Alternative Transportation Fuels Workshop

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The Linde Group based on two pillars with extensive synergies

The Linde Group

Linde Gas

• Global Presence > 100 Countries
• 60,000 Employees
• € 14 Bn
• World leader in Hydrogen production, distribution and fueling technologies

Linde Engineering
Clean Energy - a strong focus in key growth areas

<table>
<thead>
<tr>
<th>Merchant Liquid Natural Gas (LNG)</th>
<th>Enhanced Oil Recovery (EOR)</th>
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<tbody>
<tr>
<td>- Displace diesel</td>
<td>- Maturing oil fields</td>
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<td>- CO₂ reduction</td>
<td>- High oil prices</td>
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<thead>
<tr>
<th>Carbon Capture &amp; Storage / Usage</th>
<th>Biofuels &amp; Green Hydrogen</th>
<th>H₂ as fuel</th>
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<tbody>
<tr>
<td>- Regulations</td>
<td>- Renewable Hydrogen</td>
<td>- Zero emissions</td>
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<tr>
<td>- Funding</td>
<td>- De-carbonization</td>
<td>- Drive performance</td>
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<td>- Coal reserves</td>
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<th>CO₂ Networks</th>
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<td>- Increasing need for CO₂</td>
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<td>recycling</td>
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<td>- Integrated solutions</td>
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Linde covers the entire hydrogen value chain

**Production**
- Conventional H₂ (e.g. SMR)
- Green H₂ (e.g. BTH)

**Supply/Storage**
- LH₂ storage
- Onsite SMR
- Onsite electrolysis

**Compression/Transfer**
- Ionic compressor
- Cryo-pump

**Dispenser**
- 350 bar
- 700 bar
Innovation:
Linde’s advanced hydrogen fuelling technologies

The Ionic Compressor
- High throughput of 30 kg/h at 900 bar\(^1\)
- Energy consumption reduced by 25\(^\%\)\(^2\)
- Very small number of moving parts (liquid piston)
- Reduced wear and long service life
- Four times longer maintenance intervals* 
- Fulfils industry standard SAE J 2601-A

The Cryo Pump
- Very high throughput of up to 120 kg/h at 900 bar
- Energy consumption reduced by 70\(^\%\)\(^2\)
- Hydrogen with highest purities
- No additional cooling system
- High reliability, little maintenance effort and low costs
- Fulfils industry standard SAE J 2601-A

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\(^1\) For one system. Modular setup allows for higher throughputs.
\(^2\) In comparison to a conventional piston compressor
Innovation: Development steps in advanced hydrogen fuelling technologies

- **Dry running compressor**
- **Ionic compressor / cryo pump**
- **Potential**

**Capex**
- 100% → ~ 50%

**Costs per maintenance**
- 100% → ~ 50%

**Maintenance intervals**
- 100% → ~ 400%

**Energy demand**
- 100% → < 75%

Fulfill SAE J 2601 A70 refueling protocol

Source: Linde internal analysis
Innovation -- Hydrogen production pathways
Biomass to Green Hydrogen

Pilot plant in Leuna

Pyroreformer

Pyrolysis

Glycerol storage & cleaning

Glycerol (raw, clean, residue)
Renewable Hydrogen - Magog, Quebec Canada

- H2 feedstock: waste gas from sodium chlorate plant
- Power: Hydro-electric
- Production: 15 Ton/day
- Minimal GHG
Perseverance: Reference projects prove technological maturity

**Linde reference projects**
- OMV, Stuttgart
- TOTAL/CEP, Berlin
- AC Transit, SFO Bay
- Ariake, Tokyo
- Linde Hydrogen Center Munich
- Zero Regio, Frankfurt

**Key facts**
- More than **80 hydrogen stations** equipped in 15 countries
- More than **300,000 successful fuelings**
- **Leading supplier** of hydrogen fuelling technologies

**Key Learnings**
- Proving the technology
- High level of standardisation reached
  - Standardised fuelling protocol
  - Standardised H2 quality
- Comparable fuelling experience
  - 3 min / fuelling
  - Touch & feel like conventional stations
  - Integration into existing infrastructure
- High throughput stations
Demonstration of technical viability for H2 cars & H2 fuel

Mercedes Benz World Drive

- 125 days around the globe
- Linde exclusive H2 infrastructure supplier
- 3 vehicles, > 30,000 km
- Appr. 130 fuellings per vehicle (in total 400)
AC Transit Emeryville
Largest Bus H2 Fueling station in the US
Forklift truck hydrogen
An economical environmentally friendly solution is here today

Hydrogen FLT Fueling
Typical 450 kg/day
(BMW, Spartanburg, SC)
Long Term Approach: “H₂ Mobility” Initiative – Overcoming the Chicken and Egg Dilemma

Memorandum of Understanding for “H₂-Mobility” signed Sept. 10th 2009 in Berlin
Ten key stakeholders from industries (OEM, oil, utility & industrial gas) and NOW as public-private-partnership
Intention to build up hydrogen fueling infrastructure and establishing Germany as a lead market
Staged investments along population centres
Linde & Daimler invest in 20 additional fuelling stations

Key facts

— Initiative by Daimler and Linde
— Bridge the gap between demonstration (CEP) and commercialization (H2 Mobility)
— 10 + 10 additional public hydrogen stations in Germany
— Build-up in 2013, 2014, and 2015
— Strengthen existing cluster and establish links
— Will allow to drive through Germany with hydrogen cars

Distribution of stations (preliminary)
Conclusions/Challenges

— Hydrogen and fuel cells will play a key role in mobility & material handling
— Leaving demonstration, entering pre-commercial phase
— Cooperation is key
— Cost is coming down...but performance is key!
— Challenges
  — Public awareness & acceptance
  — Harmonization of Codes & Standards
  — Customers acceptance will also depend on attractive products *(moment of truth)*