Hydrogen as an enabler

- Decarbonisation of hydrocarbons with CCS provides an energy source with zero or very reduced CO2 emissions
- Produced hydrogen allows for decarbonised energy distribution and energy storage
  - Transportation
  - Heating and power
  - Energy intensive industry
- Integrated with green energy projects, it can provide carbon neutral energy storage and back-up
- Viable projects will only happen if you can answer two fundamental questions:

Where will the CO$_2$ go?
Who will pay?
The Rise and fall ... and rise? ... of CO₂ capture

- Power companies drove interest in CO₂ capture from large coal power station 2005-2012

- 2008 recession eventually led to demise of most projects – the US being the exception due to existing enhanced oil recovery (EOR) demand for CO₂

- Renewed interest in US, EU, Canada, China
  - Multiple projects with a single storage solution
  - Energy clusters with hydrogen integration for distribution and storage

[Diagram showing Patent Applications on CO₂ Capture]

[Figure showing a line graph with years from 1990 to 2020 on the x-axis and applications on the y-axis. The graph shows an increase in applications around 2005, followed by a decline around 2010.]
US leadership in CCS Projects

- More operating projects than ROW combined
- 100s of miles of existing super critical CO2 pipelines for EOR
- Long term EOR experience
- Federal 45Q – Tax credit provided for projects that capture and store CO2.
  - Updated in 2018
    - $35/MT for use in enhanced oil recovery (EOR)
    - $50/MT for sequestration

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Onstream</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Century Plant</td>
<td>Texas, United States</td>
<td>Operating since 2010</td>
<td>Industry, Natural Gas Processing</td>
</tr>
<tr>
<td>Terrell Natural Gas Processing Plant</td>
<td>Texas, United States</td>
<td>Operating since 1972</td>
<td>Industry, Natural Gas Processing</td>
</tr>
<tr>
<td>Petra Nova Carbon Capture</td>
<td>Texas, United States</td>
<td>Operating since 2017</td>
<td>Power, Coal Power Generation</td>
</tr>
<tr>
<td>Air Products Steam Methane Reformer</td>
<td>Texas, United States</td>
<td>Operating since 2013</td>
<td>Industry, Hydrogen Production</td>
</tr>
<tr>
<td>Enid Fertilizer</td>
<td>Oklahoma, United States</td>
<td>Operating since 1982</td>
<td>Industry, Chemicals (ammonia)</td>
</tr>
<tr>
<td>Coffeyville Gasification Plant</td>
<td>Kansas, United States</td>
<td>Operating since 2013</td>
<td>Industry, Chemicals (ammonia)</td>
</tr>
<tr>
<td>Illinois Industrial Carbon Capture and Storage</td>
<td>Illinois, United States</td>
<td>Operating since 2017</td>
<td>Industry, Refining (biofuels)</td>
</tr>
<tr>
<td>Shute Creek Gas Processing Plant</td>
<td>Wyoming, United States</td>
<td>Operating since 1986</td>
<td>Industry, Natural Gas Processing</td>
</tr>
<tr>
<td>Lost Cabin Gas Plant</td>
<td>Wyoming, United States</td>
<td>Operating since 2013</td>
<td>Industry, Natural Gas Processing</td>
</tr>
<tr>
<td>Great Plains Synfuel Plant and Weyburn-Midale</td>
<td>North Dakota, United States &amp; Saskatchewan, Canada</td>
<td>Operating since 2000</td>
<td>Industry, Refining (SNG)</td>
</tr>
</tbody>
</table>

CCS North America (ref International Energy Agency)
Project Overview: State-of-the-Art Carbon Capture from Two Port Arthur, TX SMRs

- American Recovery and Reinvestment Act Funding
- ~1 million tons of CO2 to be recovered and purified annually starting late 2012
- Valero providing land, rights-of-way, utilities
- Air Products supplying compressed and purified CO2 to Denbury for injection into TX oilfields for enhanced oil recovery
Air Products’ Port Arthur CO2 Project

Technology to recover anthropogenic CO\(_2\) for EOR

- Retrofit of two Steam-Methane Reformers (SMR) located in the middle of a refinery
- Capture and purification of CO\(_2\) from hydrogen plants for EOR
- Technology developed by Air Products - Vacuum Swing Adsorbers
- 90%+ capture of CO\(_2\) from syngas
- ~2600 t/d (50 MMSCFD) of CO\(_2\) to Denbury’s Green Pipeline for West Hastings oilfield EOR
- 30 MWe cogeneration unit to generate power and make-up steam
- Full capacity achieved April 2013

Capturing 1 million tonnes/year of CO\(_2\) since 2013
CO₂ Capture – Port Arthur Project Answers

● Where will the CO₂ go?
  - Port Arthur is 13 miles (21 km) from Denbury’s existing “Green” 300+ Mile (~500 km) CO₂ Pipeline used for CO₂ EOR

● Who will pay for the CO₂ capital and operating costs?
  - US Government grant from the American Recovery & Reinvestment Act
  - Tax credits 45Q for CO₂ stored by EOR
  - Denbury pays for CO₂ to use in EOR applications

Map shows Denbury’s Green CO₂ Pipeline. Data source is Denbury, December 2011, CO₂ Flooding Conference
Air Products’ CCS focus

- Looking for viable CCS opportunities
- Further retrofits of existing hydrogen SMRs
- CO₂ Capture from Gasification
  - In preparation Air Products has purchased key Gasification technology of the leading suppliers
  - Gasification with CO₂ capture allows you to use high carbon content feed stocks to produce high value products with minimal carbon emissions
  - Air Products has developed a “Road Map” of technology applications for CO₂ capture on coal and refinery heavy residue feedstocks
- Development of in-house technology e.g. CO₂ VSA
- Decarbonization of natural gas
- Partnerships for storage options
Summary

- Fossil fuels will be part of the global energy supply for many years to come
  - CCS means we can continue whilst meeting CO₂ emission targets
- CCS allows the use of lower cost carbon rich “heavy” feedstocks with low atmospheric CO₂ emissions
- All the necessary technology to capture, purify and store CO₂ exists and is proven in long term operation
  - Technology available to commence projects immediately
  - R&D will improve efficiency and reduce cost
- A competitive alternative to other Green Energy projects
- Seed projects can be an enabler for further R&D, pilot plants, smaller scale investments

Where will the CO₂ go?
Who will pay?
Thank You

tell me more