Linde is involved in the clean energy business worldwide:
Some examples
Energy Generation and Use: A changing landscape
The energy trilemma

— Balancing the growing global energy demand with the need to conserve natural resources is a major challenge. Successful solutions must be economically viable.

— Tomorrow’s power supply will be dominated by a steady increase of efficiency and a smart utilisation of new technologies.
Linde adds value along the entire NG/LNG value chain

**Upstream**
- World-scale LNG
- Floating LNG
- Biogas
- Stranded gas
- Pipeline

**Production/Sourcing**
- Terminal
- LNG plants
- 3rd party

**Distribution**
- Trucking
- Shipping
- Storage
- Fuelling

**Customers**
- Marine
- Truck
- Industry
- Utilities
Hammerfest LNG plant, Norway
CO₂ reinjection via subsea pipeline

World’s first industrial project to deliver CO₂ separated onshore back offshore and injected into a reservoir

- Europe's first export facility for liquefied natural gas (LNG)
- Terminal and process plant on Melkøya island outside Hammerfest in northern Norway
- Annual LNG export: 5.67 billion Nm³
- CO₂ content: 5.0% to 8.0%
- CO₂ captured in onshore plant, conveyed back with subsea pipeline, stored underground
- Emission reduction of more than 50%
- Norwegian CO₂ tax = 50 €/t
Small- and mid-scale LNG plants and offloading terminals

Description

- Increasing importance of small- and mid-scale LNG plants
- Size makes them ideal for sites near industrial parks and cities, keeping them close to the customer
- Compared with fossil fuels such as diesel, petrol and oil, natural gas reduces carbon dioxide emissions by around 20 percent

Scope

- Linde a one-stop provider for entire LNG terminals, supplying everything from the LNG production plant to the storage tanks for trucks and ships, and from the on-site storage units to the on-board reliquefaction units and liquid-to-gas converters

Reference projects

- Baltic Sea’s first LNG terminal in Nynäshamn (S)
- Australia’s first LNG plant in Dandenong
- Stavanger (N), Kwinana (AUS), Shan-Shan and Ji Munai (PRC), Lysekil (S), Emden (D, under construction)
Serving the shale gas boom
Enhanced natural gas extraction with the help CO$_2$ and LIN

Description

— Advances in horizontal drilling and hydraulic fracturing (fracking) have made huge reserves of North American natural gas economically feasible to extract

— Carbon dioxide (CO$_2$) and liquid nitrogen (LIN) are commonly used during the fracking process as energized fluids offering unique characteristics and economics

— Depending on the reservoir, fracking with CO$_2$ and/or LIN can substantially reduce water consumption and requires less or no chemical additives

Scope

— Linde serves as a supplier of energized fluids and field service supported by a national CO$_2$ and LIN supply network

— Extensive industry relationships

— Engineering Division has been awarded contracts worth around USD 1.3 bn for the supply of NG plants from the US since 2010
Biogas as environmentally friendly vehicle fuel

Description

— Biogas is captured, cleaned and either compressed or liquefied → environmental friendly fuel
— Reducing methane emissions, 25 times more harmful to the atmosphere than CO₂

Scope

— Linde engineers and builds plants to capture, purify and liquefy gas from landfills, biomass or animal waste
— Tailored solutions to reuse gas by customer, retail of waste stream gas to other industries

Reference projects

— Altamont, CA, USA: JV with US company Waste Management Inc.: landfill gas generated via fermentation is processed to fuel 300 refuse collection trucks in California
— Contributing in a collaborative effort in Stockholm, Sweden, supplying up to 11 biogas fuelling stations
Solvent based post-combustion CO₂ capture is currently a leading option:

- Applicable to new or retrofit plants
- Capture all or part of flue gas
- Applied at large scale in other applications
- Novel solvents (e.g. OASE® blue) are stable in presence of flue gas contaminants & oxygen
- Significant progress made toward the capture cost goal
BASF / Linde post-combustion CO₂ capture partnership
Delivering total solutions with confidence

BASF Solvent/Process Expertise
Basic Design Package
Process performance
Emissions performance

Linde Engineering Expertise
Process optimization
Basic/Detailed Engineering Package/EPC wrap

Founded: 1865
Sales (2015): €70.5 billion
Employees: ~112,000

Founded: 1879
Sales (2015): €17.9 billion
Employees: ~64,000
BASF OASE® blue technology roadmap
Adopted and optimized for PCC applications

Equilibria
Kinetics
Stability

- Ludwigshafen, Germany
- Solvent selection & performance verification

Pilot: 0.45 MWe (2009)
- Niederaussem, Germany
- Process opt., materials & emissions testing

Pilot: 1.5 MWe (2014)
- Wilsonville, AL (NCCC)
- Design improvements, emissions confirmation

Large Pilot (proposed): 15 MWe (2016-2020)
- Abbott power plant, UIUC, Champaign, IL
- Full value chain demo.
CAPTURING CARBON FROM ABBOTT POWER PLANT

PHASE 1 COMPLETED & PHASE 2 PROPOSAL IN EVALUATION BY DOE/NETL FOR 15 MWe CAPTURE FACILITY

• Strong Illinois team led by University: University of Illinois, Linde, BASF, Affiliated Engineers, ACS
• Vigorously Tested, Proven, and Matured Carbon Capture Technology from Linde/BASF
• Phase 1 (Project Definition and Pre-FEED)
• Phase 2 (build & test) is a $75 Million project; Phase 2 proposal submitted March 31, 2016
• Syndicated public/private partnership for Phase II with $58.5 Million from DOE/NETL and the remaining from the University and private sector companies
• Phase 3 plans by University to set up a CO2 utilization Research Center
Linde Covers The Entire Hydrogen Value Chain

<table>
<thead>
<tr>
<th>Large-Scale Production</th>
<th>On-site Supply &amp; Storage</th>
<th>Compression/Transfer</th>
<th>Dispenser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional (e.g. SMR)</td>
<td>CGH2 storage</td>
<td>Ionic compressor</td>
<td>350 bar</td>
</tr>
<tr>
<td>Green (e.g. BTH)</td>
<td>LH2 storage</td>
<td>Cryo pump</td>
<td>700 bar</td>
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<tr>
<td></td>
<td>Onsite SMR</td>
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<td></td>
<td>Onsite Electrolyzer</td>
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</tbody>
</table>
**Linde hydrogen refueling solutions**
Reference projects prove technological maturity

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

**Key facts**
- More than 80 hydrogen stations equipped in 15 countries
- Over 1,000,000 successful refueling events
- Leading supplier of hydrogen fuelling technologies
- Cover the entire hydrogen value chain

**Key learnings**
- Technological maturity reached
- High level of standardisation reached
  - Standardised fuelling protocol
  - Standardised H₂ quality
- User-friendly fuelling process
  - 3 min / fuelling
  - Touch & feel like conventional stations
  - Integration into existing infrastructure
How is Linde Playing a Part?
An economical environmentally friendly solution is here today

BMW, Spartanburg, SC
Largest H2 Fueling station in the world
fueling >350 FLTs
Approaching ~ 1 TPD
West Sacramento Station
1st truly retail hydrogen station in operation

- Credit Card Ready (No user Agreements)
- DMS Approved for sale by KG
- SAE J2601 Compliant
AC Transit – Emeryville, CA (SF Bay Area)
Linde Hydrogen Fueling Stations

- 12 Fuel Cell Buses, >~ 213K kg dispensed, >9000 bus fills and 1000 car fills, > 300Kg/dy H2 Fueling
- Largest FC Bus station in the world
World’s 1st Hydrogen Fuel Cell Car Share Program by Linde
Project overview and key facts

Project scope and key facts

Development of an decentralized hydrogen energy storage plant

- Location: Mainz (Germany)
- Partners: Stadtwerke Mainz, Linde, Siemens, RheinMain University
- Connected to a wind-farm (8 MW)
- 6 MW peak electrolyzer (3 stacks, each 2 MW)
- 1000 kg H₂ storage (33 MWh)
- 200 tons H₂ target annual output
  - Injection in local gas grid
  - Multi-use trailer-filling
- Budget: total 17 m€
- Funding: ~50% (BMWi)
- Timeline: 4 years (10/2012 – 12/2016)

Source: Energiepark Mainz
Project overview and key facts

Electrolysis

- Three electrolysis units (SILYZER 200)
- Electrical power consumption:
  - 1.3 MW continuous
  - 2.0 MW time limited peak load
- \( \text{H}_2 \) output pressure level of up to 3.5 MPa
- Highly dynamic operation over a broad load range (ramp speed 10% per sec.)
- Widely adjustable DC power supply

Source: Energiepark Mainz
Thank you for your attention.