Project CO_2NCEPT

2016 NETL CO_2 Capture Technology Project Review Meeting

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Agenda

NRG

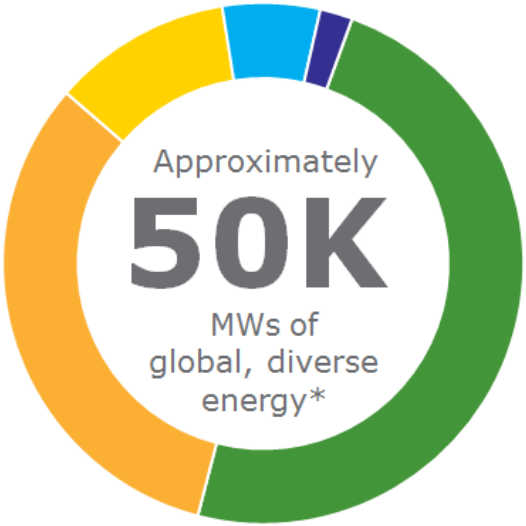
- CCS Challenges
- Project CO_2NCEPT
- Configuration

Inventys

- Technology
- Results
- Next Steps

- Q&A

NRG is the nation's leading integrated competitive power company



Nearly **3,000,000**

recurring retail customers

One of the largest renewable generation companies in the U.S.

$3 billion+

Invested on environmental improvements

Largest independent power producer in U.S.

Fortune 200

- and –

S&P 500 Index

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CCS Challenges

1. Cost	Commercially available technologies are capital intensive
2. Competition	More options and technologies are needed
3. Scale	Technologies need to be proven at a sufficient scale
4. Development	Approaches and incentives need to be reevaluated
5. Reputation	Confidence in this space has eroded

NRG is in pursuit of finding the next post-combustion technology that makes a giant leap forward and Inventys could be the breakthrough this industry needs

Changing the CCS Conversation

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Project CO_2NCEPT

CO_2NCEPT - **C**onfirmation **O**f **N**ovel **C**ost-effective **E**merging **P**ost-combustion **T**echnology.

- A 25 MWe (500tpd @ 90% capture) demonstration of the Inventys' VeloxoTherm™ post combustion carbon capture technology at an NRG coal plant with the goal to prove that the cost of capture, both from an upfront capital requirement as well as from an operating standpoint, is lower using this technology when compared to existing baseline technologies.
- Sponsored by Funding Opportunity Announcement DE-FOA-0001190 "*Small and Large Scale Pilots for Reducing the Cost of CO_2 Capture and Compression*."
- The team successfully completed Phase 1 to validate the proposed concept, select the location, determine the approach, design a layout, and develop an indicative estimate and schedule to execute the project during Phase 2 if awarded.

A new novel CO_2NCEPT in pursuit of a game changer

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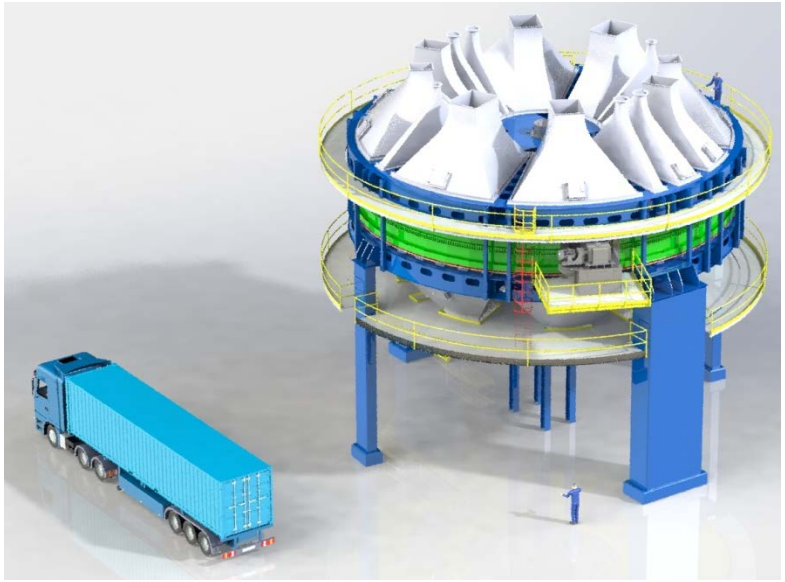
Project CO_2NCEPT Configuration

- Phase 1 results proved to the execution team that Phase 2 could be accomplished within the merits of the FOA.

Flue Gas

Utilities



CO_2

Inventys Rotary Adsorption Machine (RAM)

Economically and mechanically viable to develop at a pilot scale

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INVENTYS INTRODUCTION

Company

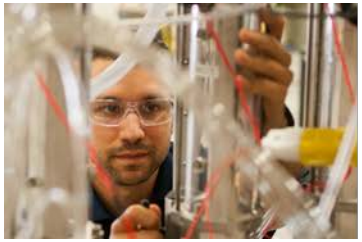
- Energy technology company focused on post-combustion CO_2 capture
- Company created in 2007 to apply the founder's expertise in developing and deploying commercial gas separation technology using structured adsorbents

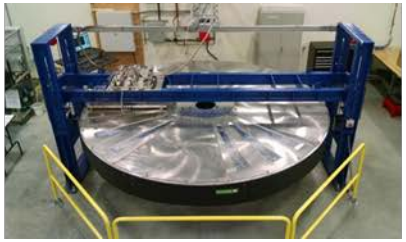
Technology

- VeloxoTherm™ intensified Temperature Swing Adsorption (TSA) using structured adsorbents and novel embodiment that can enable step-change reduction in post-combustion CO_2 capture costs
- Patents granted in US on all major aspects of technology

Team & Facilities

- Strong financial partners and project participants, as well as critical Board leadership
- Private company, 21,000-sq-ft manufacturing facility and a state-of-the-art adsorption characterization laboratory, multiple process testing & demonstration platforms

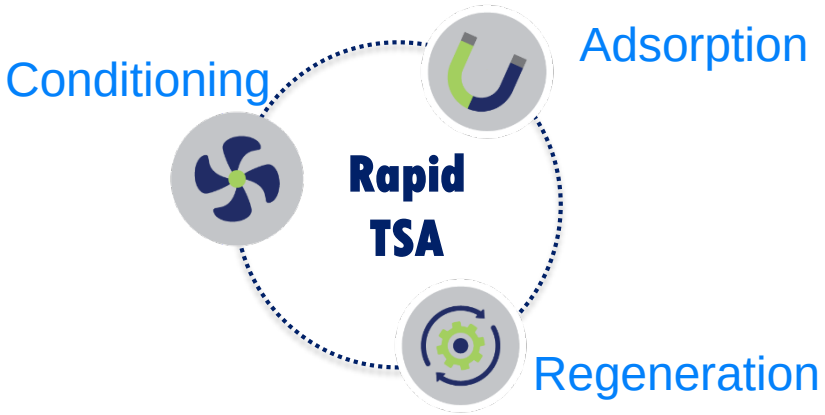



TECHNOLOGY BACKGROUND
VELOXOTHERM™

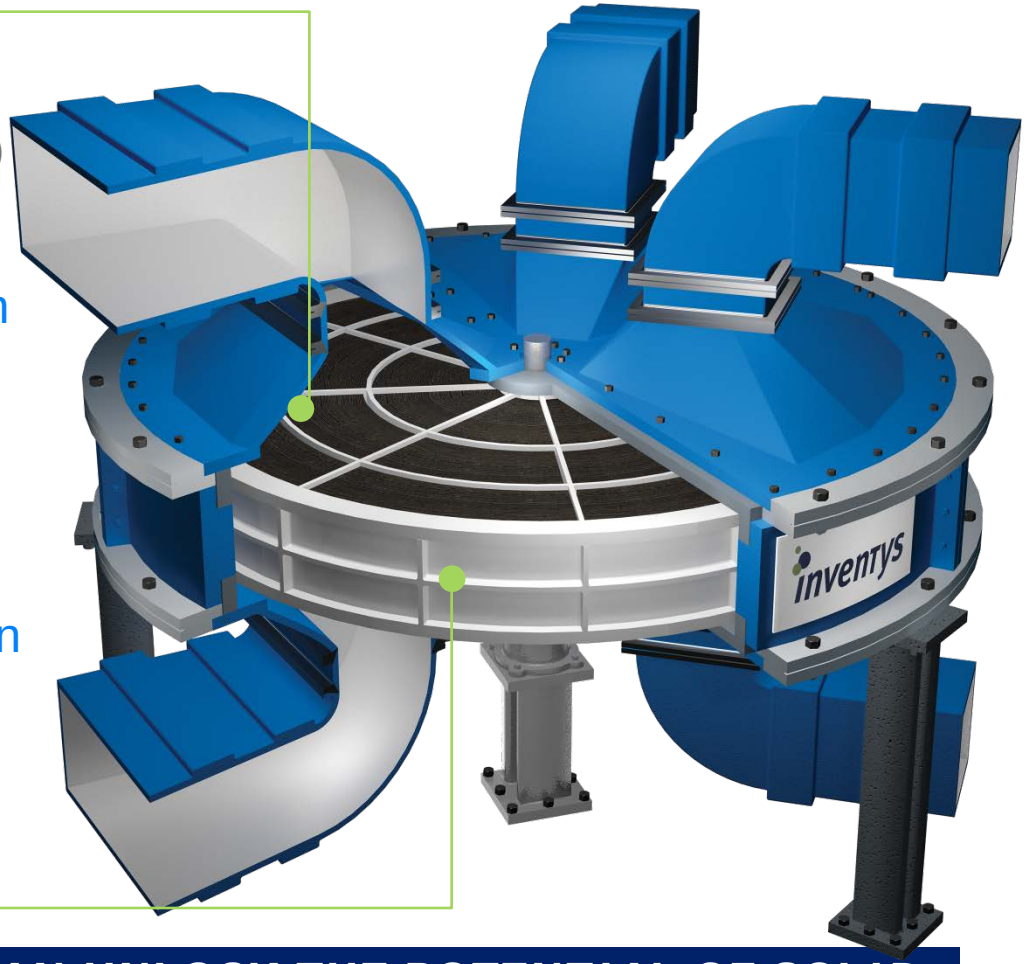
Structured Adsorbent

Solid sorbents = Low regeneration energy
Structured Adsorbents = Intensification (small equipment)



Rotary Embodiment

Continuous process created by rotating beds
Based on existing rotary air preheaters used in power plants

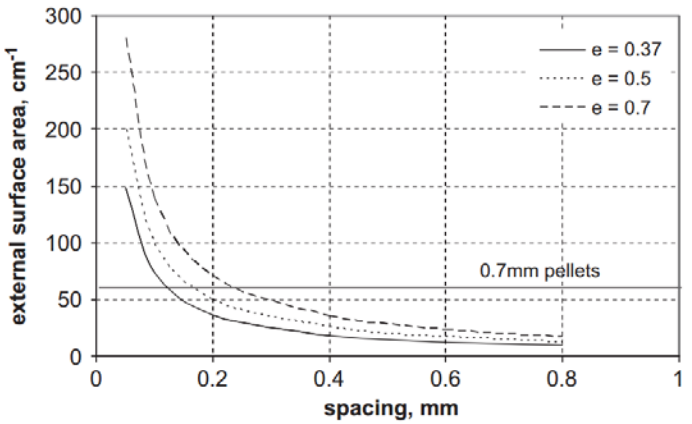


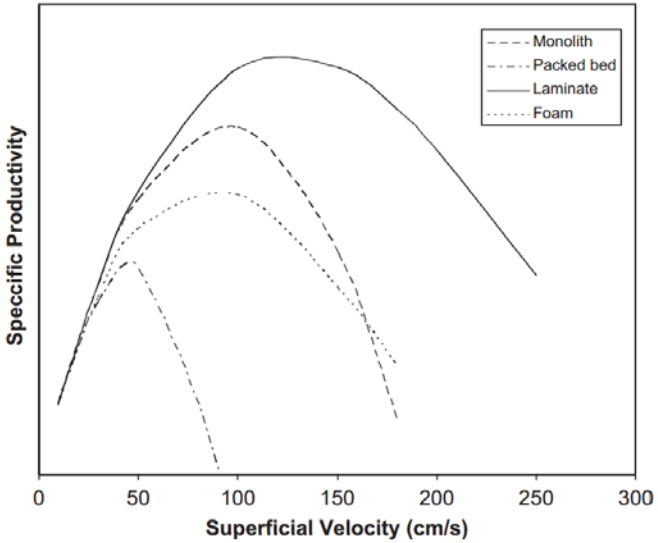
STRUCTURED ADSORBENTS CAN UNLOCK THE POTENTIAL OF SOLID SORBENTS FOR CO2 CAPTURE

STRUCTURED ADSORBENTS

The hydrodynamics, specific surface area, and transport properties of structured adsorbents enable critical advantages:

- low pressure drop;
- Immobilized adsorbent with no fluidization or attrition;
- High geometrical (surface) areas per reactor volume;
- High heat and mass transport due to short diffusion paths within the structured materials;
- High heat retention due to the anisotropic heat transfer properties;
- Engineered thermal properties of laminates; and,
- Laminate design allows degrees of freedom to tailor void fraction, packing densities, hydrodynamics.



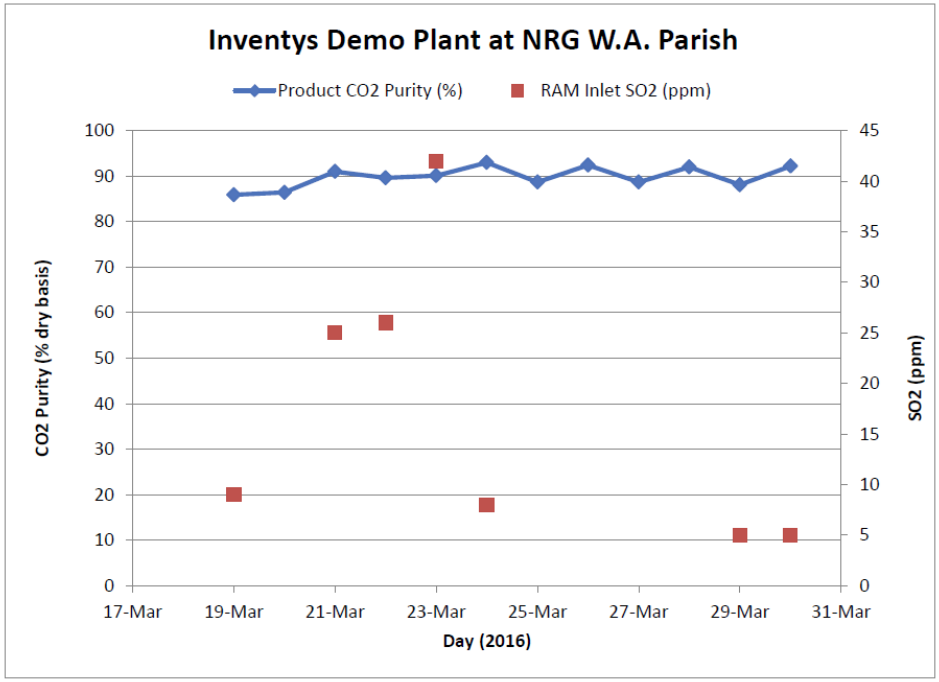


Charts: Rezaei, F., Webley, P., "*Optimum structured adsorbents for gas separation processes*", Chemical Engineering Science (2009)

CONTAMINANT RESILIENCE

- Rapid cycle TSA process with structured adsorbents has shown ability to withstand elevated levels of SOx and other coal flue gas contaminants
- Field testing of small RAM on coal flue gas slipstream has provided important learnings, including ability to regenerate bed capacity
  - Stable operation @ ~10 – 40 ppmv SOx, beds saw extended durations of ~250ppmv during shutdowns

Contaminant	Testing Completed
SOx	• Coal flue gas slipstream - ~40 – 300 ppmv (671 hrs) • Accelerated exposure testing, including sulphuric acid
NOx	• Natural gas boiler flue gas @ 72 ppmv - >2,000 hrs
PM	• Testing on in-house coal w/o PM control • Coal flue gas slipstream testing post-baghouse (671 hrs)

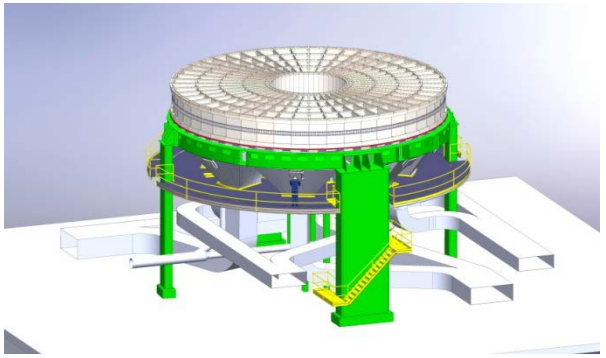


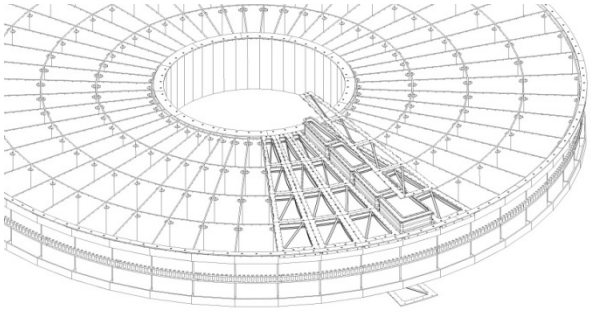
Design Methodology
First Principles to Viable Process

SCALE-UP RISK MITIGATION

During Phase 1, Inventys worked with an OEM for the rotary machine module and developed strategies for mitigating the risk of scaling up to a Large Pilot Scale Rotary Adsorption Machine:

Example of Scale-up Risk	Mitigation
Flow Distribution	CFD analysis & experience of rotary heat exchanger OEM
Size of Adsorbent Beds	Modular approach to adsorbent beds – repeating units ~1m characteristic dimension
Scale-up of proprietary gas seal design	Modular seal segment design, allowing in-house testing of actual seal dimensions and conditions – segmented seals reduce differential wear
Rotor Imbalances & Process Asymmetry	Multiple cycles per revolution & process loads balancing machine weight





PHASE 1 FINDINGS & RESULTS

- Significant Achievements
  - Conceptual design work completed for 15m diameter Large Scale Pilot Rotary Adsorption Machine, including scale-up risk mitigation strategy on a component & system level
  - Robust project baseline in terms of budget, scope & execution schedule completed with EPC firm to de-risk further development of Large Scale Pilot
  - Preliminary E,H&S Risk Assessment and detailed technology gap analysis completed
- Achieving overall process performance targets was based on increasing structured adsorbent bed density & using a vacuum-assisted regeneration strategy for the coal flue gas TSA cycle
- During Phase 1, performance testing of higher density adsorbent beds with vacuum regeneration showed higher than expected energy consumption
- Determined that adsorbent selection & optimization work required to de-risk ultimate economic targets for capture costs

PATH FORWARD

- VeloxoTherm™ structured adsorbent technology platform & rapid cycle TSA process architecture has demonstrated ability to unlock performance potential of solid sorbents vs other process schemes
- Promising path towards step-change reduction in capture costs relative to SOA approaches by combining VeloxoTherm™ technology platform with recent advances in raw adsorbents for CO_2 capture

Inventys capture system operating on coal flue gas slipstream at NRG Parish

Q&A

Thank you!

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