Transformational Sorbent System for Post Combustion Carbon Capture (Contract No. DE-FE-0031734)

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Project Objective

- Objective is to develop a transformational sorbent system that can:
  - Capture more than 90% of CO$_2$ emissions
  - Recover CO$_2$ at 95% purity
  - Reduce COE by 30% more than can be achieved by amine based systems and achieve capture cost less that $30 per tonne of CO$_2$

- A highly stable high capacity metal-organic framework (MOF) based physical adsorbent is being developed to remove CO$_2$ from the flue gas using a novel adsorption cycle scheme

- Main Project Tasks
  
  **BP1**
  - Demonstrate sorbent performance in lab scale
  - Assess impact of flue gas contaminants (SO$_2$, NOx, HCl)
  - Develop adsorption cycle sequence
  - Preliminary Techno-economic analysis (TEA)

  **BP2**
  - Scale-up sorbent production
  - Complete Life Tests
  - Optimize adsorption cycles and update TEA

  **BP3**
  - Complete field tests (6 months duration)
  - High Fidelity TEA and EH&S assessment
**Overall Project Duration**
- Start Date = June 1, 2019
- End Date = May 31, 2022

**Budget**
- Project Cost = $3,750,000
- DOE Share = $3,000,000
- TDA and its partners = $750,000

**Budget Period 1 Duration**
- Start Date = June 1, 2019
- End Date = May 31, 2020

**Budget**
- Project Cost = $1,212,387
- DOE Share = $969,887
- TDA and its partners = $242,500
TDA’s CO$_2$ Capture Process

- Sorbent operates at ~50-60°C during adsorption
- Various options will be explored for the regeneration
  - Vacuum swing adsorption (VSA) - mild vacuum (0.2-0.3 atm) under isothermal conditions
  - Temperature swing adsorption (TSA) – mild TSA (40-70°C max) to recover CO$_2$ at high pressure
  - Concentration swing adsorption (CSA) – use low grade steam
  - Any combinations above
**Previous Sorbent Development**

**CO₂ Removal from Portable Life Support System using space vacuum**
- High vacuum (1-2 torr)
- Low water (a sublimator is in place)
- VSA - Adsorb at 2500 torr regenerate at 1 torr

**Harvesting CO₂ from Mars to produce propellants for return trip using TSA**
- TSA - Adsorb at 5 torr regenerate at 3800 torr (5 atm)
- Very low water

**Removing CO₂ from Virginia Class Submarines using VSA/TSA**
- 130 person crew
- Adsorb at 5000 torr 30°C and regenerate at 760 torr at 100°C(1 atm)
- High water

**We also completed a DOE SBIR Phase I project, showing the potential of the new sorbent in post-combustion capture (removing CO₂ from low concentration generators, such as NGCC plants)**
- VSA, high moisture
TDA’s MOF Sorbent

- Very high CO$_2$ uptake (2-3 mmol/g) at 0.15-0.20 bar CO$_2$ partial pressure
- High CO$_2$ selectivity over N$_2$
- Relatively low energy input requirement for sorbent regeneration

<table>
<thead>
<tr>
<th>$P_{CO_2}$ (bar)</th>
<th>CO$_2$/N$_2$</th>
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<tr>
<td>0.05</td>
<td>9.32</td>
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<tr>
<td>0.1</td>
<td>16.29</td>
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<tr>
<td>0.15</td>
<td>22.92</td>
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<td>1</td>
<td>57.52</td>
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</table>
TDA developed a palletization method using pill press

TDA’s MOF had a marginal loss in CO₂ adsorption capacity due to pelletization, while the rate of the adsorption (kinetics) met requirements
CO₂ capacity of the pelletized sorbent was measured in a fixed bed test unit:

**Adsorption:** 12.6% CO₂, 86 ppm NO, 73 ppm SOx in N₂; 10,000 h⁻¹

**Desorption:** N₂ T = 25°C

- The sorbent achieved a CO₂ capacity of 4.0% wt. CO₂
- CO₂ capacity is not degraded upon exposure to NO and SOx
Life Tests in TGA

Adsorption: 1, 5, 10 or 16% vol. CO₂ in N₂;
Desorption: N₂; T = 28°C

TDA’s sorbent showed stable performance over 10,000 cycles