OPTIMIZING THE COSTS OF SOLID SORBENT-BASED CO_2 CAPTURE PROCESS THROUGH HEAT INTEGRATION

ADA-ES, Inc. NETL Contractor's Meeting

July 29th, 2014

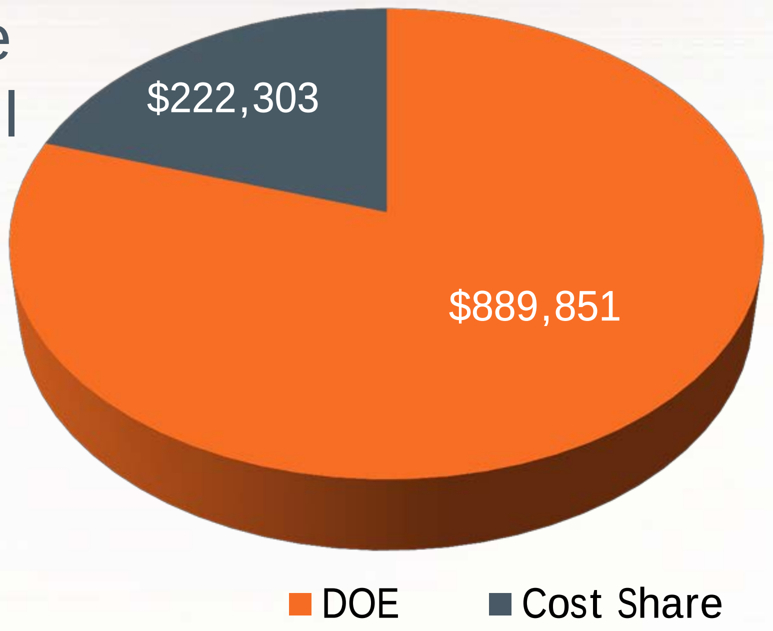
DE-FE0012914

Meeting Overview

- Project Overview
  - Funding, Objectives, Timeline
  - Project Team
- Technology Background
  - CO_2 Capture Process
  - Heat Exchanger Concepts
  - Benefits of Cross Heat Exchanger in TSA
  - Challenges
- Scope
- Status
- Future

Project Funding, Objective, and Timeline

- The overall objective: reduce the energy penalty and/or the overall levelized cost for solid sorbent-based CO_2 capture
- Outcome: progress towards meeting the overall DOE Carbon Capture Program performance goals



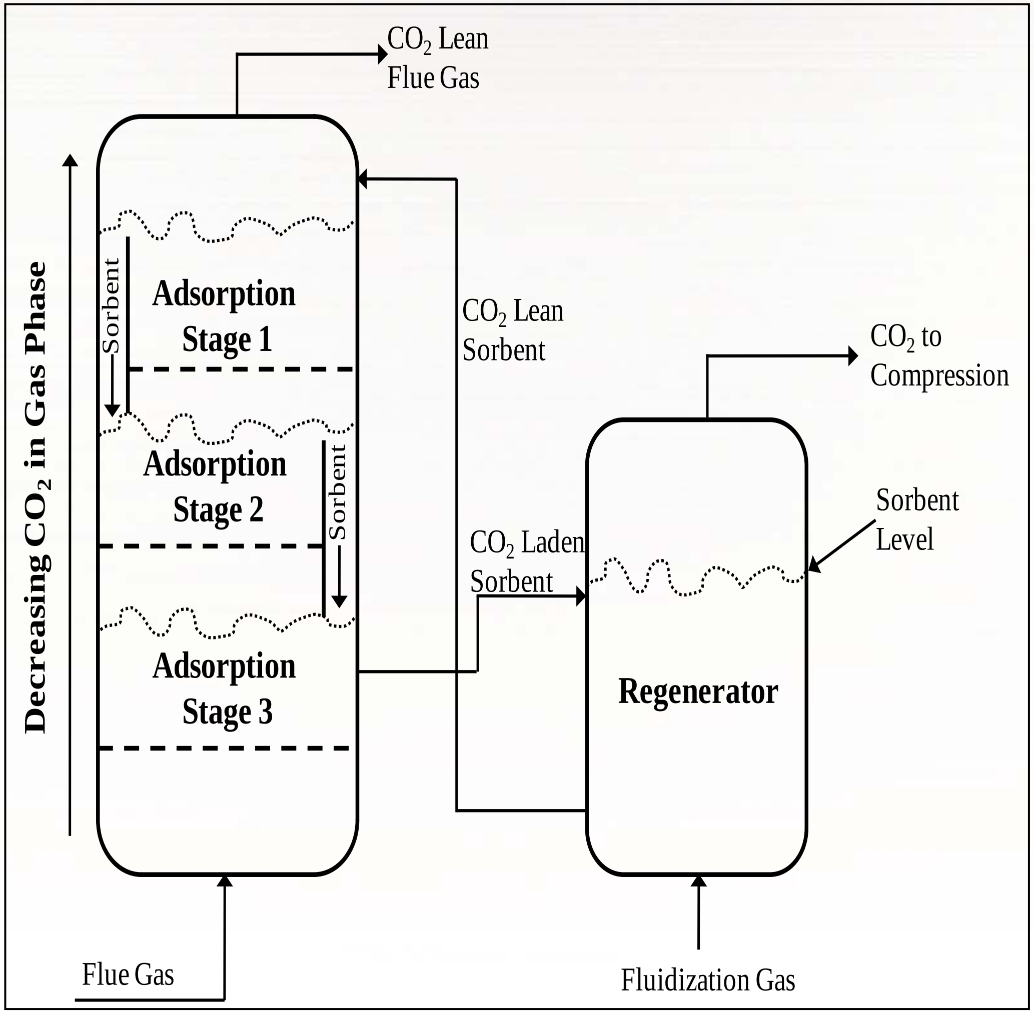
Cooperative Agreement (Award No. DEFE001291)
Administered by DOE-NETL: Project Manager Bruce Lani
Project Duration: Nov 2014 – March 2015

Project Team

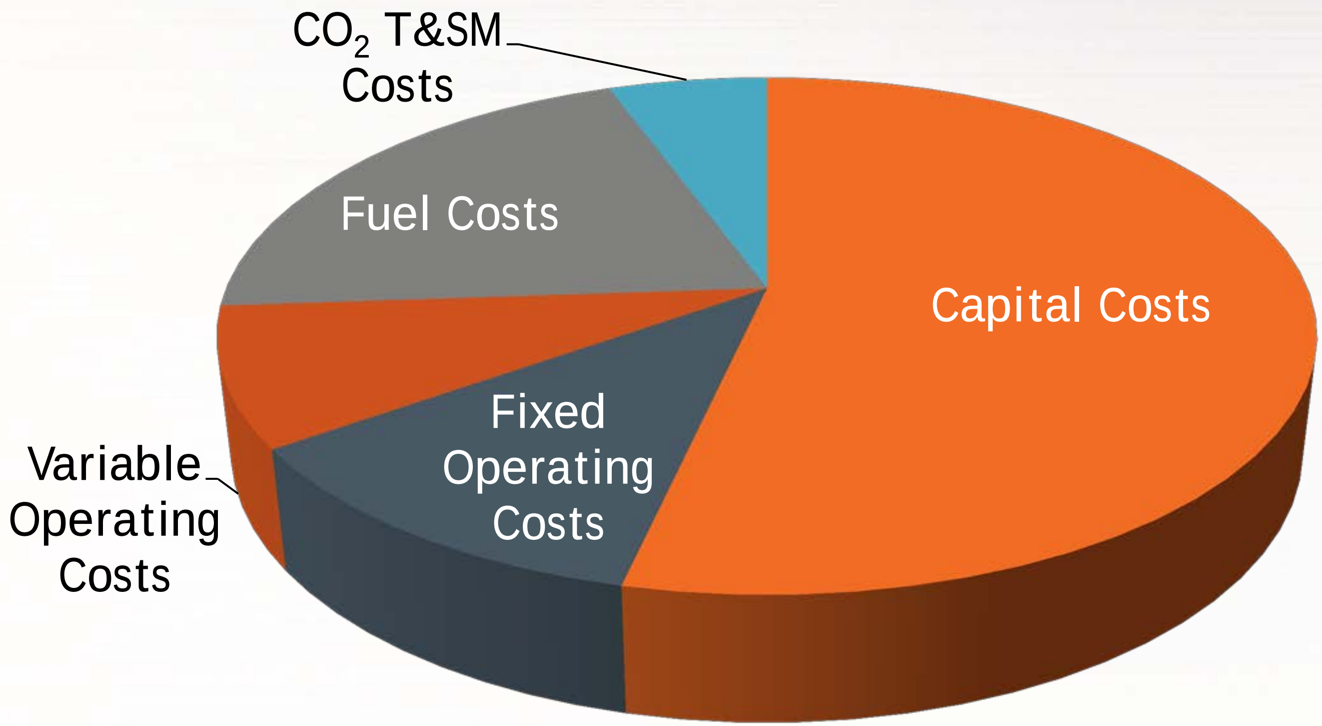
- **DOE - NETL**
  - o Project Sponsor
- **ADA-ES, Inc.**
  - o Project Management
  - o Technology Selection and Integration
  - o Techno-Economic Assessment
  - o Project Cost Share
- **Technip Stone and Webster Process Technology with Dorr Oliver Division**
  - o Conceptual Process
  - o Detailed Engineering, Design, and Costing
  - o Experience w/ multiple types of FB reactor designs (single, multibed, heat exchanger)
- **Solex Thermal Science**
  - o Experience w/ Moving Bed Heating and Cooling
  - o Thermal Modelling & Costing
  - o 400 Installations in 23 countries
  - o Project Cost Share
- **Lehigh University Energy Research Center**
  - o Broad Process Modelling Capabilities w/ ASPEN
  - o Conceptual Process Design
  - o Techno-Economic Assessment
  - o Project Cost Share

ADAsorb™ Process Overview

- Flue gas passes through adsorber module where sorbent particle adsorbs CO_2
- Regenerable solid sorbent cycles between adsorber and regenerator.
- Increased temperature in regenerator releases CO_2

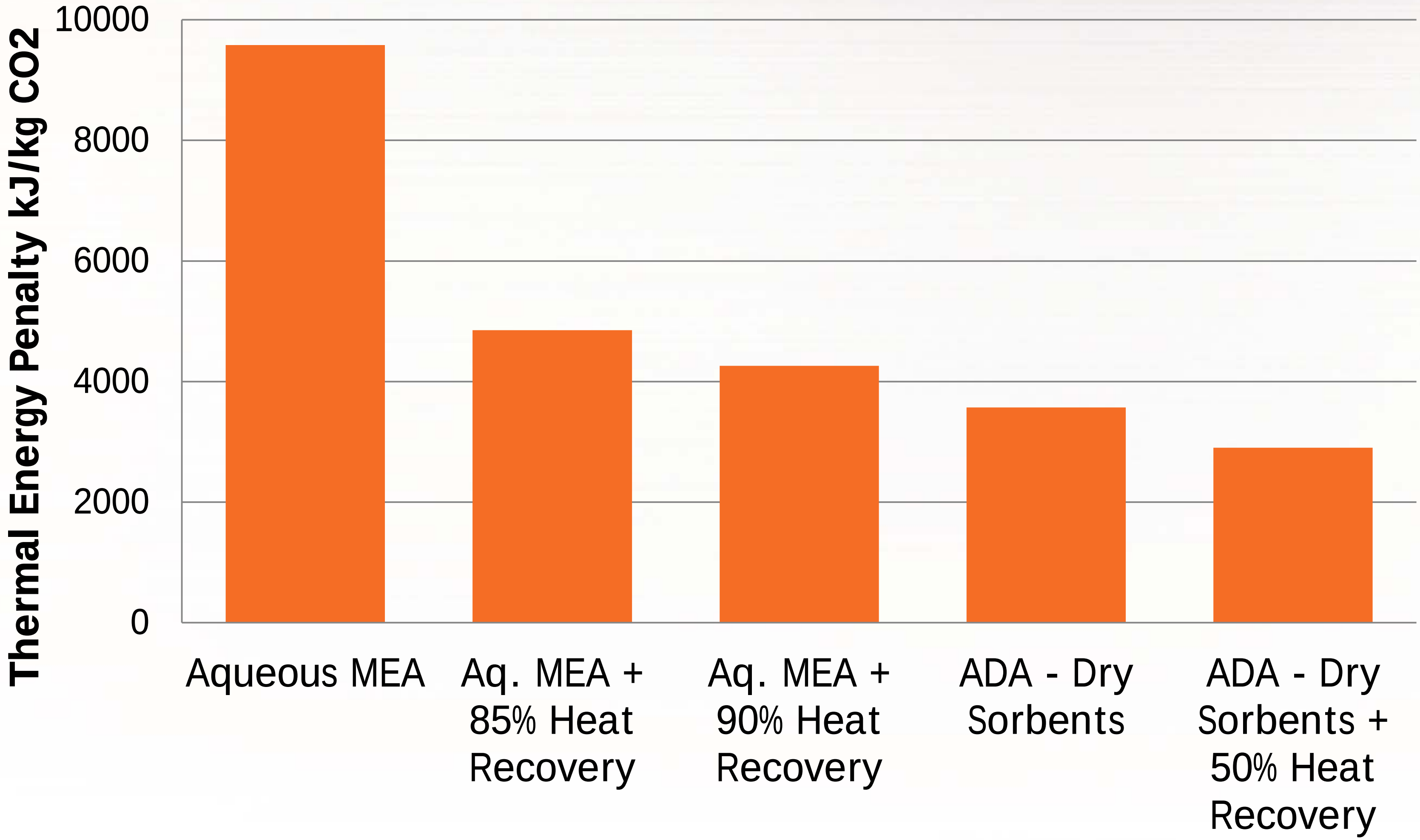


CO_2 Capture LCOE Relative Costs



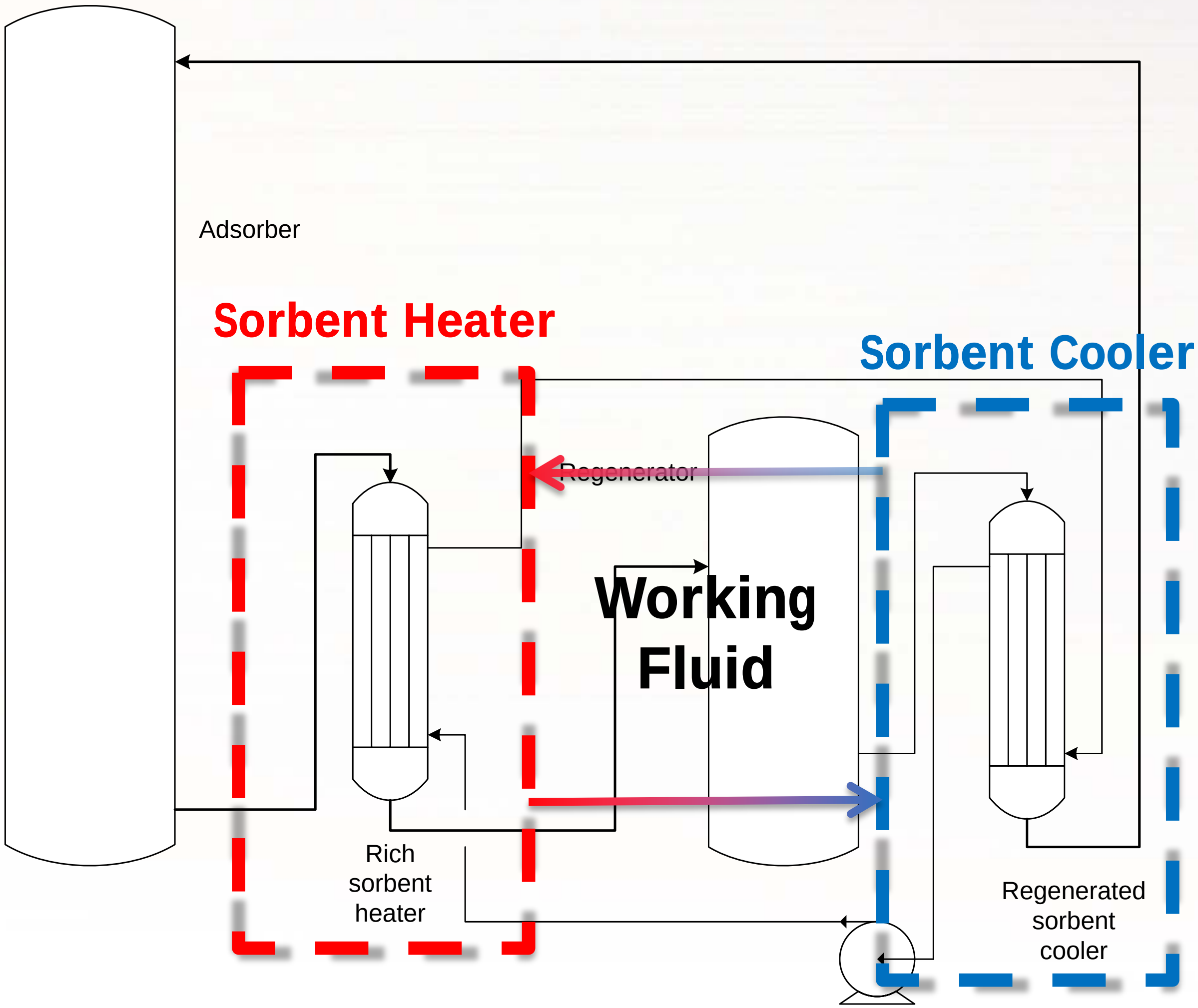
Project focus: Enhanced Efficiency.
→ Reduced fuel costs, CO_2 capture/compression costs, operating costs, and capital costs

Thermal Energy Penalty



MEA information extracted from Ziaii et al., IECR, 2009, 48, 6105-6111

‘Big Picture’ Cross Heat Exchanger Concept



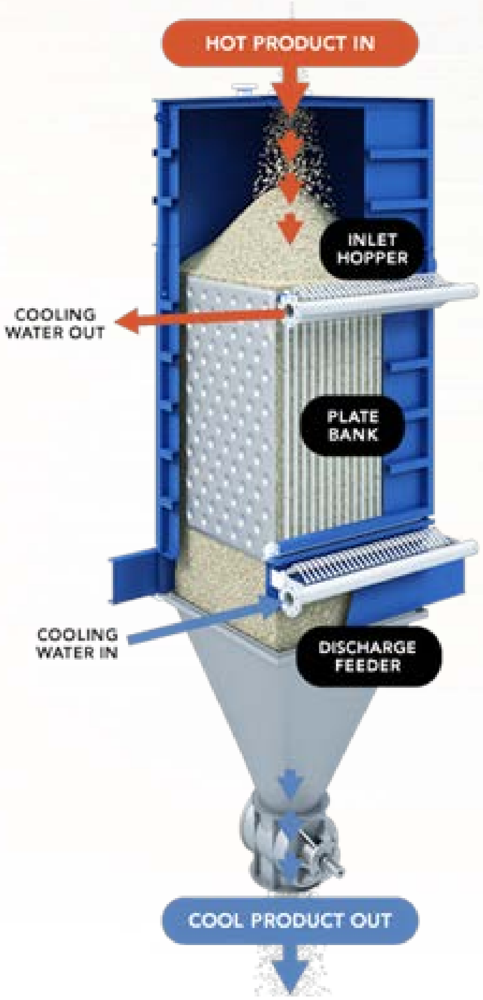
Fluidized and moving bed concepts will be assessed

Additional sources of process integration heat will also be evaluated

Need to optimize and will study fluidized and moving bed technologies

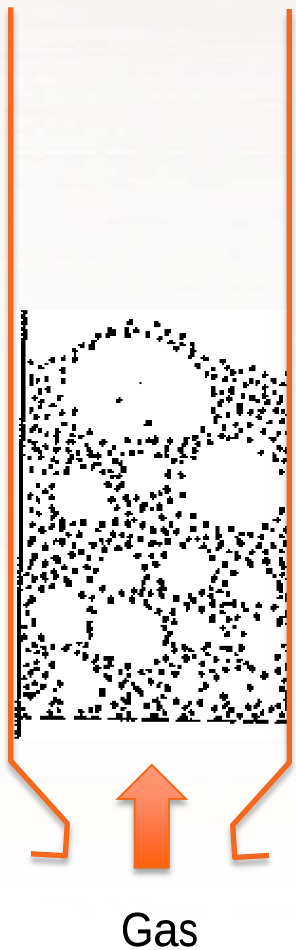
Design Options

Moving Bed



Courtesy of Solex

Fluidized Bed

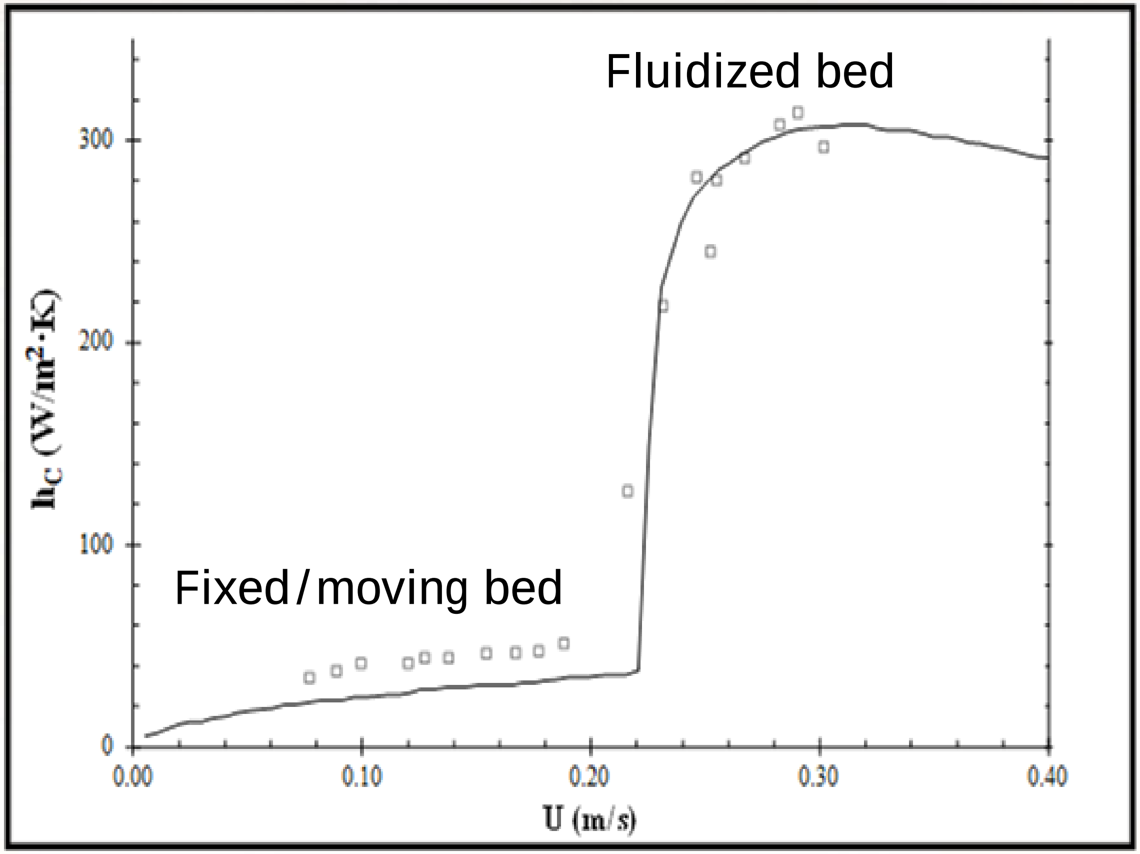


Moving Bed Advantages

- Reduced blower requirements: little or no fluidizing gas is necessary
- Counter-Current flow between solids and heat transfer media
  → possible to achieve an aggressive approach temperature and high heat recovery using only two moving beds per CO_2 capture train (one moving bed for heating and one for cooling)
- *Note: Heat transfer coefficient of a sorbent in a moving bed will be lower than that of the same sorbent in a fluidized bed*

Benefits of Fluidized Beds

- Low mass transfer limitations
- Good heat transfer
- Equipment components have been demonstrated successfully on the required scale
- Industry process scalability knowledge

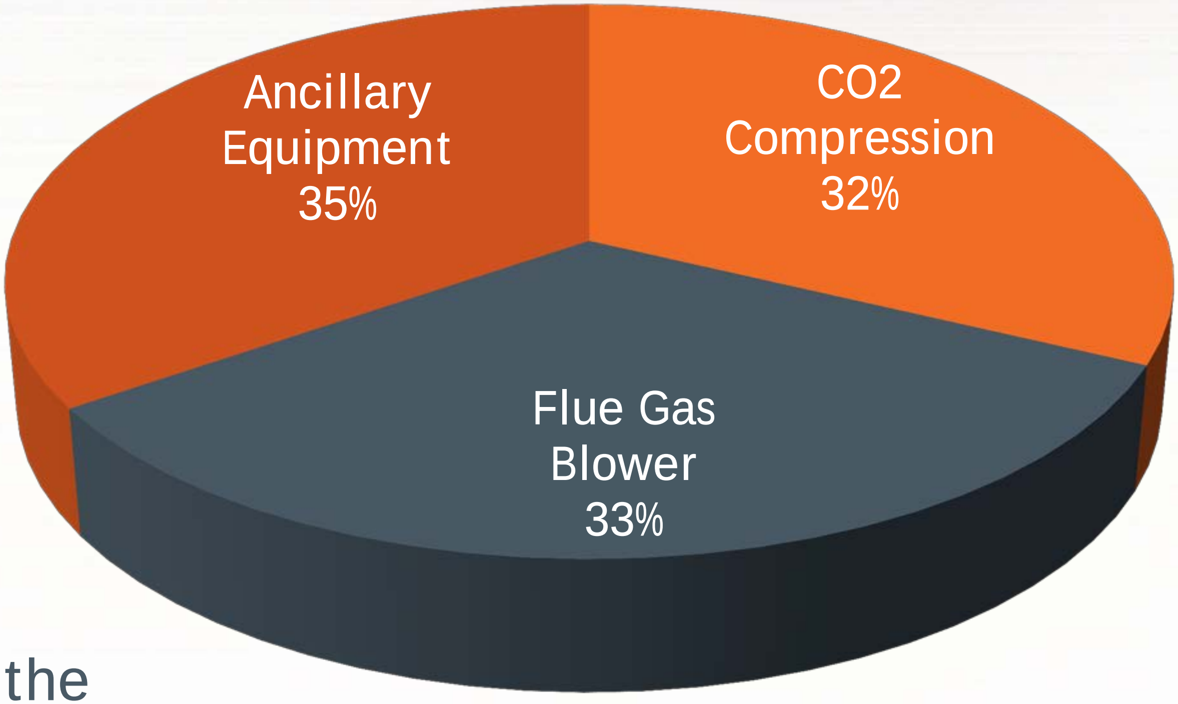


J.F. Davidson, "Fluidization" 1985

Impacts Extend Beyond Thermal Penalty

Breakdown of Estimated Parasitic Load

(DOE Case 10 Analysis, ADAsorb™ without heat integration)



Pressure drop across the adsorber and regenerator represents a significant contribution to parasitic load. Reducing the pressure drop has the potential to significantly decrease electrical energy penalty associated with ADAsorb™

Benefits of Incorporating a Heat Exchanger

- Sensible heat recovery
- Reduced Adsorber Pressure Drop
  - Sorbent is currently cooled in top adsorber bed.
  - Reduced cooling requirements → smaller bed → reduced flue gas blower power → reduced thermal regeneration input & cooling duty
- Need to quantify:
  - Pressure drop from additional heat exchangers
  - Modeling and optimization required to minimized COE
  - Other potential process integration heat sources
- Reduced Regenerator Pressure Drop
  - Sorbent enters regenerator at higher temperature. Less heat transfer surface required

Challenges of Heat Exchanger Implementation

- As illustrated, capital costs provide the most significant impact to LCOE.
  - Heat recovery benefits must outweigh capital costs
- The addition of a cross heat exchanger may increase the footprint of the existing capture unit.
  - For many existing power plants, overall site footprint may be a limiting factor
- A heat exchanger will necessitate more sorbent residence time and increase the amount of sorbent required for the process.
- Sorbent cycling time flexibility will be limited by heat exchange requirements.

Project Scope

- Collect empirical bench-scale test data to evaluate moving and fluid bed cross heat exchangers.
  - Solex to perform bench scale testing for moving bed design
  - Technip to build on existing bench scale data for fluid bed design
- Evaluate multiple cross heat exchanger configurations and identify the most cost-effective option through computational modeling.
- Optimize approach temperature and cross heat exchanger design to minimize overall CO_2 capture costs while balancing capital and O & M costs.

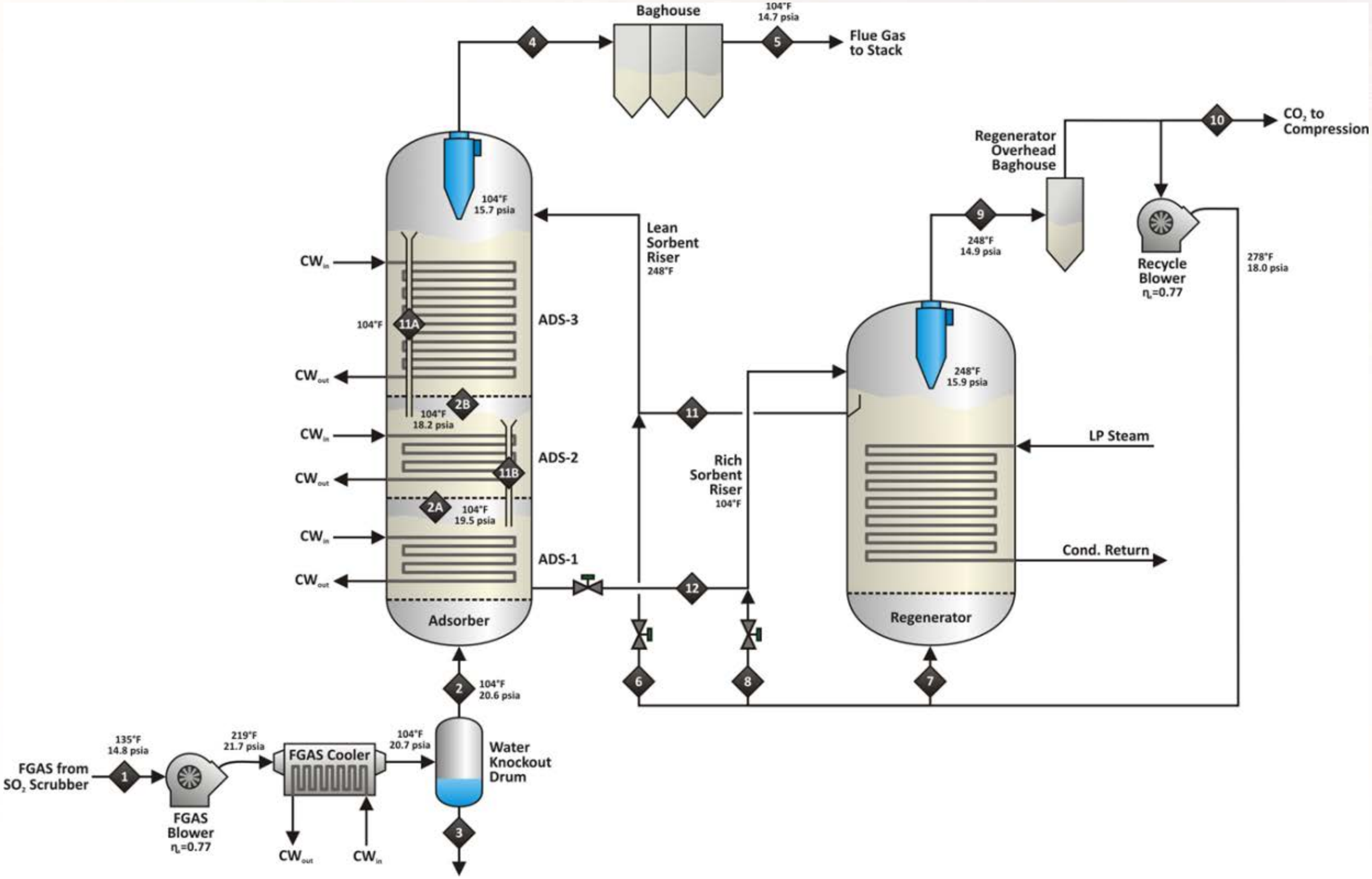
Project Scope (cont.)

- Complete a sensitivity analysis of the technical capabilities, capital costs, and O & M costs which encompass:
  - CO_2 process integration:
    - Heat recovery using the optimal cross heat exchanger
    - Flue gas dehumidification
    - Optimized design to reduce pressure drop
  - CO_2 and power process integration
- Perform techno-economic analysis (TEA) to identify cost drivers which optimize the ADAsorb™ process
- Update the 550MW$_e$ TEA and identify costs and expected energy requirements for an optimized ADAsorb™ process

Project Schedule

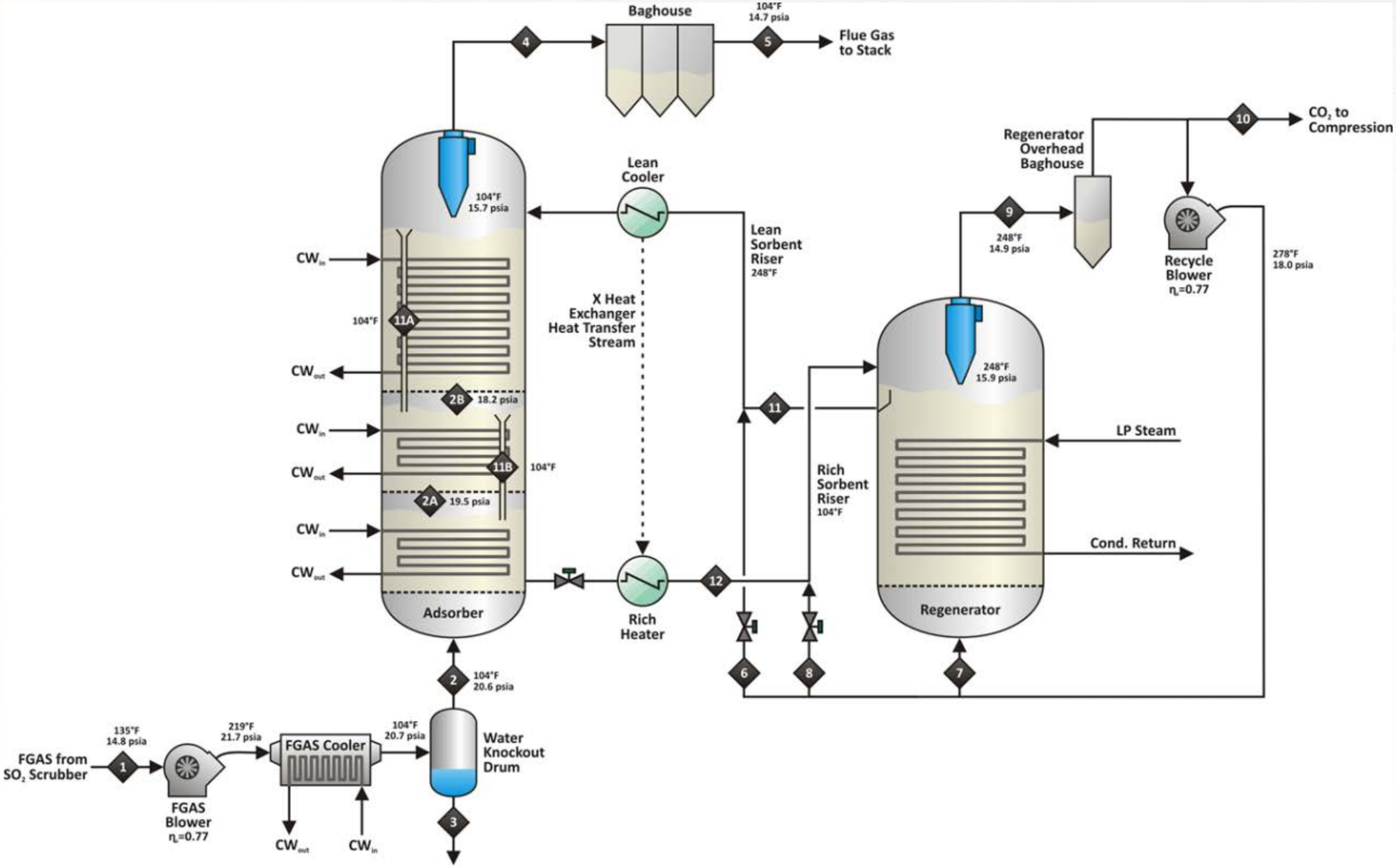
Task Description	Schedule
Bench Scale Testing: Moving Bed	April-July 2014
Modeling: Moving Bed	July 2014
Design Integration: Fluidized Bed	Aug. 2014
Heat Integration and Optimization: Economic Sensitivity Analysis	Feb 2014 – Jan 2015
Techno-Economic Assessment	Sept 2014 – Mar 2015

Lehigh's Aspen Model w/o X-Heat Ex



Advancing Cleaner Energy

Lehigh's Aspen Model w/ X-Heat Ex.



Preliminary Lehigh Model Results

- Heat rate reduction up to ~13.3% is possible with ideal heat exchanger.
  - Significant improvements in process efficiency can be achieved.
  - Pressure drop reduction of approximately 1.3 psi may be realized reducing the blower requirements for the adsorber.
  - Total CO_2 captured to maintain 90% capture rate is reduced.
  - Gross/Net generation ratio is substantially improved.

ADA and Solex Bench Scale Testing Results

Successful Bench Scale Test

- Sorbent heated and cooled with the heat exchanger through process range (40-120^{o}C)
- Sorbent flow smooth and consistent, no bridging between plates observed
- Minor bridging observed at the outlet of the exchanger. Proved to be manageable.

Future Project Tasks

- Develop a working understanding of sorbent desorption behavior in the heat exchanger.
  - Determine the gas handling requirements of desorbed gas in the heat exchanger.
- Develop commercial design of both heat exchanger concepts.
- Apply commercial designs from Technip and Solex to Lehigh's process model.
  - Assess the maximum process and cost benefits of various heat exchanger designs and approach temperatures.

Summary

- Project is structured to advance development of PCCC technologies
- Project focus areas and technical approach will facilitate reduction of energy penalty as well as the overall levelized costs associated with CO_2 capture

Questions?

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