H2@Scale Workshop
NREL – Golden, CO
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Praxair at a Glance

- A Fortune 250 company
  - 2015 sales of $12 billion
- Global Industrial Gas Supplier
  - Largest in North and South America
- Operating in more than 50 countries
- 27,000 employees
- One million customers worldwide

**End Markets**

- Food & Beverage: 8%
- Healthcare: 8%
- Electronic: 8%
- Chemicals: 10%
- Metals: 17%
- Energy: 13%
- Aerospace: 3%
- Other: 9%
- Manufacturing: 24%

- A component of the Dow Jones Sustainability Index – 11 years
- 100 Best Corporate Citizens for 2013 by Corporate Responsibility Magazine
- Regularly rated among the most shareholder-friendly chemical companies (Institutional Investor)
- Named among the “World’s Most Innovative Companies” by *Forbes*
H2 Molecule Sources

<table>
<thead>
<tr>
<th>Hydrogen Molecule Sources</th>
<th>Hydro-Carbon</th>
<th>Electrolysis</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Natural CH4</td>
<td>Fossil Electricity</td>
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<td></td>
<td>Bio CH4</td>
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<td>Others (ROG)</td>
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<td>Natural Gas Liquids</td>
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<td>Purpose Production</td>
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<tr>
<td>Hydro-Carbon Reforming (SMR)</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Electrolysis</td>
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<tr>
<td>By-Product Production</td>
<td>Ethane Crackers</td>
<td>✓</td>
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<tr>
<td>Chlor-Alkali Production</td>
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</tbody>
</table>

Reforming \( \text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 4\text{H}_2 \)  
Electrolysis \( 2\text{H}_2\text{O} \rightleftharpoons \text{O}_2 + 2\text{H}_2 \)  
Cracker \( \text{C}_2\text{H}_6 \rightleftharpoons \text{C}_2\text{H}_4 + \text{H}_2 \)  
Chlor-Alkali \( \text{NaCl} + \text{H}_2\text{O} \rightleftharpoons 2\text{Cl}_2 + 4\text{NaOH} + 2\text{H}_2 \)

Discussion Points

- Renewable H2 production & use of by-product H2 sources
- Capital requirement will influence development pathways
- Feedstock variable cost stability is an important factor
Commercial Delivery Modes

Luxfer-GTM Technologies

Compressed Gas

High Pressure Pipeline Supply

Liquid Hydrogen
Storage

Compressed

- 2K – 10K psi
- Unlimited capacity
- High capital intensity
- Thermal Management for filling
- Codes & Standards compliance
- Can be filled off pipeline delivery

Liquid Storage

- High density storage
- Cryogenically efficient
- Codes and standards compliance
- “Over the road” transport, only.
- Refrigerant value (heat of compression)
- Capital intensive

Pipeline

- Unlimited: Inputs & Supply Points
- 500 – 2K psi range
- Ability to “pack” for added storage
- Cavern Storage (geology critical)
- Capital intensity
- Federal & State regulations
Thank You