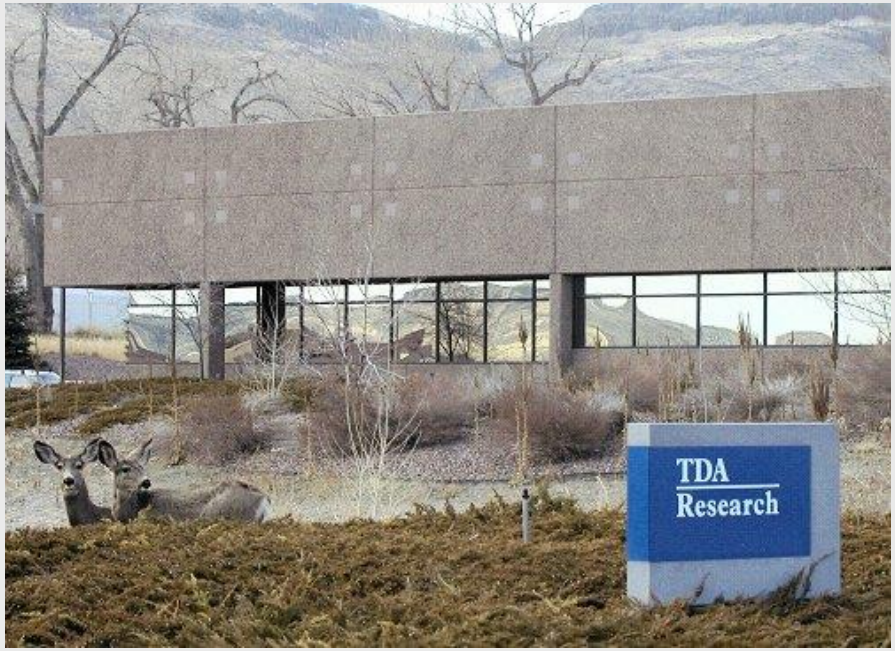
Sorbent Based Post- Combustion CO_2 Slipstream Testing

Project # DE-FE0012870



Jeannine Elliott

Girish Srinivas

Bob Copeland

2014 NETL CO_2 Capture Technology Meeting

July 29, 2014

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Project Overview

DoE Project DE-FE0012870

Funding - Total Project $5,880,378

- DOE: $4,704,509
- Cost Share: $1,175,868

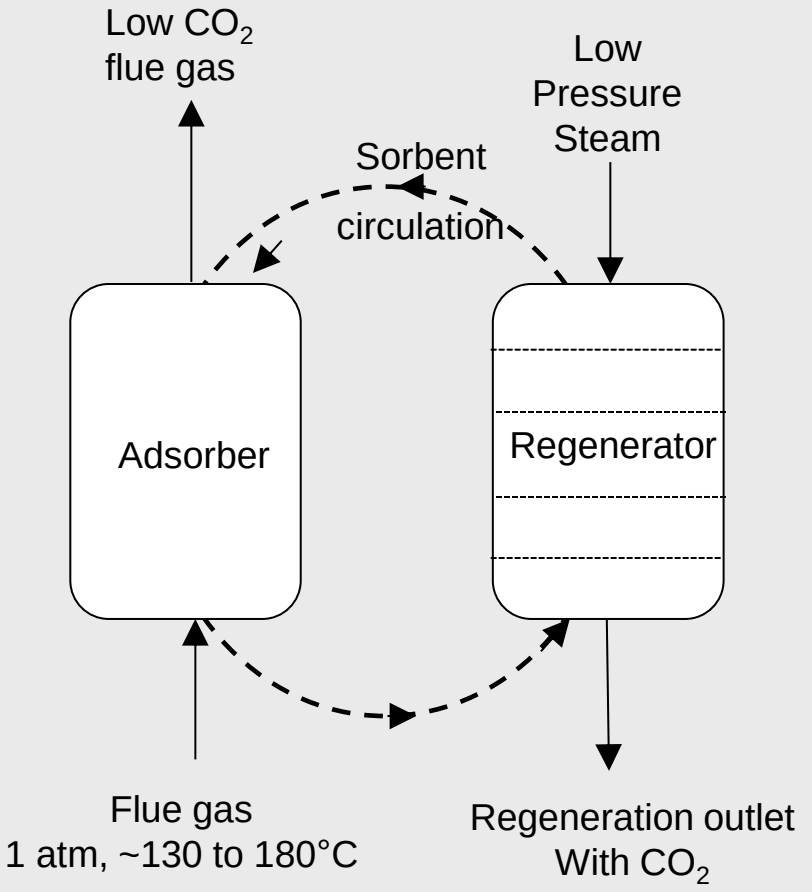
Project Dates

- April 1, 2014 to December 31, 2017

Technology Background & Approach

TDA's Approach

- **TDA Research has developed:**
  - **A solid alkalized alumina adsorbent, and**
  - **An CO_2 capture process designed around this process**



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TDA's Post Combustion CO_2 Capture

- **Process advantages:**
  - An inexpensive, durable sorbent
  - Regenerates with low pressure
  - steam
  - Operates at near isothermal conditions
  - Does not require heat recovery from solids
  - Extremely low heat of adsorption
  - Uses counter-current operation to:
    - Maximize capture efficiency
    - Maximize sorbent loading

Process Design

- Multiple Fixed Bed Contactor
  - Provides counter-flow contact between the solids and gases
- Beds cycle between adsorption and regeneration functions
- Gas flows in series across regeneration beds
- Multiple fixed beds are flexible and can allow demonstration of multiple process design configuration.

Continuous Operation

- **Demonstrated continuous CO_2 capture in 8 bed bench-scale unit in field testing with coal gas at Western Research Institute**
- **Slipstream project builds on previous DoE funded research**
  - Contract #DE-NT0005497

Testing of 8 bed apparatus at Western Research Institute

Slipstream Testing

- **Project Goal:** Demonstrate TDA's sorbent technology under realistic conditions at 0.5 MW_e (~10 tpd) scale to collected data necessary for scale up to next level plant.

- Design, construction, and operation of slipstream test unit to capture CO_2 from flue gas at the National Carbon Capture Center (NCCC)

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Project Scope

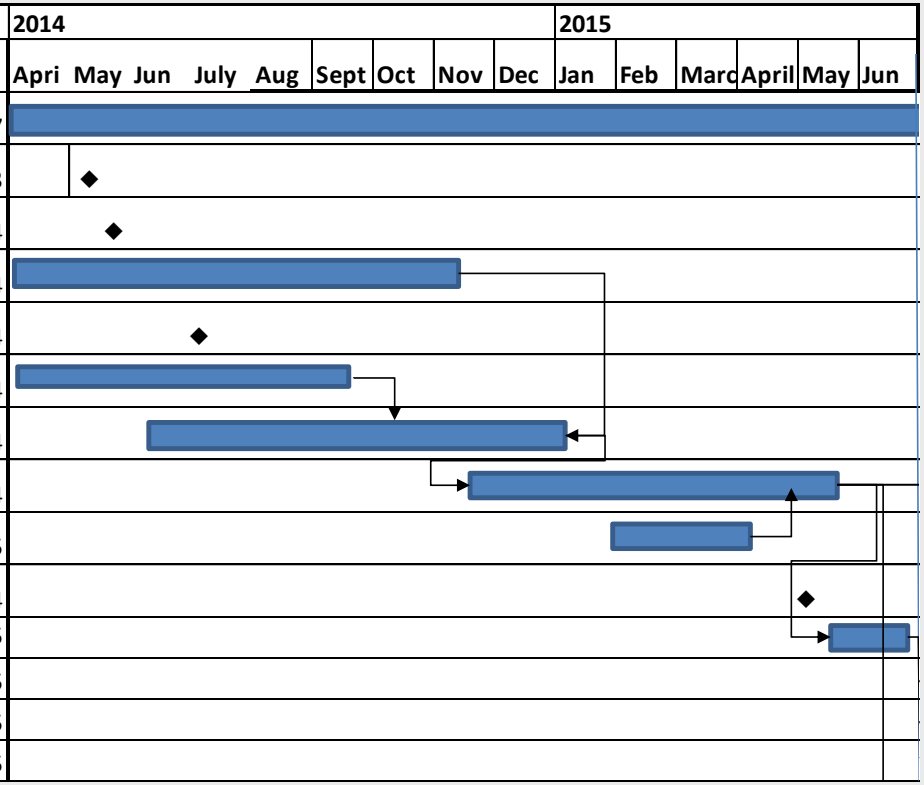
Project Schedule

- **Budget Period 1: Design**
  - April 2014 to June 2015
- **Budget Period 2: Construction & Installation**
  - July 2015 to Sept 2016
- **Budget Period 3: Operation**
  - Oct 2016 to Dec 2017

Budget Period 1

Budget Period 1 Schedule

ID	Task Name	Start	Finish
1	Task 1. Project Management	4/1/2014	6/1/2017
2	Milestone 1-1: PMP	5/1/2013	5/15/2013
3	Milestone 1-2: Kick-off Meeting	5/20/2014	5/20/2014
4	Task 2. Preliminary TEA Case 1-4	4/1/2013	11/15/2014
5	Milestone 2-1: Preliminary TEA Case 1	7/1/2014	7/1/2014
6	Task 3.1. Determine Optimal Flow Pattern	3/15/2013	9/15/2014
7	Task 3.2. Basic Process Specific. & Design	5/1/2013	11/1/2014
8	Task 4.1 Pilot Plant Detailed Engineering	11/15/2014	5/1/2014
9	Task 4.2 EH&S Assessment	1/1/2015	3/31/2015
10	Milestone 4-1: Pilot Unit design	5/15/2015	5/15/2014
11	Task 5. Determine Construction Cost	5/2/2015	6/15/2015
12	Milestone 5-1: Submit Design Package	6/30/2015	6/30/2015
13	Milestone 5-2: Year 1 Annual Review	6/30/2015	6/30/2015
14	**Go/No go Decision Point**		7/1/2015



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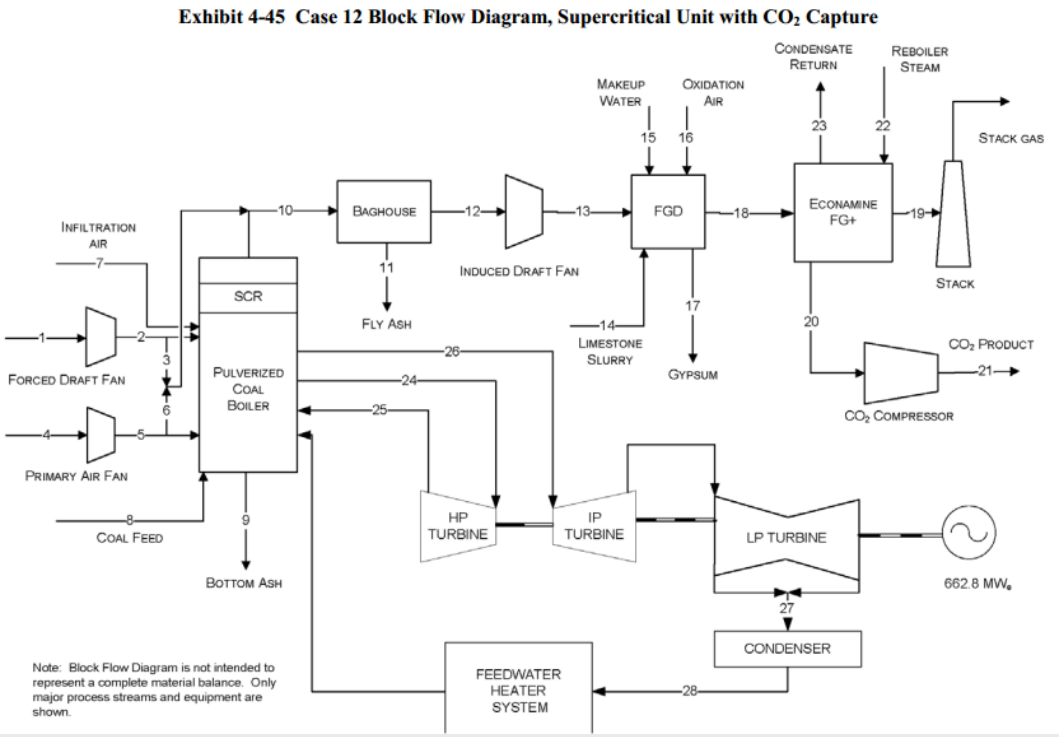
Budget Period 1 Tasks

- **Task 1: Project Management**
- **Task 2: Preliminary Techno-Economic Analysis**
  - Based on integration with a nominal 550 MW_e greenfield supercritical plant
- **Task 3. Pilot Plant Design Optimization and Basis Design**
  - Process experiments to finalize process design
  - Basic process specification and design
- **Task 4. Pilot Plant Detailed Design and Engineering**
  - Design a 0.5 MW_e pilot plant to capture 10 tons per day of CO_2,
  - Perform an initial Environmental, Health and Safety (EH&S) study
  - Hazard Review with NCCC
- **Task 5. Determine Slipstream Unit Construction Cost**
  - Develop a firm cost estimate for the slipstream unit

Preliminary Techno-Economic Analysis

- Integration with greenfield supercritical 550 MW coal fired power plant
  - Cost and Performance Baseline for Fossil Energy Plants (Black 2010) Case 12
  - Analysis will follow DoE guidelines
- Work being performed by University of California at Irvine (UCI)



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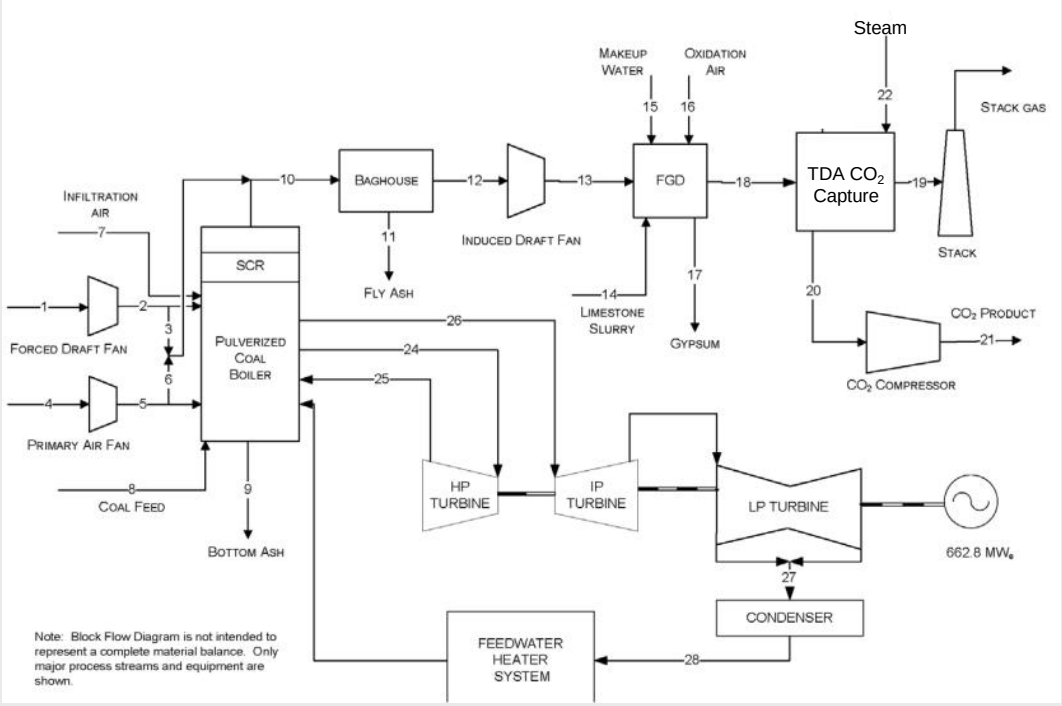
Economic Analysis

- **Total of four cases will be studied as part of the TEA**
  - Baseline Case 1 run initially
  - Three additional cases will be evaluated for optimization
- **TEA economic analysis is underway**

TDA CO_2 Capture on Supercritical 550 MW plant



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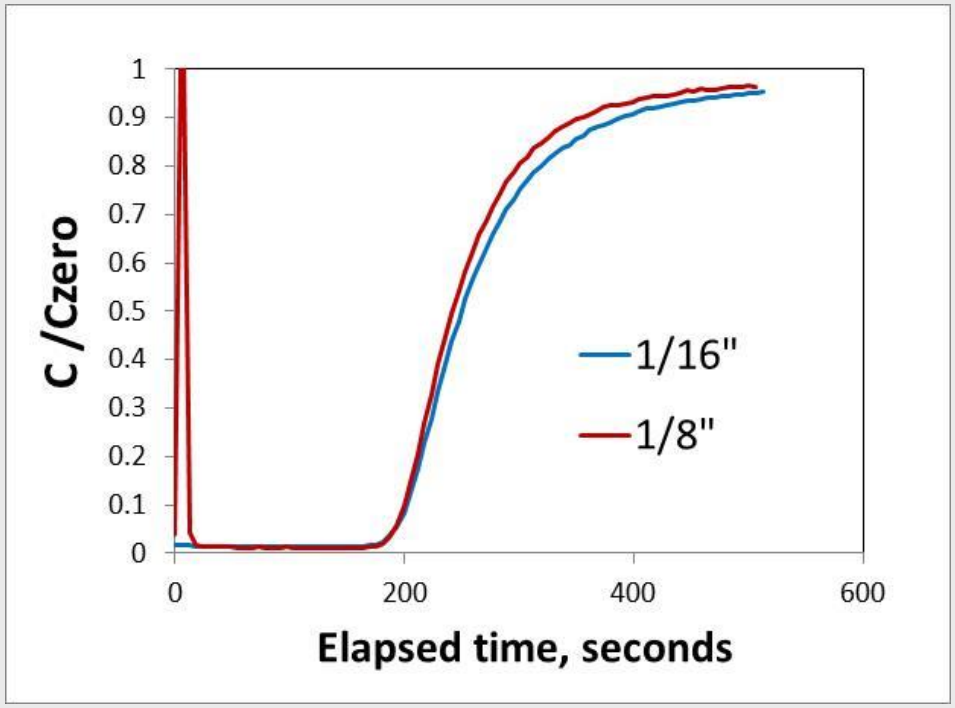
Slip Unit Design Data

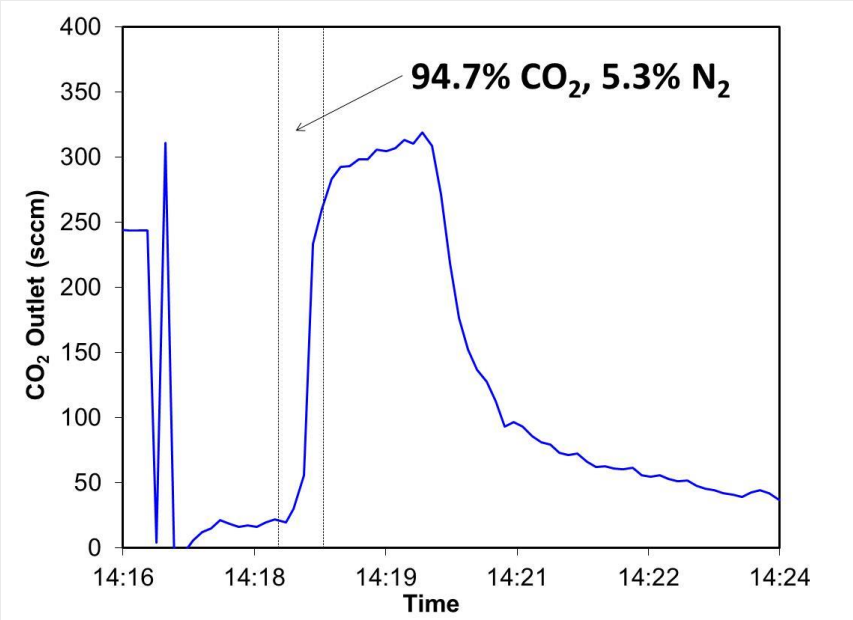
- Collect experimental data needed to design pilot plant unit
- Characterize breakthrough performance and pressure drop considerizations
  - Evaluate different pellets sizes
- Conduct process optimization in bench-scale unit to determine optimum flow/cycling logic for pilot plant

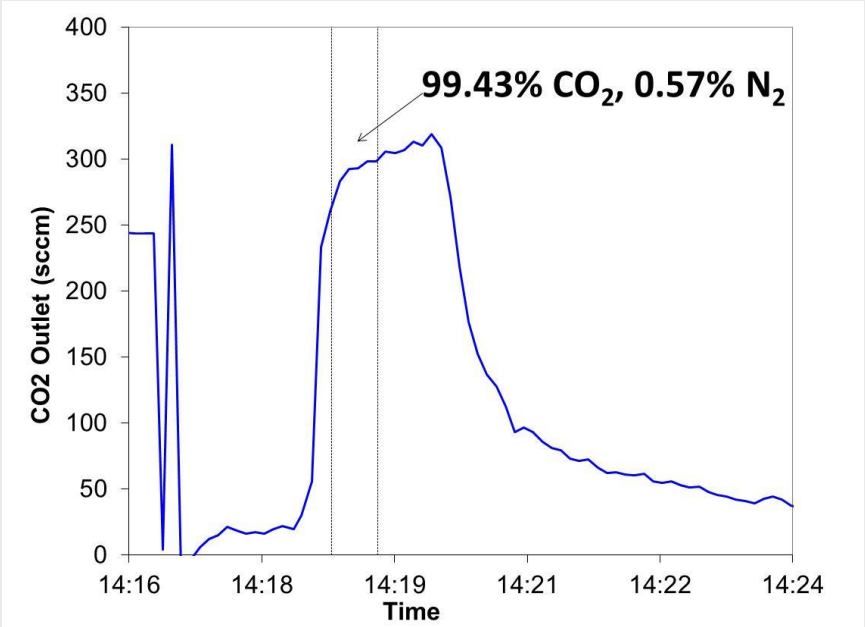
Effect of Pellet Size



- **Breakthrough curves measured for two different sized pellets**
  - **Maintained same space velocity**
- **No loss in performance with 1/8” pellet size compared to 1/16” pellets**

CO_2 Product Purity





- **Evaluated of composition of regeneration product gas**
  - Measured by GC
- **Average CO_2 out meets 95% purity standard**

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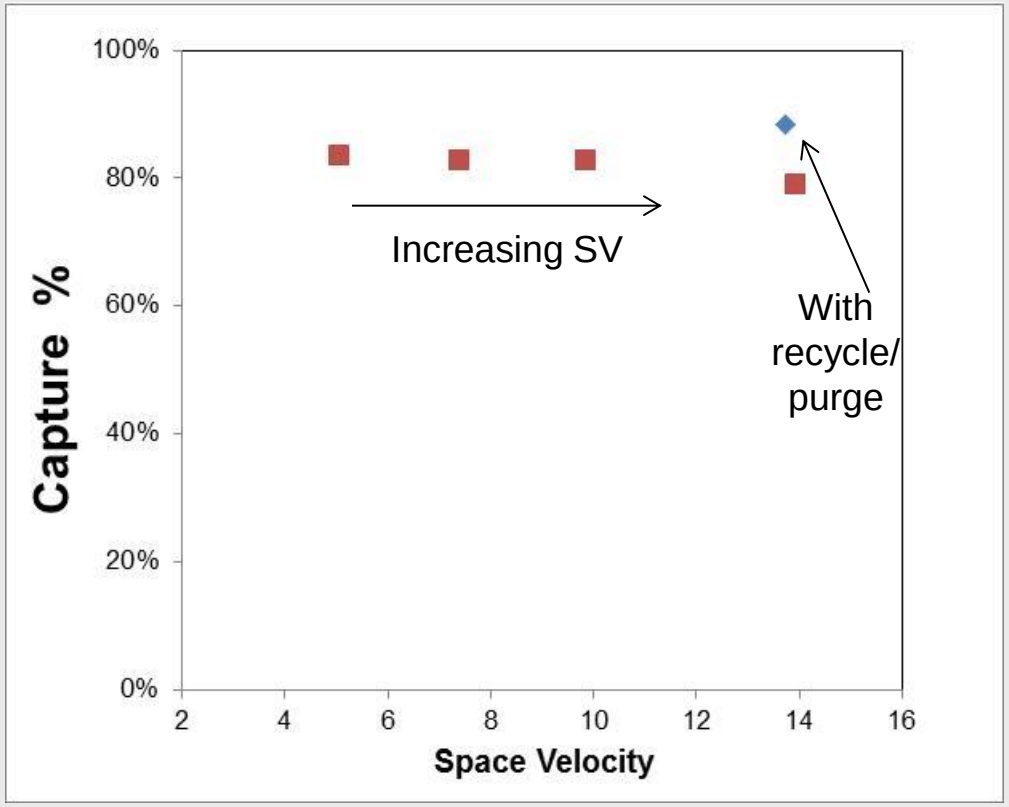
Kinetic Studies



- Performance as a function of space velocity
  - Future studies to evaluate regeneration and adsorption side separately

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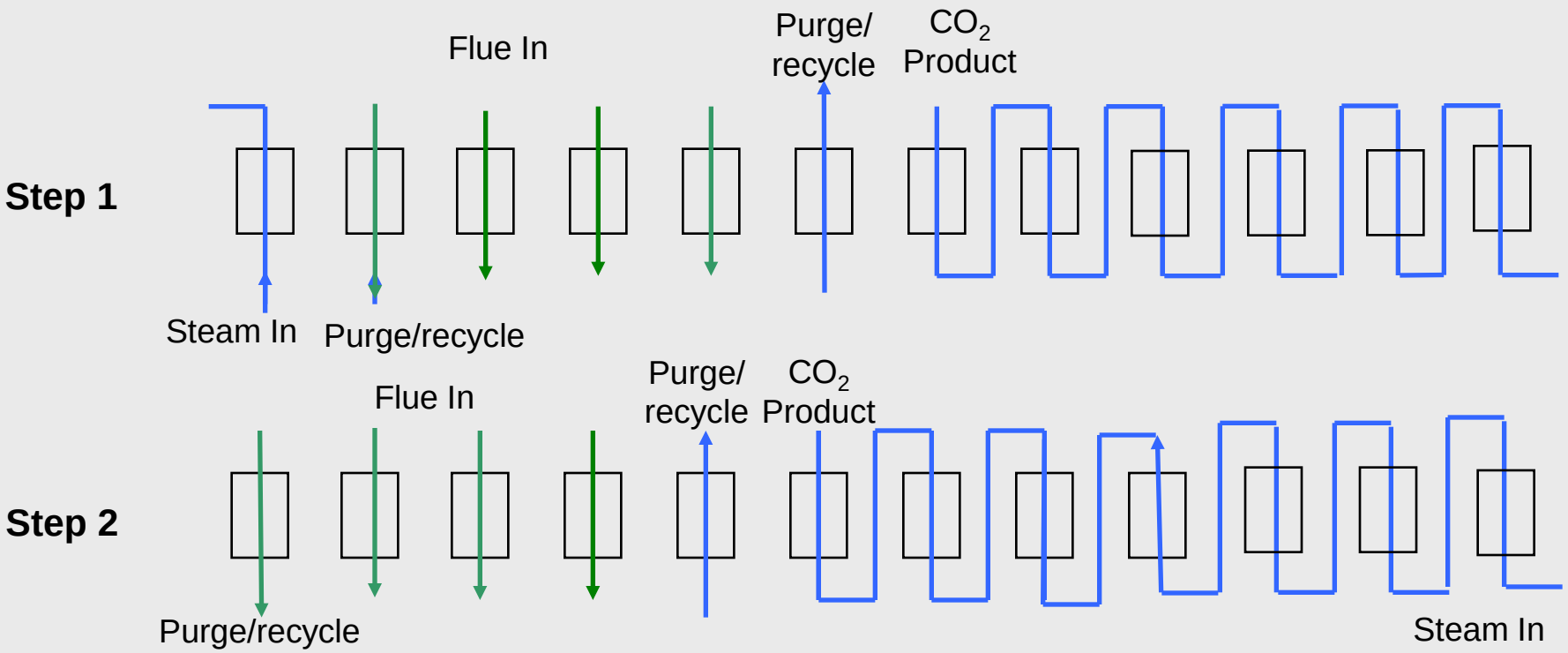
Process Design Optimization

- Underway to modify existing bench-scale unit to mimic design to be constructed
- New system will have additional dedicated beds for purge between adsorption and regeneration steps
- Collect data to evaluate trade-off of adding beds and performance recycles/purge steps

Slipstream Unit Test System



- Adsorption, regeneration and purge beds
- Each stage operates for a full cycle
  - Current unit has some stages operating for a fraction of a cycle

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Slipstream Unit Design

- 0.5 MW_e Skid mounted system
- Adsorber/Regeneration Contractor is a multiple fixed bed unit
  - Beds switch between adsorption, regeneration, purge operations
- Sorbent is regenerated by steam
- Adsorber/Regenerator operates near isothermal (adiabatically) at 140 to 160°C with about 17 psia steam
- Operation pressure is near atmospheric pressure
- Slipstream unit includes adsorber/regeneration beds, heat exchangers, blower

Pilot Plant Engineering Design

- Budget Period 1 will determine cost to construct Slipstream Unit
  - Final Process Flow Diagram, General Arrangement Sketch, Elevation Sketch
- Hazard analysis to be conducted per NCCC requirements
- Estimated CO_2 delivery conditions: pressure, temperature, flow rate, and gas composition
- Startup, steady-state operation, and shut-down procedures
- Sorbent disposal plan
  - to be disposed of by NCCC

Budget Periods 2 & 3

Budget Period 2 Tasks

Budget Period 2 July 2015 to Sept 2016

- Scale-up production of the sorbent
- QA/QC testing of sorbent at TDA
- Fabricate the sorbent bed vessels for the pilot plant and other modules
- Finalize Test Plan
  - Operating conditions and key parameter parametric conditions selected
  - Operator training
- Integrate the unit at the NCCC.

Budget Period 3 Tasks

Budget Period 3 Oct 2016 to Dec 2017

- Demonstrate this process in slipstream testing at the NCCC under both parametric and steady state conditions using coal derived flue gas.
- Update the Techno-Economic Analysis and finalize the EH&S assessment.
- Data from the pilot plant test will be used to develop recommendations for the next level of scale up

Summary

- **Slipstream testing will assess and demonstrate technical viability of this CO_2 capture approach**
- **0.5 MW slipstream testing at NCCC**
- **Technical Experimental work in progress to design optimal slipstream unit**
- **Initial TEA in in progress**

TDA Research Inc.

Privately Owned/Began operations in 1987

80 Full-time technical staff

Located just west of Denver, CO

Wheat Ridge Facility

Golden Facility