A Novel Process for Carbon Dioxide Conversion to Fuel (DE-FE0031714)

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Project Objectives

• The objective is to develop a new sorbent and the process around it for CO₂ utilization
• The sorbent converts CO₂ into CO in a redox process using CH₄ (natural gas) and a small fraction of H₂ generated by reforming/electrolysis
  • CO and H₂ mixture (referred to as synthesis gas) is then used to synthesize a wide range of fuels, alcohols and oxygenates (methanol); methanol to gasoline or chemicals

• Specific objectives
  • Sorbent synthesis and development
  • Bench-scale tests to assess technical feasibility
  • Long-term cycling to demonstrate sorbent life
  • Prototype design
  • Prototype fabrication and proof-of-concept tests
  • Process design and development
    • Gasoline synthesis via methanol-to-gasoline process
    • Diesel fuel synthesis via Fischer-Tropsch
Project Partners

Project Duration
- Start Date = January 10, 2019
- End Date = January 9, 2021

Budget
- Project Cost = $1,000,000
- DOE Share = $800,000
- TDA and its partners = $200,000
Reduction: $\text{CO}_2(g) + \text{M} = \text{CO}_2(g) + \text{MO}$
Partial Oxidation: $\text{CH}_4(g) + \text{MO} = \text{CO}_2(g) + 2\text{H}_2(g)$
Net Reaction: $\text{CH}_4(g) + \text{CO}_2(g) = 2\text{CO}_2(g) + 2\text{H}_2(g)$

Dry reforming can be achieved with very high level of conversion
Initial Results

Reduction in 2% CH$_4$/N$_2$, 600°C
Oxidation: 100% CO$_2$

- Modified sorbent has 9.5% wt. oxygen uptake at 600°C in TGA tests
- CH$_4$ conversion (at 5,000 h$^{-1}$ GHSV) is strongly dependent on temperature
  - Nearly 100% CH$_4$ conversion at 700°C
  - Performance at 700°C (green) is higher than 600°C (orange)
CH$_4$/C$_2$H$_6$/C$_3$H$_8$ and CO$_2$ Cycling

Reduction: 2% CH$_4$ or 2%C$_2$H$_6$ or 2%C$_3$H$_8$ Balance N$_2$; 40 minutes
Oxidation: 100% CO$_2$; 20 minutes

- C$_2$H$_6$ and C$_3$H$_8$ have much higher activity than CH$_4$ that will enable lower light-off temperatures
- Formation of CO and olefins were evident during the sorbent reduction step

Product Distribution with 2%C$_3$H$_8$/N$_2$ reduction, T= 600°C
### Preliminary Simulation Results

<table>
<thead>
<tr>
<th>CASE</th>
<th>CASE 1 H2-MeOH</th>
<th>Case 2 H2-FT</th>
<th>Case 2 NG-FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Entering Plant, tonne/h</td>
<td>56</td>
<td>56</td>
<td>32</td>
</tr>
<tr>
<td>Steam Turbine Power, kWe</td>
<td>10,395</td>
<td>11,793</td>
<td>10,625</td>
</tr>
<tr>
<td>Net Electricity Imported, kWe</td>
<td>427,905</td>
<td>375,798</td>
<td>133,505</td>
</tr>
<tr>
<td>Product(s), tonne/h</td>
<td>37.54</td>
<td>13.97</td>
<td>13.97</td>
</tr>
<tr>
<td>Cost of Product(s), $/tonne</td>
<td>567</td>
<td>1,362</td>
<td>784</td>
</tr>
<tr>
<td>Cost of Product(s), $/gal</td>
<td>1.71</td>
<td>3.81</td>
<td>2.19</td>
</tr>
</tbody>
</table>

- Under a separate DOE project (DE-FE0029866), TDA and UCI developed an Aspen Model for the CO₂ conversion to fuels
- The use of H₂ and natural gas was evaluated as reductants
  - FT Liquids are produced at $3.81/gal or $2.19/gal based on the reductant source (H₂ or CH₄, respectively)
- An Life Cycle Analysis (LCA) will be carried out to fully assess the carbon capture and utilization