The Linde Group
Global presence >100 countries, +62' people & EUR 15.2 bn (2012)
Technology portfolio
Linde is involved in the clean energy business worldwide

- **Hydrogen refuelling stations**: Germany, USA, Japan, China
- **LNG plant, Statoil, Hammerfest, Norway**
- **LNG import terminal, StatoilHydro, Nynäshamn, Sweden**
- **PCC flue gas wash, RWE, Niederaußem, Germany**
- **Landfill gas LNG plant, Waste Management, Altamont, USA**
- **Biogas refuelling station, LNG back-up, Sweden**
- **N₂ EOR plant, Pemex, Cantarell, Mexico**
- **CO₂ network, OCAP, Rotterdam/Amsterdam, Netherlands**
- **Hydrogen refuelling stations: Germany, USA, Japan, China**
- **CO₂ injection for EGR, Gaz de France, Maxdorf, Germany**
- **CO₂ injection/storage, GFZ Potsdam, Ketzin, Germany**
- **N₂ EOR ASU plant, ADNOC, Mirfa, Abu Dhabi**
- **Network of LNG plants for truck fleet fuelling, Australia**
- **Oxyfuel pilot plant, Vattenfall, Schwarze Pumpe, Germany**
# Technology portfolio
Clean energy growth markets for Linde

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Merchant Liquid Natural Gas (LNG)** | - Oil vs. NG spread  
- CO₂ reduction                                           |
| **Enhanced Oil Recovery (EOR)**  | - Maturing oil fields  
- High oil prices                                                    |
| **Carbon Capture & Storage / Usage** | - Regulations  
- Funding  
- Coal reserves                                         |
| **H₂ as fuel**                  | - Zero emissions  
- Drive performance                                             |
| **CO₂ Networks**                | - Increasing need for CO₂ recycling  
- Integrated solutions                                         |
| **Photovoltaic**                | - Environmental impact  
- Efficiency-driven                                                   |
Linde possessing deep competence in cryogenic production, distribution and customer applications all around the globe.
In our Gases Division long term investments include all aspects from source to customer.

- Gases production plant
- Filling centre
- Pipeline
- On-site supply
- Transport of liquified gas
- Customer
- Retailer
- Transport of compressed gas
Linde heavily engage in the complete value chain for small scale LNG beyond Scandinavia

Small to mid-scale liquefaction plants

<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gablingen, Germany</td>
<td>21 tons</td>
</tr>
<tr>
<td>Tasmania, Australia</td>
<td>50 tons</td>
</tr>
<tr>
<td>Bergen, Norway</td>
<td>120 tons</td>
</tr>
<tr>
<td>Kwinana, Australia</td>
<td>175 tons</td>
</tr>
<tr>
<td>Stavanger, Norway</td>
<td>900 tons</td>
</tr>
<tr>
<td>Shan Shan, China</td>
<td>1,300 tons</td>
</tr>
</tbody>
</table>

Distribution & storage, refuelling equipment and components

Linde owned small scale LNG operations

Australia

Altamont, CA, USA

Scandinavia
General market opportunities for small-scale LNG

**Marine Sector**
- M/S Bergenfjord (2x 125 m³ tank)
- Status: Due to regulation and price development, huge interest by shipping industry
  - More than 20 ships equipped with tanks from Cryo AB
  - Viking Grace from 2013 fuelled by LNG

**Mobility**
- LNG truck fuelling station Stockholm
- Status: OEMs (Volvo, Westport, MAN, …) developing technology
  - First LNG refuelling station in Stockholm in operation, 2 more to come in 2012

**Industry & Power**
- Nynäshamn Terminal Supply of nearby Refinery
- Status: In stranded areas without connection to trans-European grid, gas supply alternative
  - Interest from various industries to substitute other fuels with natural gas

**Price benchmark**
- Marine Sector: ECA: MGO or HFO + scrubber
- Mobility: Diesel
- Industry & Power: LPG, Diesel, Naphta
Experience from current operations

### Australia
- LNG truck fuelling station installed October 2012, Victoria
  - Status:
    - Small scale plant capacity exist on both East and West coast.
    - Appreciation of AUD hampers development.
    - Lack of suitable vehicles, OEM backed vehicles.

### North America
- BioLNG plant in Altamont California
  - Status:
    - Huge spread between diesel and natural gas price.
    - Oil & Gas industry early adaptor of LNG to displace diesel.
    - Several players announced significant investments in infrastructure.

### Europe, UK & Scandinavia
- LNG truck fuelling station Stockholm
  - Status:
    - First few stations installed.
    - Economic drive relative low but strong interest for bio methane.
    - Good cooperation within industry.
First new generation NO loss, low cost refuelling station installed by BOC in Australia
Linde’s subsidiary BOC building LNG production and fuel station network in Australia

- Geographic focus on Eastern Australia and Tasmania
- LNG produced from grid based small scale LNG plants
- Some of the challenges faced during start-up:
  - Availability of suitable engines, high horse power engines required in Australia
  - Macro economic development 2009 and forward hurting customer’s operation, e.g. appreciation of Australian dollar
  - High losses during „ramp-up“ of new stations
    - Customer requirements
    - Too large tanks installed
    - Non-optimized fuelling equipment
- BOC broaden the scope towards off grid power and industry in parallel to road transport

Take-out: LNG validated as attractive fuel for long-haul. Slow ramp-up requires well designed and optimized cryogenic refuelling solutions. All parties need to work very close to align interests.
LNG truck refueling system (with options)
schematic overview

- LNG road tanker
- LIN storage tank (option)
- LIN cooling device (option)
- LNG bulk storage tank
- Pressure build-up unit
- LNG submerged pump
- LNG vehicle onboard tank
- LNG conditioning unit (On-the-Fly)
<table>
<thead>
<tr>
<th>Main Features</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize waiting time due to reduction of heat influx / thermosyphon</td>
<td>Innovative</td>
</tr>
<tr>
<td>Fill a truck under 3 minutes (1 kg per second)</td>
<td>Performance</td>
</tr>
<tr>
<td>Eliminate methane boil-off due to integrated LIN coils</td>
<td>Environment</td>
</tr>
<tr>
<td>MID compliant mass flow meter included in the design</td>
<td>Future</td>
</tr>
<tr>
<td>Modular Design (allow 1 – 240 fills per day)</td>
<td>Performance</td>
</tr>
<tr>
<td>Safety Concept (Resources, Product, Operations, Regulatory Affairs)</td>
<td>Safety</td>
</tr>
<tr>
<td>Cryogenic Refueling Systems (maritime/road/air)</td>
<td>Experience</td>
</tr>
<tr>
<td>Linde can deliver the most of the value chain</td>
<td>Competence</td>
</tr>
<tr>
<td>Service Concept (depends on configuration – with/without options)</td>
<td>Cost and Customer Focus</td>
</tr>
</tbody>
</table>
LNG truck refueling systems
US, UK, NL

Q8-IDS
Rotterdam

ASDA
Bristol

Linde
Springville

DHL
Bawtry
Linde North America has purchased 23 LNG trucks for own distribution fleet

- Peterbilt and Kenworth LNG trucks with LNG fuel system and 8.9L NG engine
  - Cummins Westport ISLG Engine
  - 350 HP
- Trucks deployed in Southern California, Texas and Midwest
- Lower weight, spark ignited units has even improved pay-load

Take-out: Good driver experience and economics in line with expectations. Linde always operating weight restricted which is limiting areas were low horse power engines can be
UK market very receptive to BOC’s initiative

- Carbon footprint high on agenda of major customers
- Initial focus on high mileage back to base operations
- Strong support from OEMs, e.g. Volvo and Mercedes
- Customers appreciate cryogenic expertise, SHEQ competence and own operational hauling experience
- Positive trials done with leading operators like Eddie Stobart and DHL
- 2013 will be a decisive year for measuring long term adoption of LNG
- So far, all customers looking for bio methane in mid and long term, but no room to pay for “Green value”

Take out: Hen & egg situation addressed by focus on back to base. OEM commitment radically strengthens customer willingness to adopt
LNG Truck Refuelling Station (UK)
130 fills a day

**Equipment:**
- 80 m³ LNG tank
- 10 m³ LIN tank
- 2 vaporizer units
- 2 decant dispenser units
- 2 LIN assist units

**Performance:**
- approx. 130 fills per day
- 24/7 operation
- auto mode
Linde’s Intention: Establish LNG as Alternative Fuel

Success Factors

**LNG Supply:**
- Secured LNG supply from large scale, centralised entry points (i.e. LNG import terminal) or local LNG production direct or over small-scale LNG terminals to customers
- No seasonality for freight haulage as for established gas markets
- Price formula and contracting according to needs for heavy truck operation

**LNG infrastructure:**
- Chicken-egg problem persist – funding to establish multiple access points to LNG for road transport network, e.g. public or customer specific
- Established and EU wide harmonized legislation and standards required
- Technology need to fulfil user and environmental requirements

**Customer:**
- Availability of OEM backed products
- Commercially viable business case

Security & cost of supply, availability of infrastructure and OEM backed products must come together to generate growth and avoid disappointment on either side during early market introduction.
Thank you for your attention.
Linde main supplier to the Scandinavian LNG development

- AGA part of cluster behind Norway’s first 20 kty/y LNG plant, Trondheim, starting the marine LNG area in Norway
- EPC contractor of 40 kt/y Gasnor Train 1, Bergen
- EPC contractor of 300 kt/y Skangass LNG plant, Stavanger
- EPCS contractor of 4,3 mt/y Statoil, “Snøhvit”, base load LNG plant, Hammerfest
- Supplied LNG equipment for LNG onboard storage in the North Sea to a majority of all current ships
- Built, own and operate Stockholm’s LNG terminal – first LNG import terminal in the Baltic Sea
- AGA awarded the contract to supply the first large LNG fuelled ship in the Baltic Sea, Viking Grace
LNG Processing Plant
What are the main installations?

Main Installations - Functionalties

Gas Treatment
- Removal of water, condensate and other components (e.g. CO₂, H₂S, Hg, and others)

Liquefaction
- Pre-Cooling, liquefaction and sub-cooling using refrigerant cycles

Storage and Loading
- Storage under pressure or atmospheric pressure, loading of product by various means (e.g. ship, truck, etc.)

Safety and Security
- Installations for the plant security and process safety such as access control, CCTV, fire and gas detection, firefighting, emergency shut down, flare, etc.
LNG Processing Plant
What else is required?

Utilities - Functionalities
Power Generation and Distribution
  ▶ Power generation by gas turbines, transformation and distribution by switchgear to various consumers
Instrumentation and Control Installations
  ▶ Distributed Control System (DCS), fire and gas detection, control valves, etc.
Nitrogen, Instrument and Plant Air Supply
  ▶ Generation and storage of nitrogen, instrument and plant air
Run-Off, Sewage and Waste Water Treatment Systems and Installations
  ▶ Collection of run-off, sewage and other effluents
Buildings
  ▶ Administration building with central control room, workshop and warehouse
LNG Processing Plant – Block Diagram
How to keep track and the overview?

Gas Treatment
- Pig Trap Slugcatcher
- Inlet Facilities
- Mercury Removal and Dehydration
- CO2 Removal
- Dehydration
- CO2 Recompression
- Fuels, Gas, Diesel
- Condensate Treatment
- Service System for Offshore Installations (HPU, SPCU, SCU, Corrosion Inhibitor)
- Offshore Communication
- Central Control Room
- LNG Plant

Compression and Refrigeration
- Natural Gas Liquefaction
- Drivers and Compressors
- Cryogenic Units
- Condensation (Refrigerant Make-up)
- MEG Recovery
- Condensate Treatment
- Utility Systems LNG Plant
- Flare Systems
- Safety and Security
- Telecom
- Power Import/Export
- Fresh Water Import
- Sea Water Import

Storage and Loading
- LNG Storage
- LNG Loading
- Condensate Storage
- Condensate Loading
- LPG Storage
- LPG Loading
- Return Gas from Ship
- Return Gas from Ship
- Return Gas from Ship

Waste
- Emissions to Atmosphere

Dehydration
- CO2 to Pipeline
- MEG/ pH stab./ Corrosion Inhibitor to Pipeline
- Clean Lean MEG

Service System for Offshore Installations (HPU, SPCU, SCU, Corrosion Inhibitor)
Liquefaction Process
What does a simple expander process look like?

Typicals
— simple process, low equipment count
— nitrogen or mixed refrigerant \((N_2, \text{CH}_4)\) cycle at one pressure level
— pre-cooling, liquefaction and sub-cooling realized in one heat exchanger (aluminum plate fin heat exchanger)
— specific energy consumption approximately 600-700 kWh/t LNG
— investment volume < 50 Mio. €
LNG Truck Fuel Station in UK
Linde Truck Refuelling Station
Bristol/UK
LNG Truck Refuelling Station (USA)
Linde transportation fleet
Operational experience: Nynäshamn LNG terminal and Seagas bunker barge

Case study: Nynäshamn LNG terminal

- 20,000 m³ terminal in operation since 2011 with several 250 m³ LNG tanks
- Terminal located next to the Nynas refinery

Comments
Mega-trend Energy/Environment
Importance of new technologies & industrial gases applications

**NITROGEN**

- Build, own & operate large scale nitrogen schemes, nitrogen rejection units or CO₂-supply

**METHANE**

- Build LNG-plants, terminals & fueling stations
- Own & operate LNG-terminals & fueling stations & distribute LNG to industrial and maritime customers
- Build hydrogen fueling stations & supply hydrogen

**HYDROGEN**

- CO₂ separation, conditioning and handling for flue gas from coal and gas fired power plants and from industrial sources

**CARBON DIOXID**

- Build, own and operate large scale oxygen schemes for gas-to-liquid plants

**OXYGEN**

**Cleaner fuels**

Market 2020E

€ 9-16 bn

**Clean Coal & Gas**

Market 2020E

€ 2-3 bn

**Gas-to-liquids**

Market 2020E

€ 1.5-2 bn
Bomin Linde LNG: LNG Bunker Station
Port of Rotterdam, Netherlands
Technology portfolio I
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- Network of LNG plants for truck fleet fuelling, Australia
- Oxyfuel pilot plant, Vattenfall, Schwarze Pumpe, Germany

June 2013
Operational experience:
Nynäshamn LNG terminal and Seagas bunker barge
(2/2)

Case study: Seagas bunker barge

Comments

- World’s first LNG bunker barge
- Ferry Viking Grace as lead customer (55,000 dwt)
- Bunkering of Viking Grace 5 - 6 times per week in less than 1 hour
- No methane slip due to use of dry cryogenic couplings
- Official inauguration in March 2013 in Stockholm
Bomin Linde LNG is ready to deliver in Sweden, three more terminals in permitting / approval process

Bomin Linde LNG locations in Europe

Stockholm (Linde)
- Operational
- 20,000 cbm capacity
- LNG Bunker Barge AGA Seagas

Hamburg (Bomin Linde LNG)
- Planned
- Capacity up to 4,000 cbm (Phase 1)
- Option to expand significantly

Bremerhaven (Bomin Linde LNG)
- Planned
- Initial capacity up to 2,000 cbm

Rotterdam (Bomin Linde LNG)
- Planned
- Capacity up to 1,000 cbm
- Focus on inland market
Bomin Linde LNG: Hamburg bunker station

Premises: Hamburg

Comments

- Project initiated, basic engineering started
- Truckstation and rail connection available
- Sufficient space at jetty to bunker vessels via bunker barge
- Jetty fully owned by Oiltanking, a company of the M&B group
- Jetty can accommodate ships with a maximum capacity of 100,000 m³
- Average throughput of liquid products through Oiltanking: 6.3 million tons per year
Bomin Linde LNG: Because of size and weight of newly developed typ C LNG tanks delivery via sea

Layout: small-scale bunker station in Hamburg

Initial pilot installation of a 500 cbm tank until Q1 2015
Permit application for a capacity of max 6000 cbm

LNG storage capacity of 1700 m³, length 46 m, diameter 8 m

Truck (un)loading station to establish site of Hamburg as a regional LNG hub also for mobility (heavy duty trucks) and industry usage
Bomin Linde LNG: LNG Fuelling of MS-Ostfriesland operated by AG EMS in the Tidelands from Emden to Borkum.

Länge: 93 m
Breite: 12 m
Tiefgang: 2,95 m
Passagiere: 1,200
Liquefied Bio-Gas (LBG) production for transport applications

Clean Energy & Innovation Management
JV of Waste Management and Linde USA
20 t/d LBG Plant from landfill gas, Altamont, CA, USA

Responsible
Waste Management and Linde USA Joint Venture

Capacity
20 t/d LBG or 7,300 T/a

Customers
Waste Management, Linde USA
Linde built Altamont landfill gas to LBG for truck refuelling

- The largest of its kind in the world - 13,000 gal/d
  - Purification train
  - Mixed refrigerant liquefaction developed under license from GTI
- Linde JV with Waste Management, 50/50

- Environmental benefits
  - Reduces nearly 30,000 tons CO2 annually
  - Uses renewable feedgas and electricity
  - Supplies 300 WM refuse trucks
Bio-Methane distribution for transport applications developed to significant size in Sweden

- AGA supplied compressed bio-methane, CBG, since 2003 as fuel for transportation
- No grid in large part of Sweden
- NG can be substituted seamlessly by Bio-Methane as renewable fuel
- Bio-Methane has favourable taxation and receives other incentives as well, e.g. free parking, separate cuing lane at airports, etc.
- All LNG stations foreseen to also serve LCNG
- Very good cooperation between stakeholders, e.g. joint project Blue Corridor application
Bio-Gas / Bio-Methane production potential in EU is enough to cover future demand for Liquefied Bio-Gas (LBG).

**Today's Bio-Gas Production**

Biogas production per sector:
- Landfill Gas: 31%
- Urban sewage and industrial effluent sludge gas: 57%
- Decentralised agricultural plant, municipal waste methanisation plant, centralised co-digestion plant: 12%
Linde Business Model
Bio-Methane from the grid for Liquefaction to LBG

Bio-Gas Producer

- Bio-Gas supply contract
  - long term >10 years

Bio-Gas Production

Bio-Gas upgrading (Cleaning)

Bio-Methane grid injection (measurement, compression)

Injection to gas grid for downstream liquefaction

Bio-Methane Liquefaction

- 100 tpd liquefaction capacity
- Security of Bio-Gas + green gas certificates supply
- Compliance with sustainability criteria
- LBG cost per ton competitive with LNG at Terminal

LBG for transport applications

Green Gas Certificates

Bio-Gas supply contract

Linde responsibility
(liquefaction, distribution, fueling)

Bio-Gas Producer

Bio-Gas Production

Bio-Gas upgrading (Cleaning)

Bio-Methane grid injection (measurement, compression)

Injection to gas grid for downstream liquefaction

Bio-Methane Liquefaction

LBG for transport applications

Green Gas Certificates
Assumptions

• LBG Plant capacity: 100 t/d ~ 30,000 t/a

• Truck usage: 50% Dual Fuel, 50% Otto (12.4 & 26 kg/100km)
Sustainability Criteria

EU sustainability criteria for biofuels:

- **GHG saving criteria**: at least 35% lifecycle savings (50%-60% from 2017/18) compared to fossil fuel

- **No conversion of land** with high carbon stock: densely forested areas, wetlands, peatlands

- **No raw material from land** with high biodiversity value: primary forest, nature protection areas, highly biodiverse grasslands

Have to be met in order to:

- **Count toward the targets** (share of RE in transport of 10% by 2020)

- **Count toward obligations** (put on suppliers)

- **Be eligible for financial support** (for their consumption)

Well to Wheel GHG emissions comparison in g CO2eq/km

| Source: CONCAWE et al, 2007 Source: FNR 2010 |

Bio Fuels efficiency comparison in km/ha

Source: CONCAWE et al, 2007 Source: FNR 2010
LNG today already competitive with MGO, in particular economies of scale will further improve attractiveness

Fuel: Cost perspective in shipping (MWh)

Costs + optimisation from supplier perspective

- **A**: Levers: Subsidies & learning effects
- **B**: Economies of scale
- **C**: Spread Oil-Gas (→ Shale Gas)

**Fuel costs**

- Diesel
- LNG
Why Use LNG in Heavy Truck Operation?

— **Fuel costs** can be up to 50% of a Hauliers overall costs
  — Lower fuel costs with LNG
  — Favourable price spread oil/diesel vs. gas
  — Fuel taxation & other incentives varies

— **Environmental advantages:**
  — Improved air quality (NO\textsubscript{X}, CO\textsubscript{2}, particles)
  — Reduced carbon footprint (up to 20% Well to Wheel) with a huge improvement if / when increasing Biomethane content in the future

— Less noise
— Trusted reliability since decades
— High Security & Safety

**Key success factors by operator:**
- high mileage,
- long distance back to base or point to point

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**Clean Technology by Linde**

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23/10/2014  Fußzeile