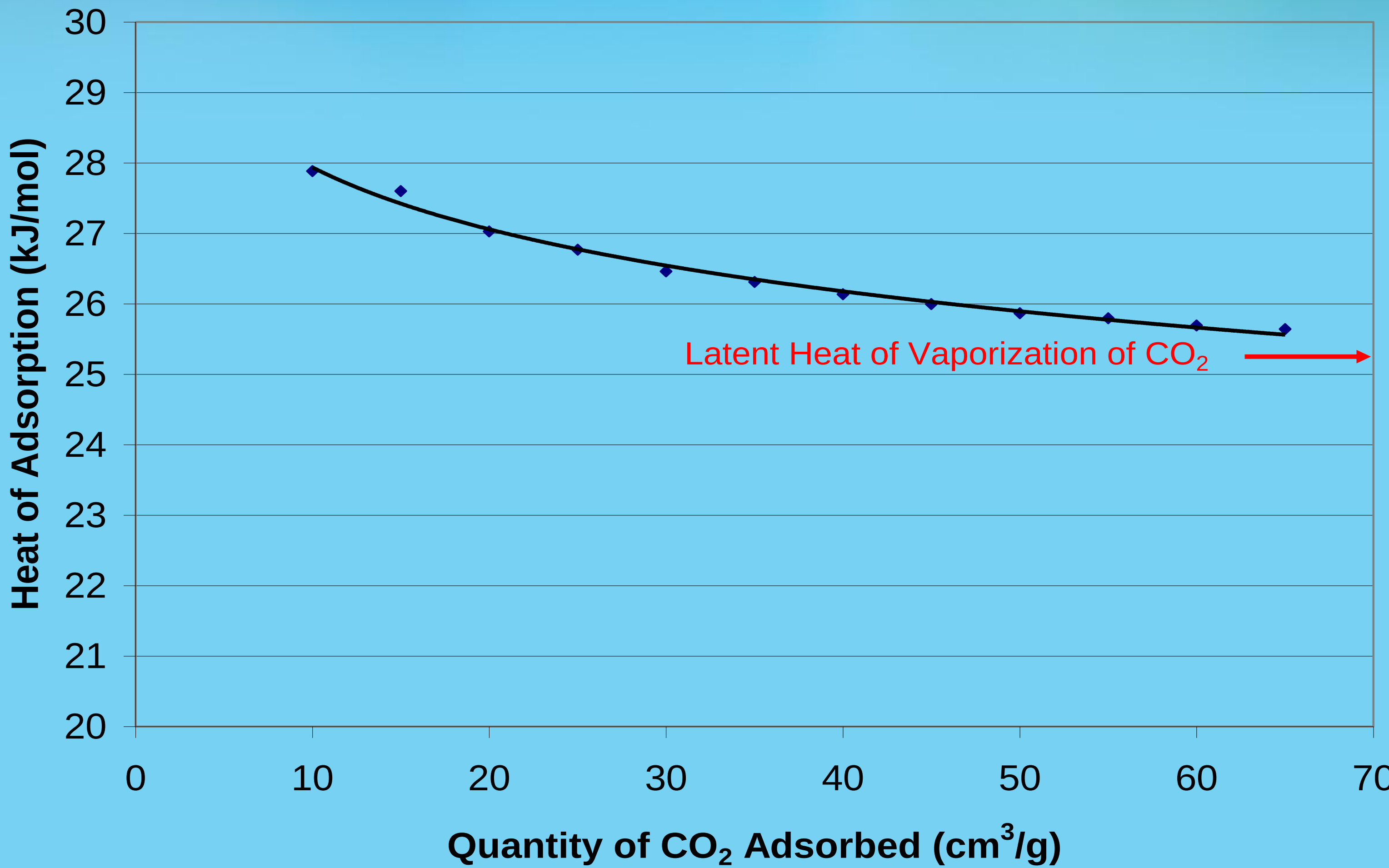
Heat of Adsorption for CO_2 on ACS Sorbent



Note: Measured heat of desorption = 27 kJ/mole

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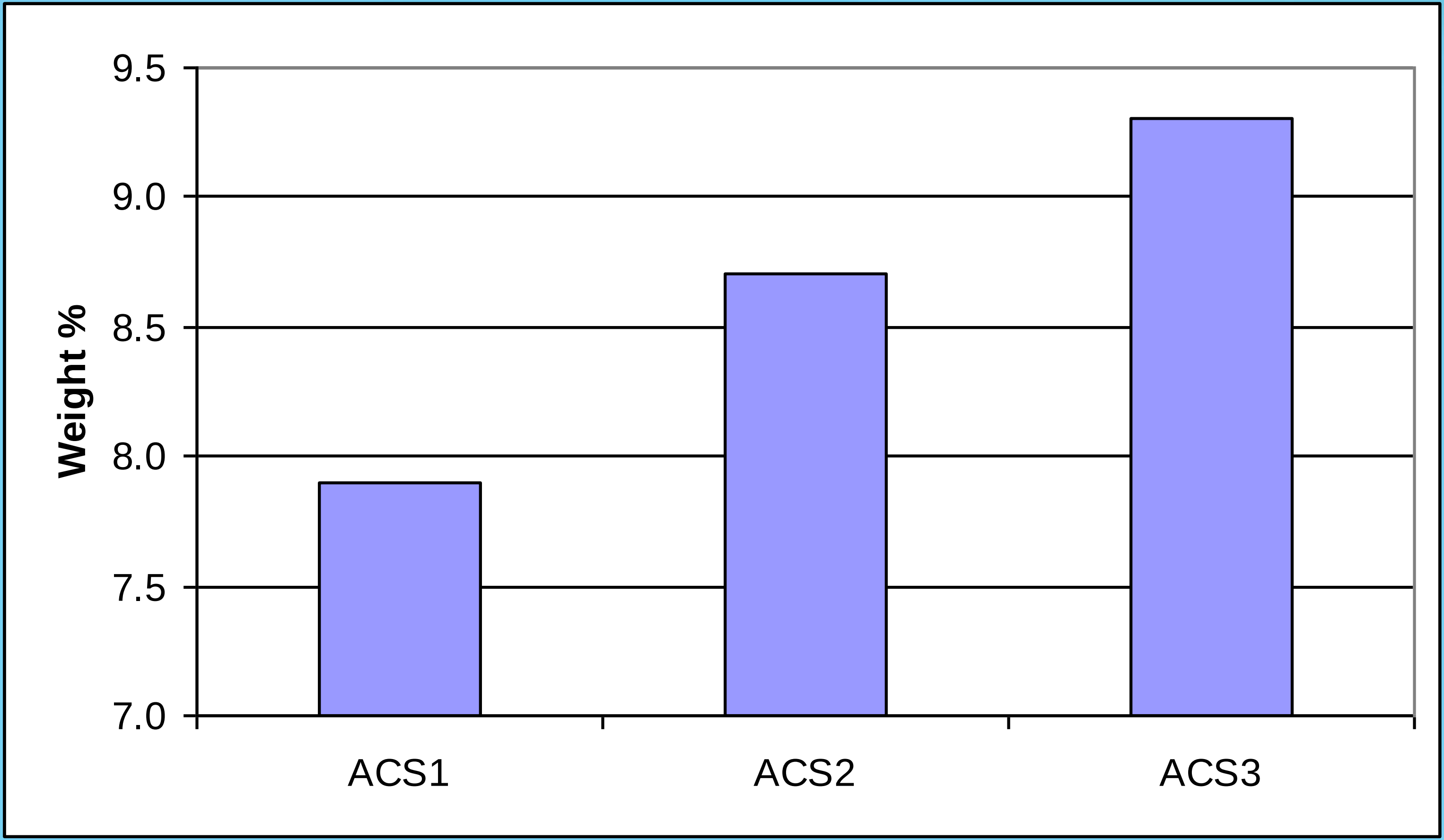
CO_2 loading Between 30° and 110°C on ACS Sorbents



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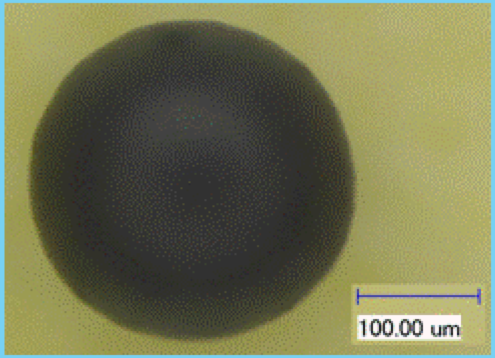
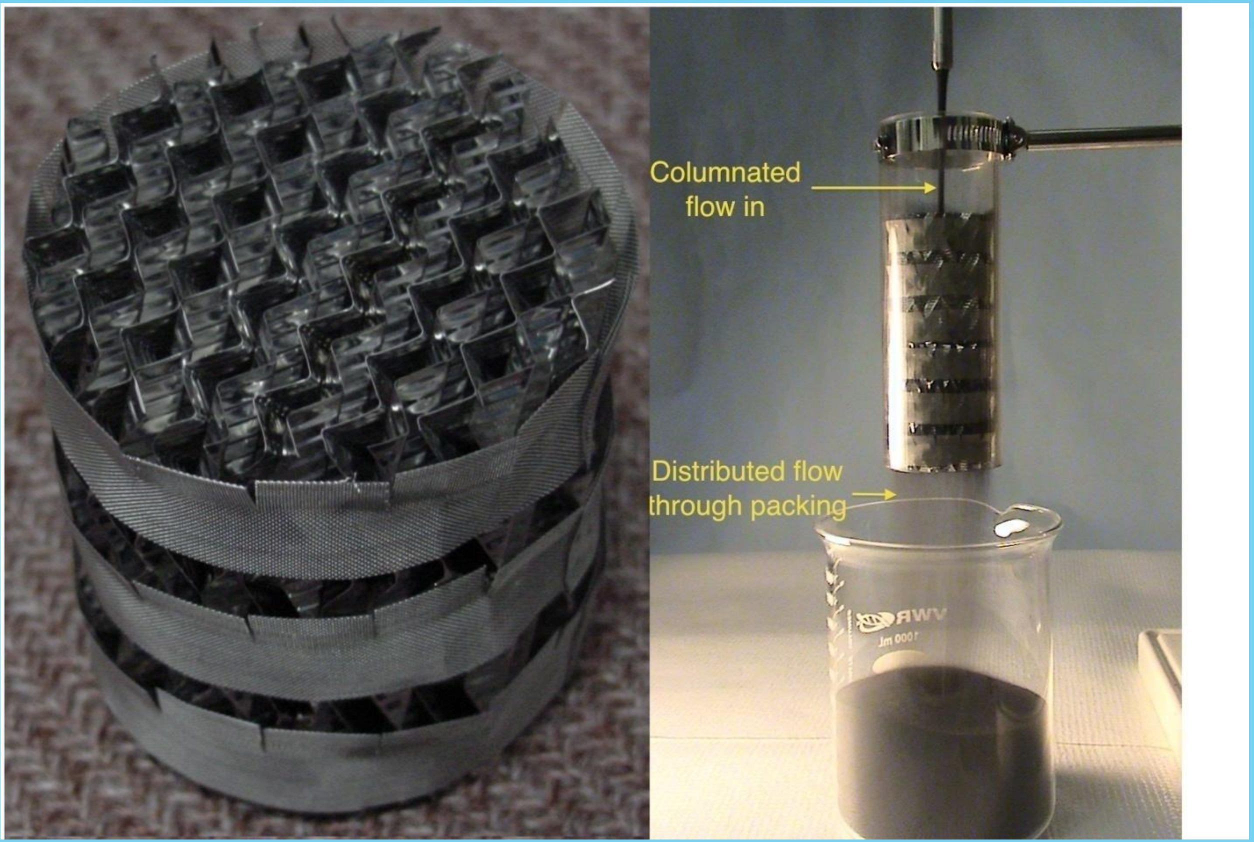
Fluid-like Flow of Sorbents Through a Commercial Structural Packing





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Rapid Adsorption and Desorption of CO_2

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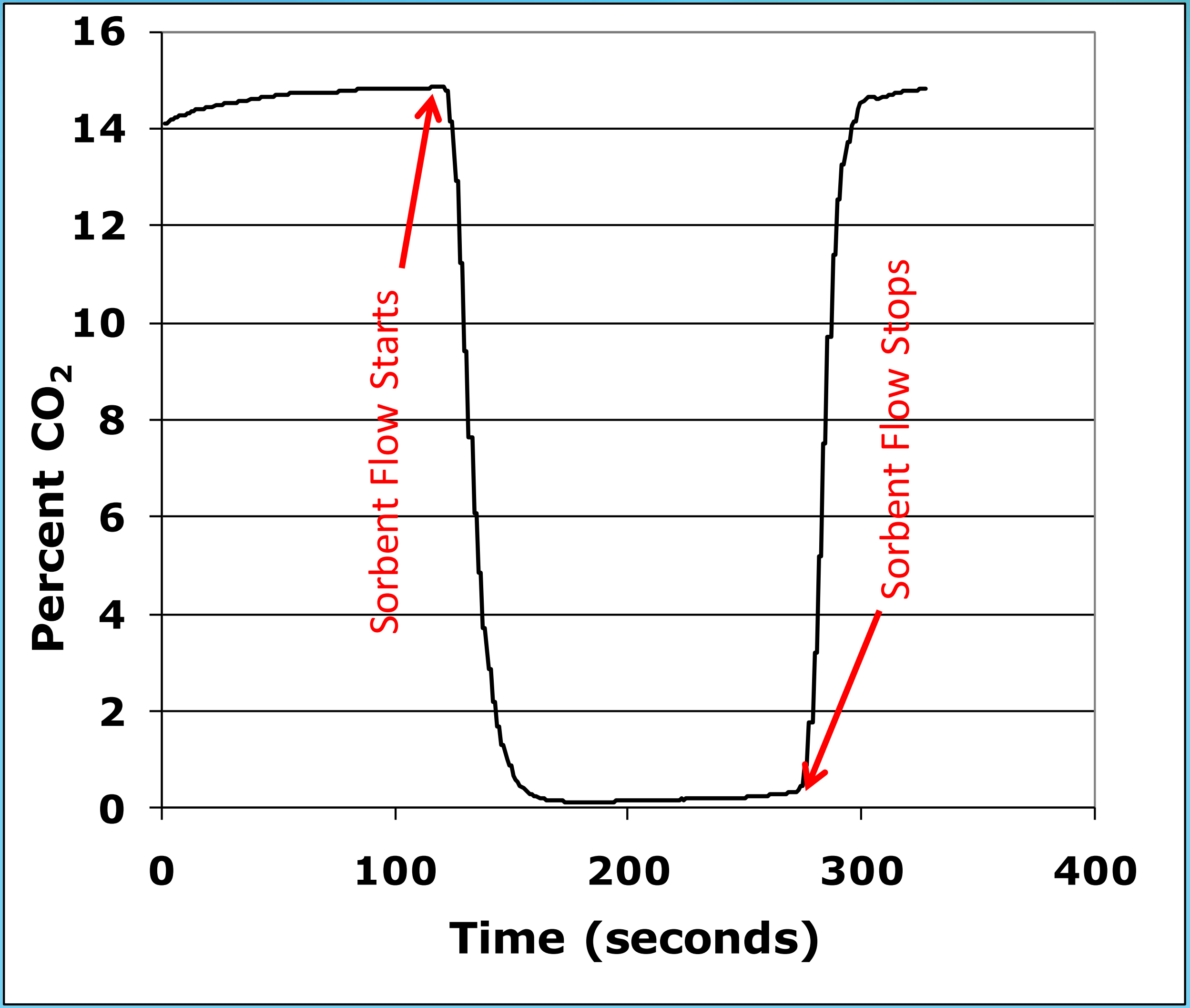
Removal of CO_2 from Air-CO_2 Mixture



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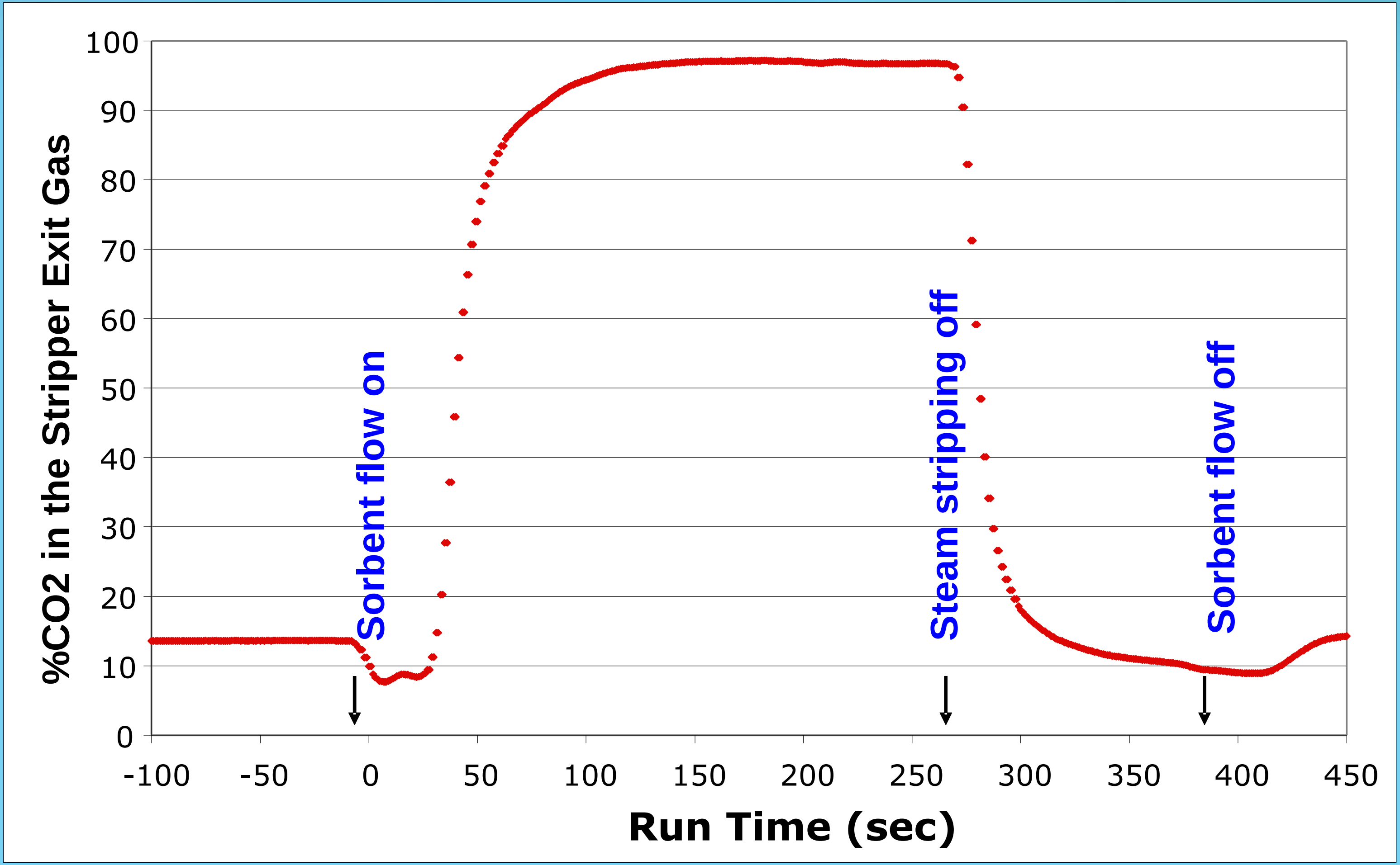
Evolution of CO_2 in the Stripper



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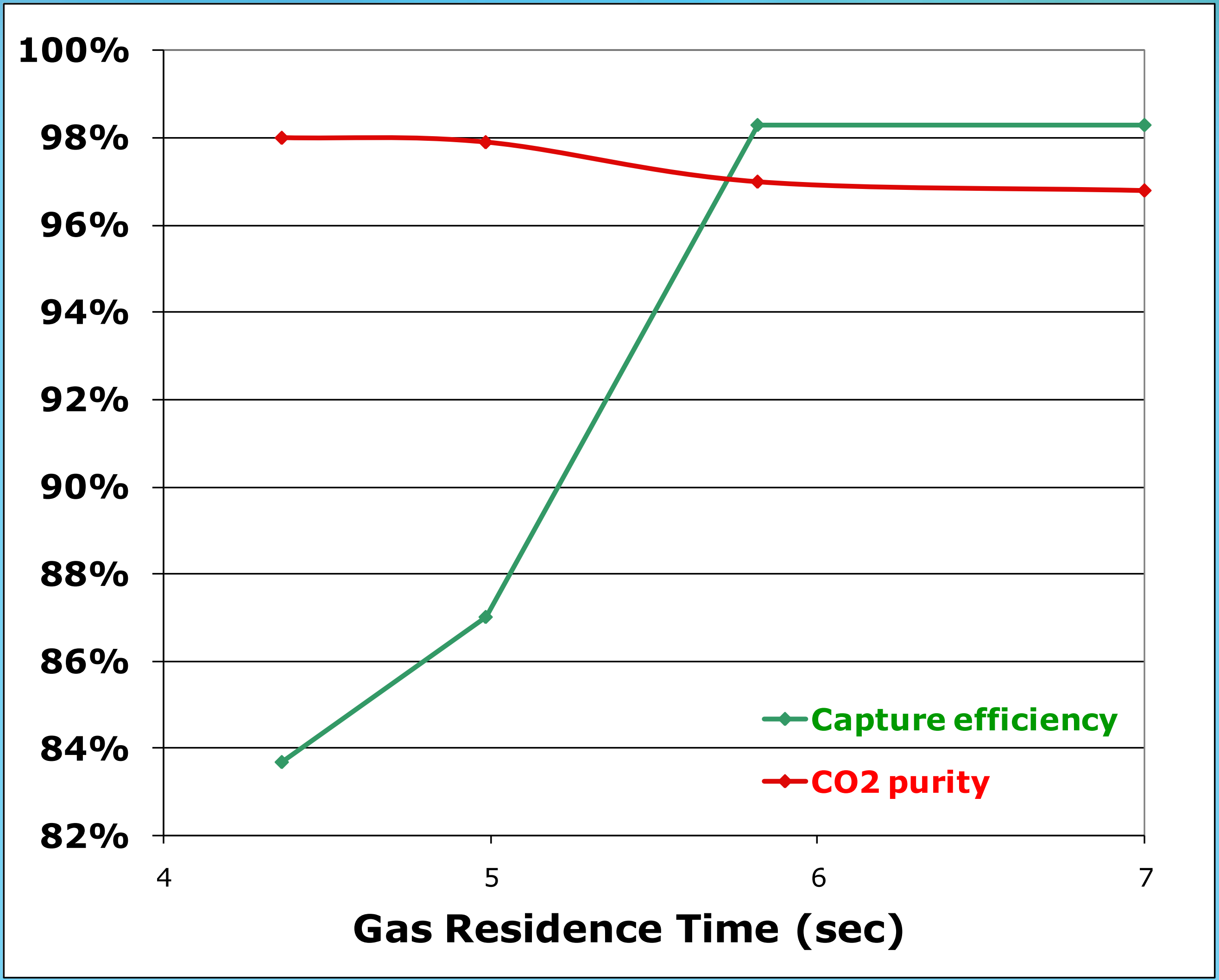
Capture Efficiency and Product Purity



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Integrated Absorber-Stripper Testing Results

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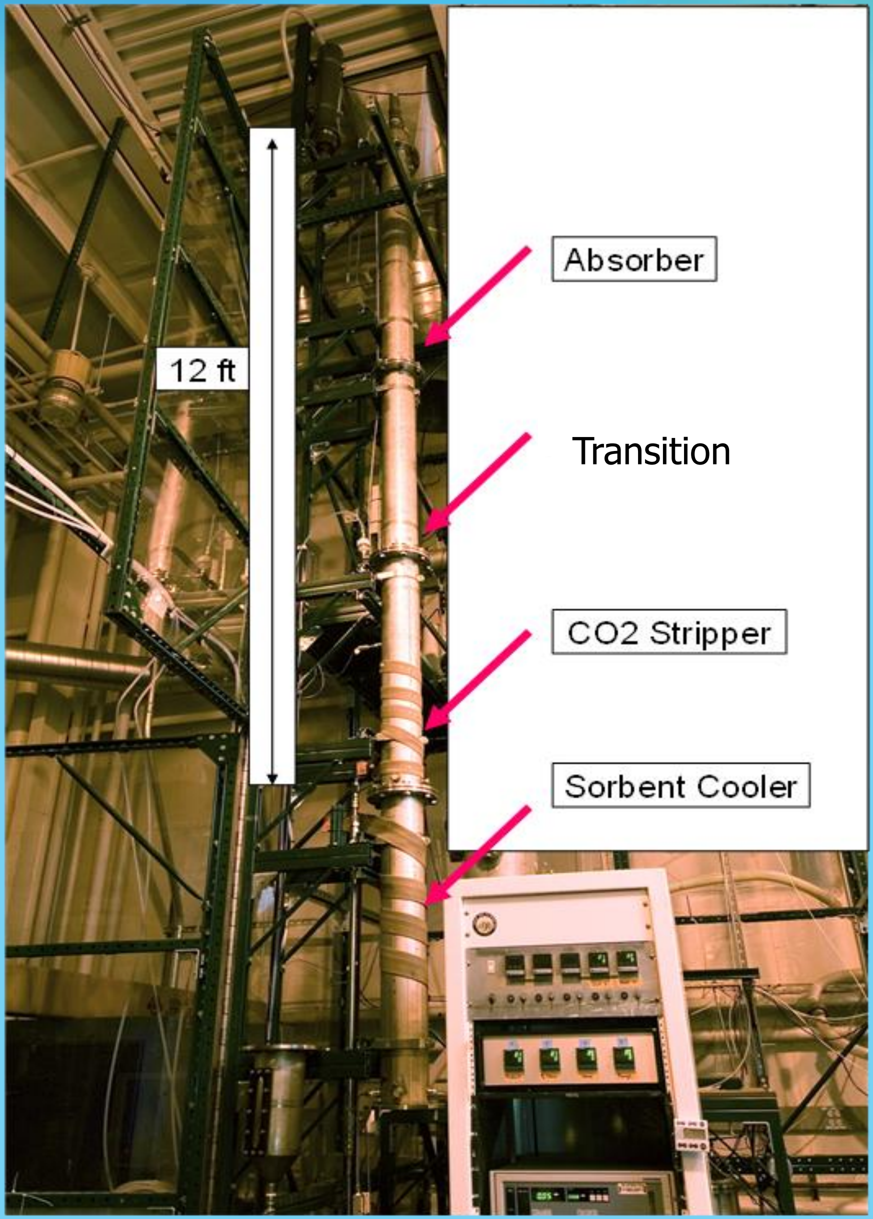
Photograph of Integrated System



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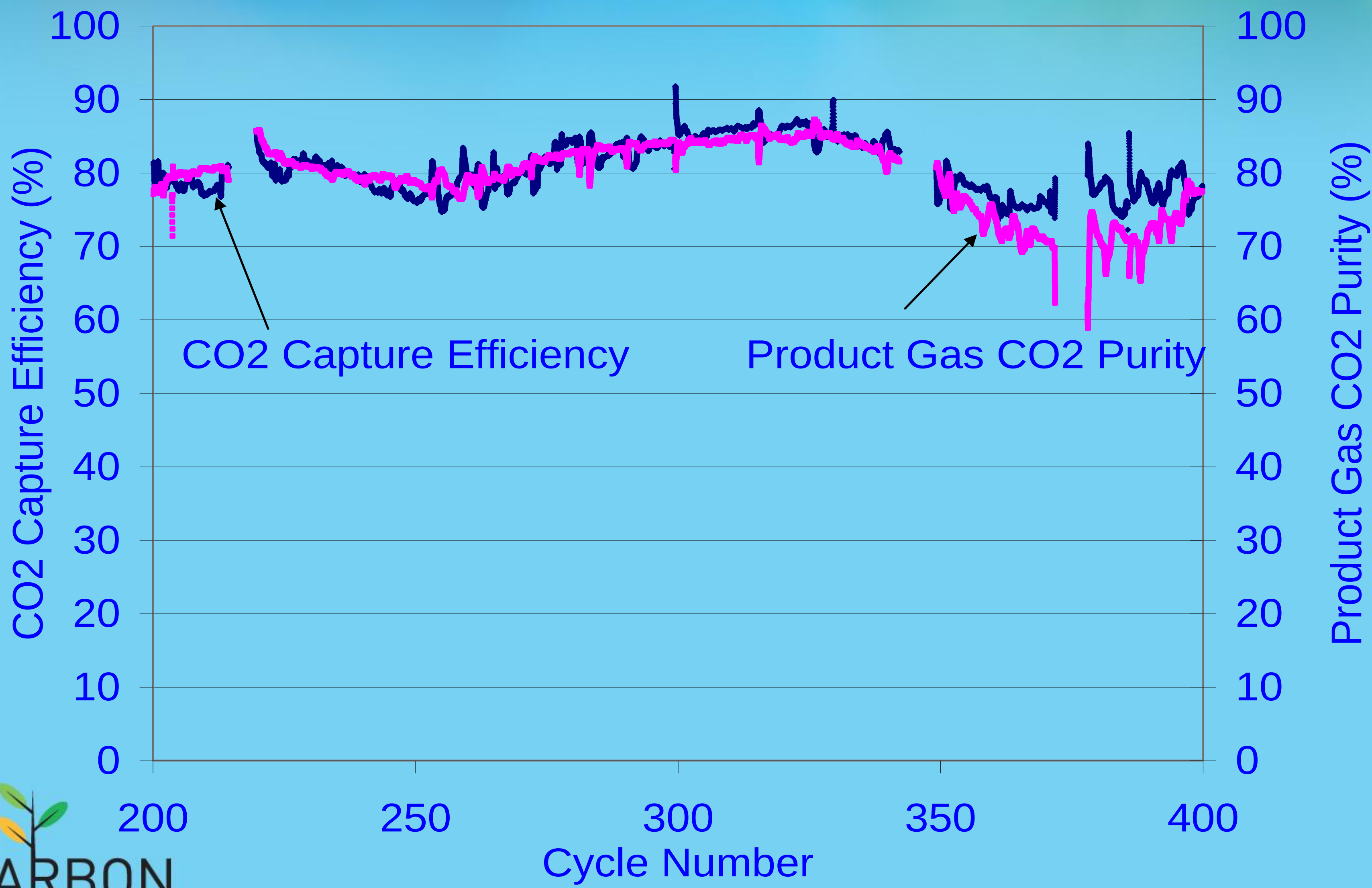
Long-Term Testing (Early Cycles)



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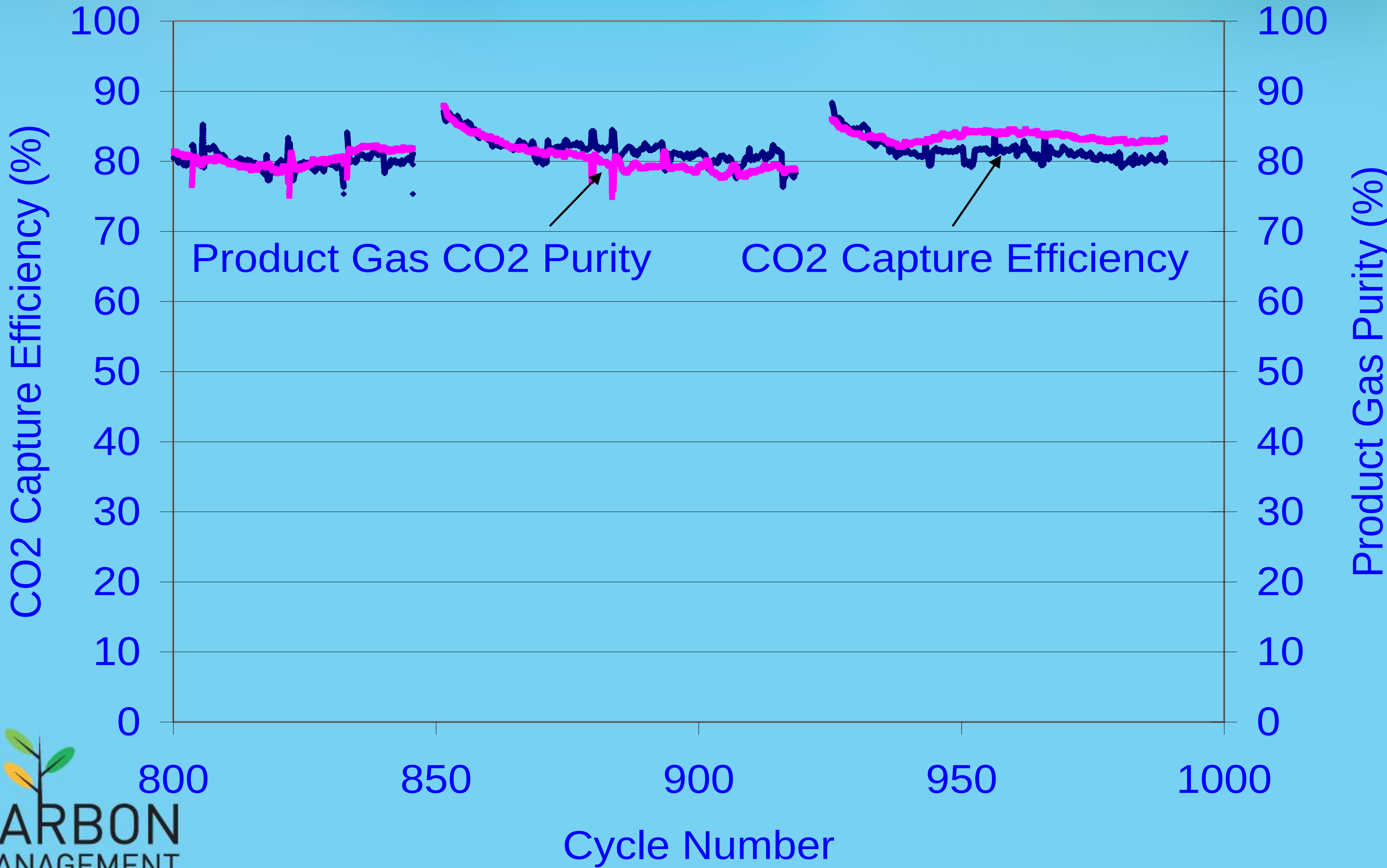
Long-Term Testing (Later Cycles)



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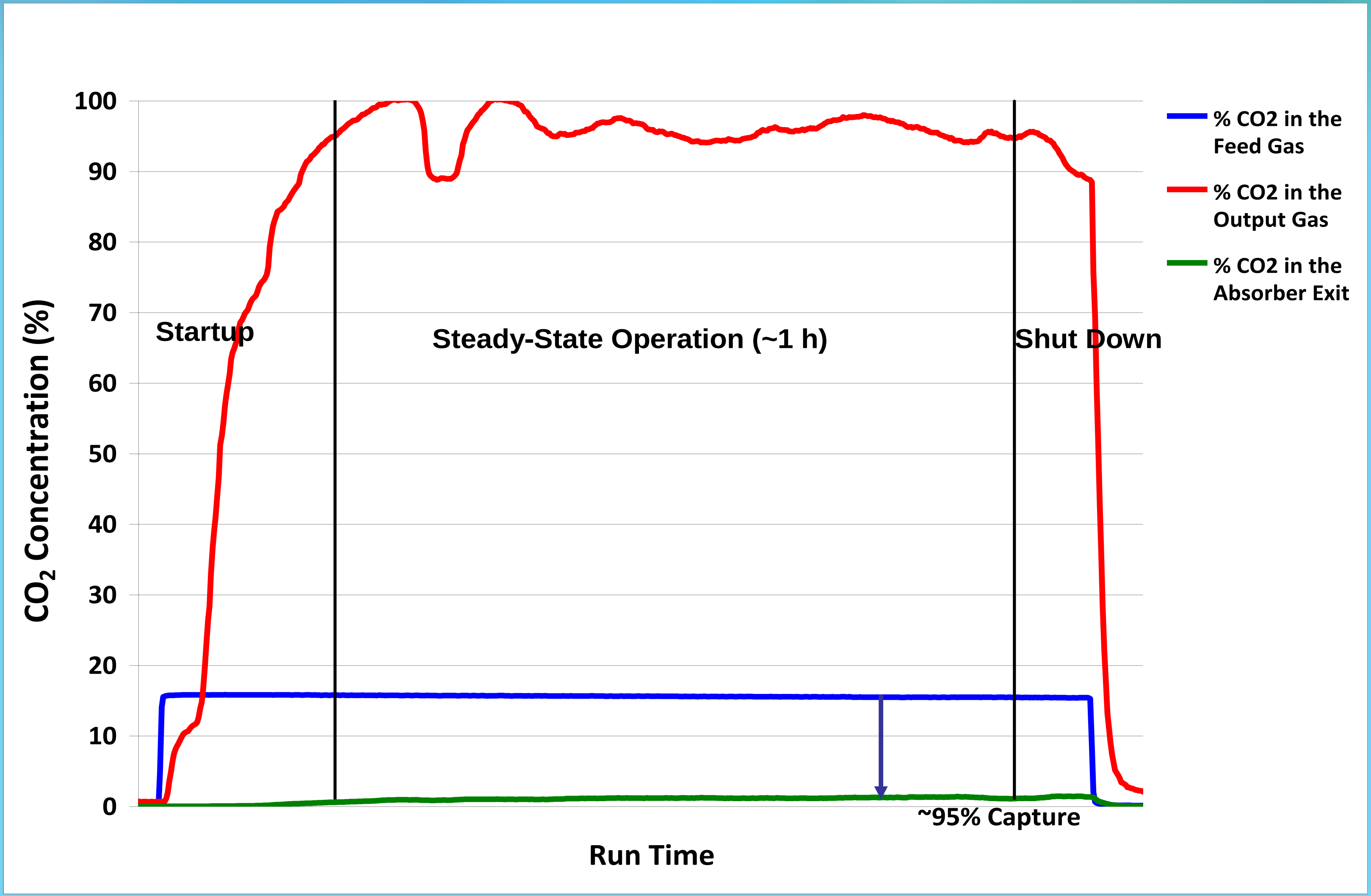
Improved Capture Efficiency and Purity



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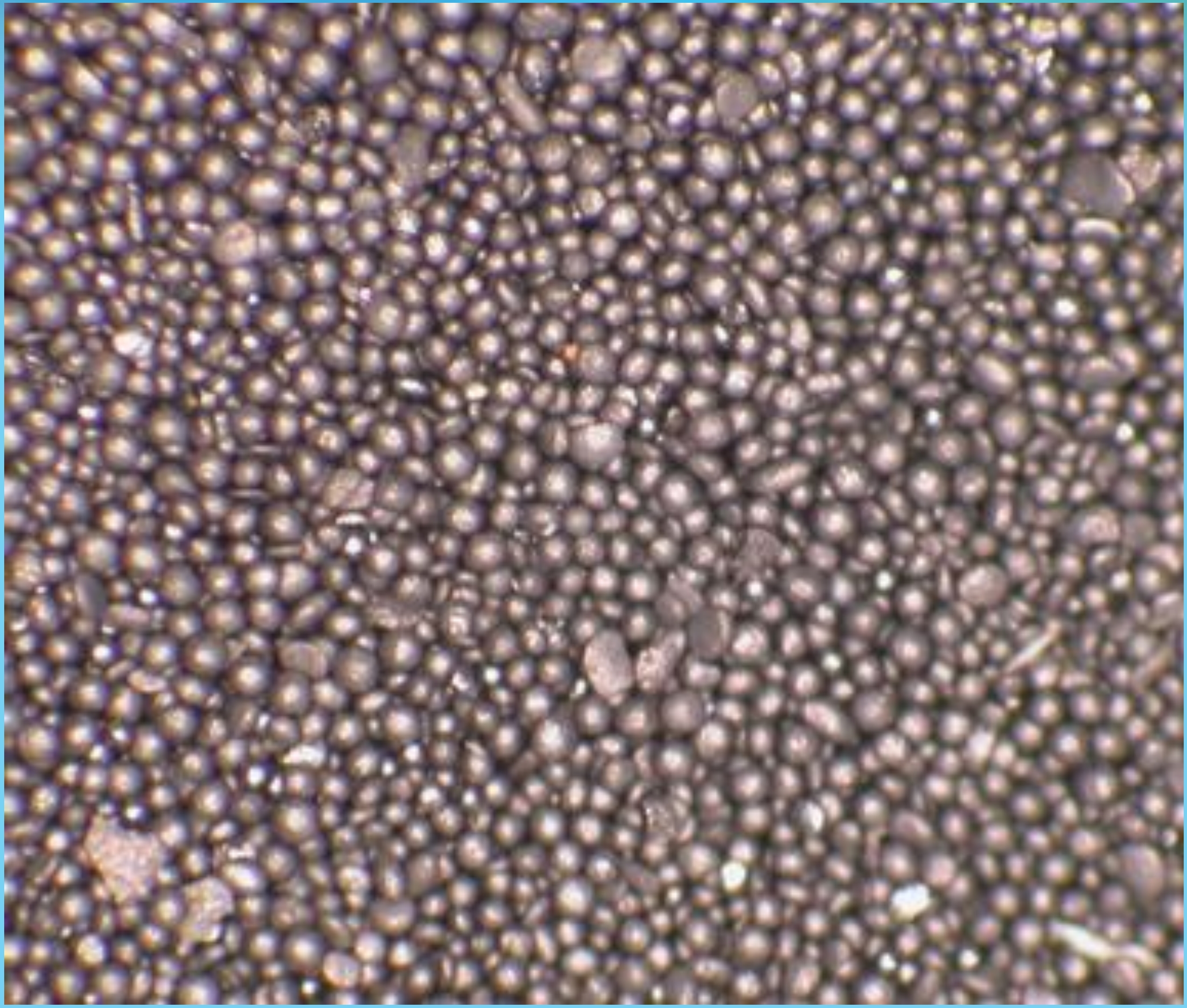
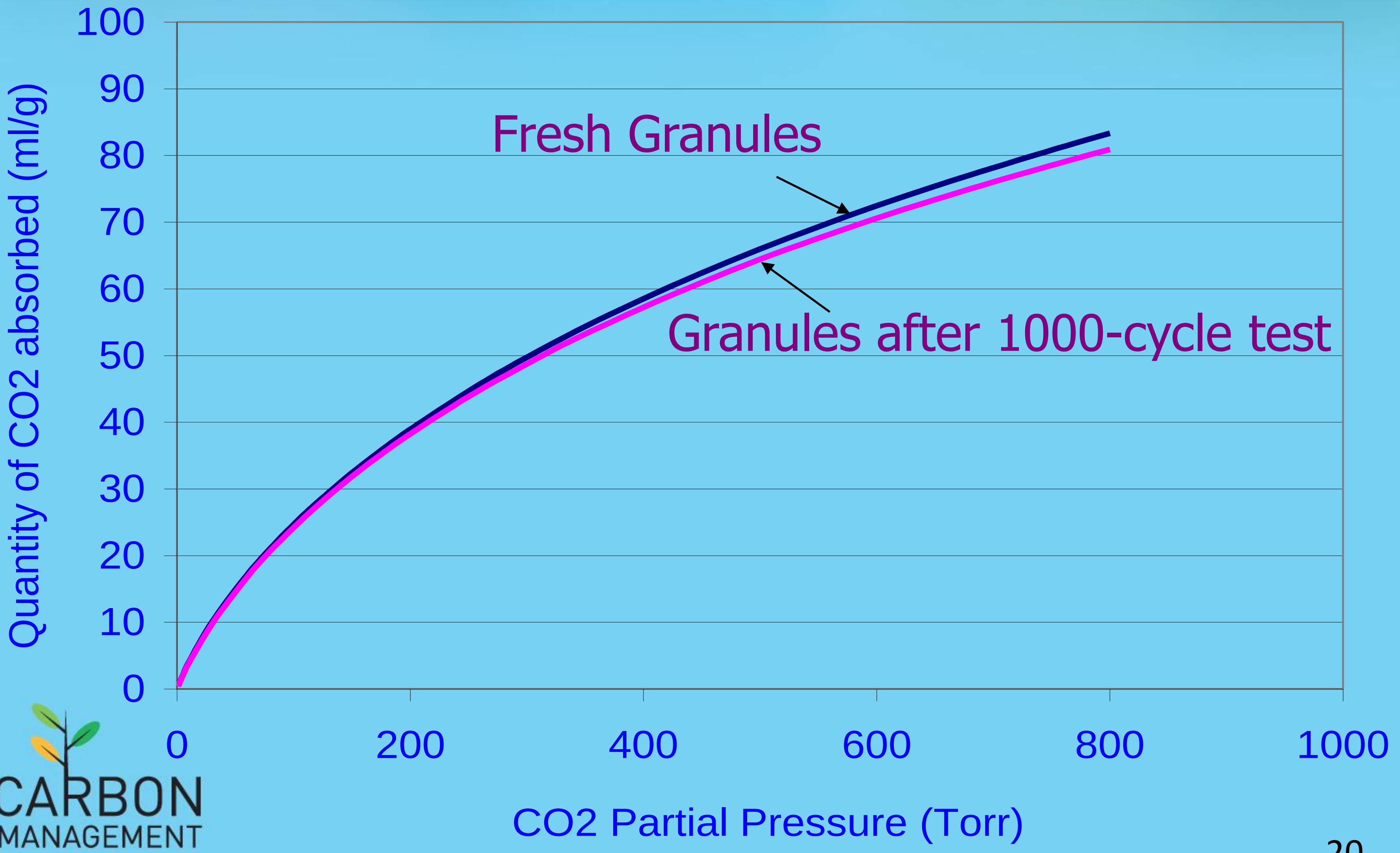
Fine Particles Recovered from Absorber Exhaust



50-hour Test Duration.

Negligible Change in CO_2 Capacity



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Process Economics

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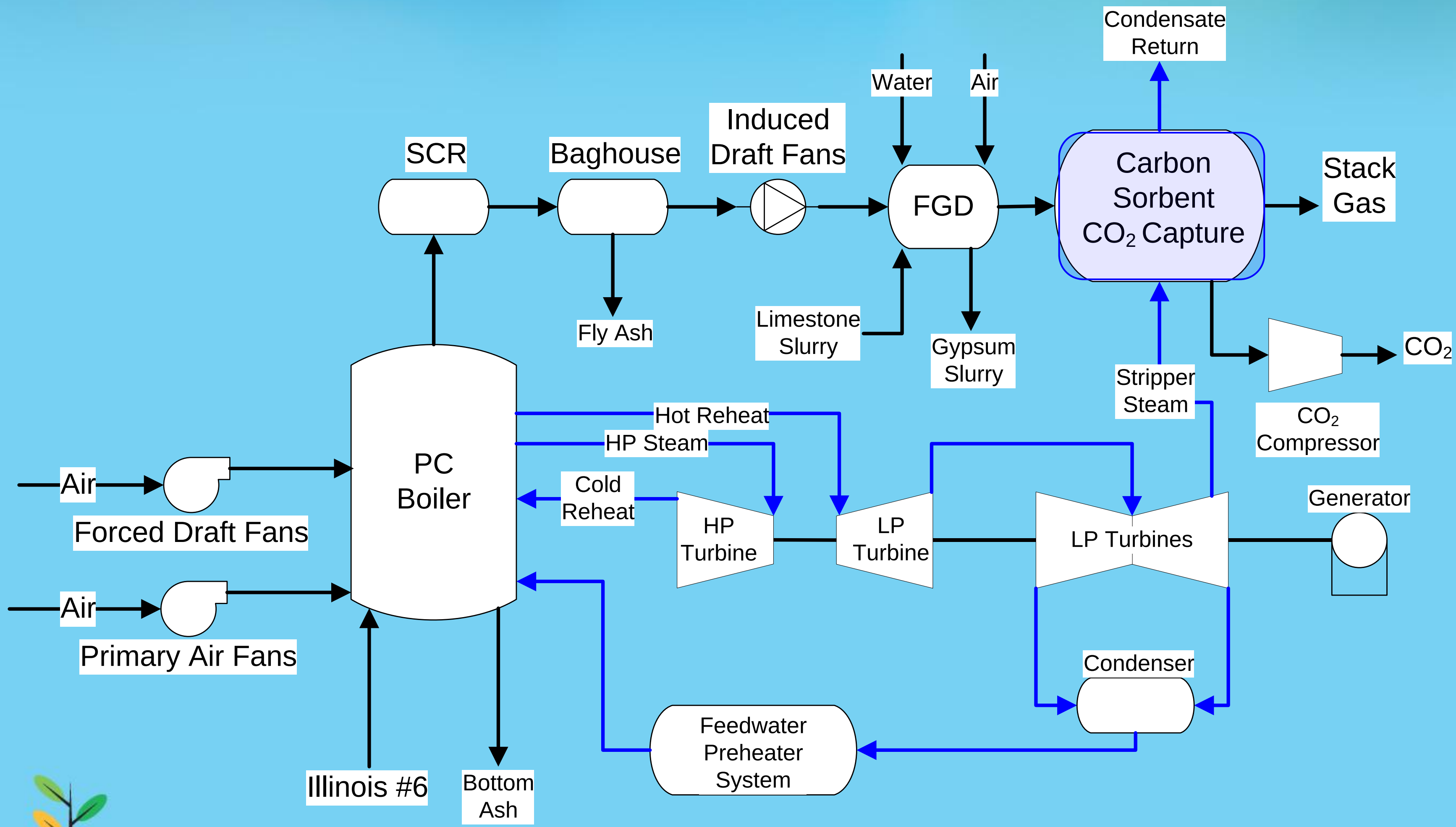
Block Flow Diagram for a Coal-Fired Power Plant



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Technical and Economic Analysis

- Steam-Pro modeling was used to generate the equipment sizing and heat and material flows.
- Use DOE cost models.
- Base case is an air-fired greenfield supercritical PC plant (700 MWe nominal) with no CO_2 capture.
- Compare a similar-size plant using CO_2 capture with carbon sorbent subsystem.

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Comparison of CO_2 Capture Costs

Parameter	Unit	No CO2 Capture	CO2 Capture with Econamine FG+	CO2 Capture with the Carbon Sorbent
Power Production @100% Capacity	GWh/yr	4,818	4,818	4,760
Power Plant Capital	c/kWh	3.17	5.96	4.40
Power Plant Fuel	c/kWh	1.42	1.96	1.55
Variable Plant O&M	c/kWh	0.51	0.87	0.66
Fixed Plant O&M	c/kWh	0.80	1.30	0.96
Power Plant Total	c/kWh	5.89	10.10	7.56
CO2 TS&M	c/kWh		0.56	0.54
BOTTOM LINE TOTAL	**c/kWh**	**5.89**	**10.66**	**8.10**
Increase in COE	**%**	**0.0%**	**80.2%**	**37.2%**

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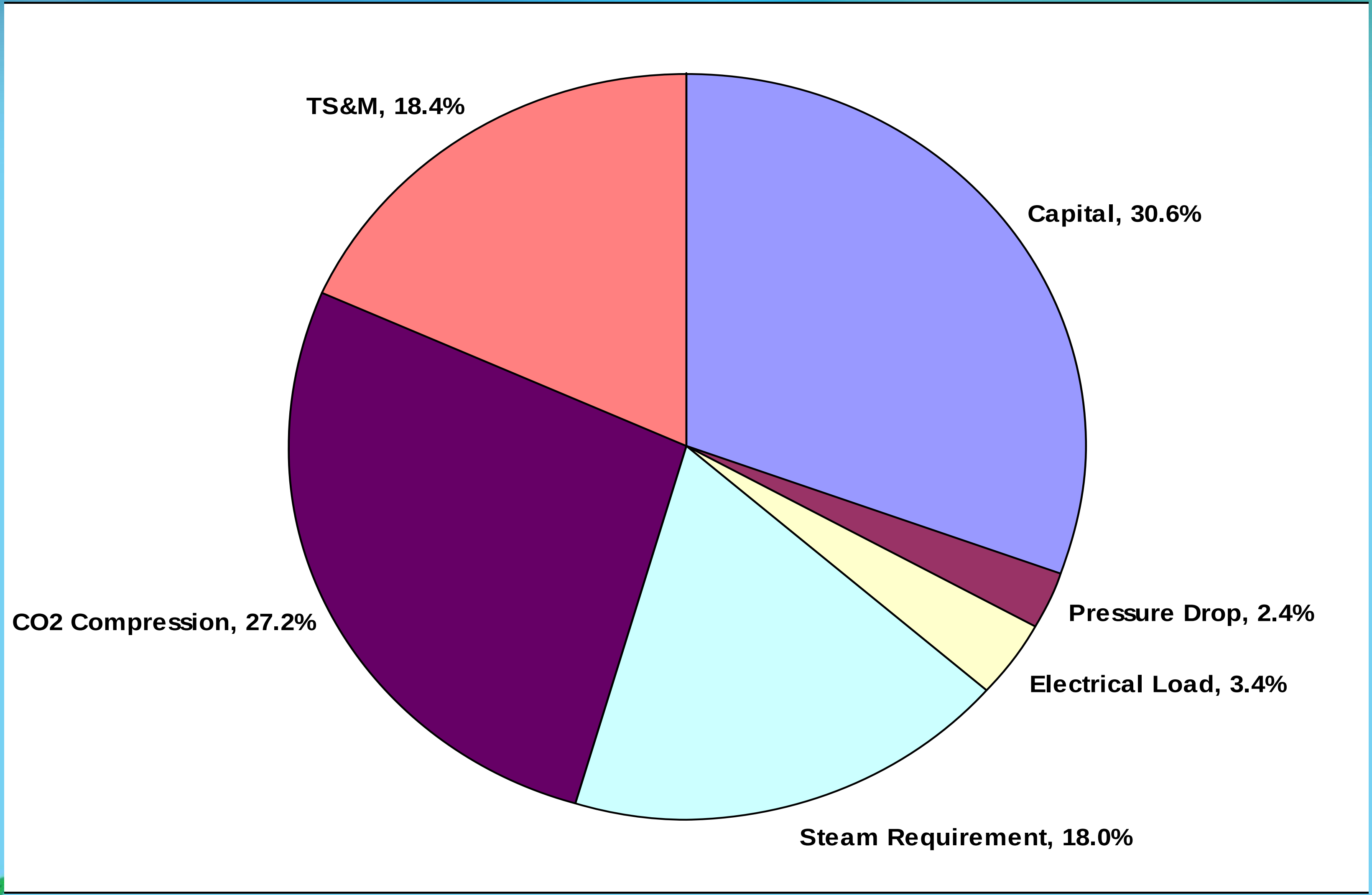
Break-Down of the CO_2 Capture Cost Using ACS Sorbent



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Cost of CO_2 Capture in Chemical Applications

Cost of CO_2 capture depends on the plant size and the concentration of CO_2 in the process gas in chemical applications. Preliminary estimate shows that:

CO_2 capture Size (kilotons/year)	Cost of CO_2 Capture ($/ton) @15% CO_2 in Process Gas	Cost of CO_2 capture ($/ton) @25% CO_2 in Process Gas
40	24.0	20.7
320	14.2	9.4
1600	10.7	6.3

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Conclusions and Summary

- Demonstrated an unique sorbent for CO_2 capture
  - Achieved ~99% CO_2 capture from air-CO_2 gas mixture
  - Achieved >98% pure CO_2 during regeneration
  - Capable of rapid adsorption and regeneration
  - Low heat requirements for regeneration
  - Fluid-like flow properties
  - High attrition resistance.
- Developed an unique reactor system
  - Integrated absorber-stripper geometry
  - Minimize solids handling
  - Minimize heat exchanger requirements
  - Stable operation over thousand cycles.
- The cost of CO_2 Capture is very favorable.

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Future Plans

- Field Testing:
  - Field test the process with the bench-scale reactor using a flue gas from an operating coal-fired boiler – Currently in progress at the University of Toledo.
  - Test the process at a pilot-scale level at a PC-fired boiler site.

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Team

- SRI International
  - Dr. Gopala Krishnan – Associate Director (MRL) and PI
  - Dr. Marc Hornbostel, Senior Materials Scientist
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  - Dr. Angel Sanjurjo – Materials Research Laboratory Director and Project Supervisor.
  - Ms. Barbara Heydorn, Director, Center of Excellence for Energy
- ATMI Inc.
  - Sorbent developer, Industry perspective
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  - Dr. Melissa Petruska, Materials Scientist
  - Dr. Donald Carruthers; Senior Research Scientist
  - Dr. Lawrence H. Dubois, Senior Vice President and Chief Technology Officer.
- DOE-NETL
  - Andrew O'Palko

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