H2@Airports

Al Burgunder
Director: Clean Hydrogen
Linde Gases US

Making our world more productive

About Linde

Linde uses its capabilities to drive clean energy projects worldwide

Key products: Plants, components, services & molecules

- Liquefaction
- Separation
- Thermal Cracking

Hydrogen, Oxygen, Nitrogen, Rare gases, Olefins, Carbon monoxide, Carbon dioxide, Synthesis gas

Key financials

Key Metrics

Sales[1]	~$28B
Op. Profit[1]	~$5B
Market Cap	~$90B
Employees	~80K
Customers	~+2M

Industrial Gas Competitors ($B)

Clean energy by Linde

Low Carbon Feedstocks

Waste Management site (landfill gas to renewable LNG)

Green hydrogen production, Energiepark Mainz, Germany

Largest Low Carbon liquid H2 production in N. America

Linde 2028 Climate Goals

Compared with a 2018 baseline

MEMBER OF
Dow Jones Sustainability Indices
In Collaboration with RobecoSAM

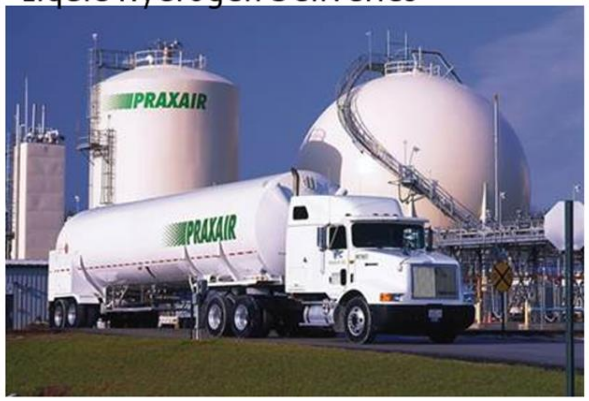
Linde has been recognized by The Dow Jones Sustainability World Index Chemicals Sector for 17 consecutive years

- Invest $1B+ in new decarbonization initiatives
  - Carbon capture
  - Green H_2 for mobility, power, renewable fuels and industrial production
- Spend at least 1/3 of our R&D annual budget on decarbonization
  - Dry reforming using CO_2 instead of water to reform natural gas,
  - Carbon capture, gas separation and sequestration technologies
  - Invest in promising green H_2 technologies
- Drive operational excellence to further reduce GHG intensity
  - 4% for HyCO
  - 7% for ASU
  - 10% fleet and other
- Double annual purchases of low-carbon power

10-year target to lower our Greenhouse Gas (GHG) emissions intensity by 35%

Hydrogen Supply Options

Liquid Hydrogen Deliveries



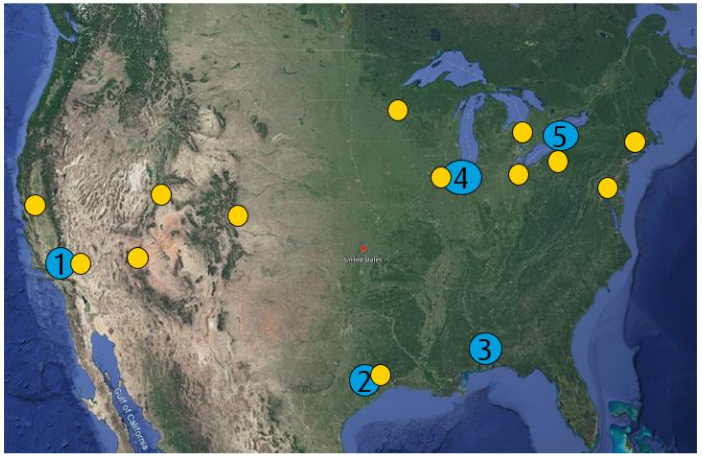
Pipeline Delivery

Gas Hydrogen Deliveries

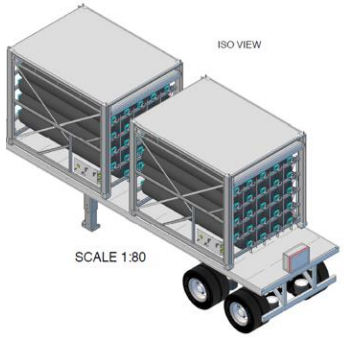
On-site Supply (SMR or Electrolyzers)

North America's Largest Merchant Hydrogen Supplier

1. Ontario, CA – 30 tns/day
2. LaPorte, TX – 30 tns/day
3. McIntosh, AL – 30 tns/day
4. E-Chicago, IN – 30 tns/day
5. Niagara, NY – 40 tns/day



- Ontario, CA (180 / 500 bar)
- Pittsburg, CA
- Garfield, UT
- Loveland, CO
- Kingman, AZ
- LaPorte, TX
- Whiting, IN
- Roseville, MN
- Toledo, OH
- Sarnia, ON
- Astabula, OH
- Suffield, CT
- Fairless Hills, PA



Linde Core technologies

Technology to deliver tomorrow's fuel today!

Core technologies

Liquid H2 supply (LH2)

Cryopump (CP)

- only solution for LH2 and high outlet pressures (>700 bar)
- energy consumption reduced by 70%[1]
- no additional, external cooling system needed
- high reliability and little maintenance
- fulfills industry standard SAE J 2601

CP versions	Outlet pressure	Capacity	Inlet pressure
CP 90/40	< 90 MPa	40 kg/h	0,2 MPa
CP 90/100	< 90 MPa	100 kg/h	0,2 MPa
CP 50/40	< 50 MPa	40 kg/h	0,2 MPa
CP 50/100	<50 MPa	100 kg/h	0,2 MPa

Gaseous H2 supply (GH2)

Ionic Compressor (IC)

- technology based on ionic liquid for compression of GH2
- energy consumption reduced by 25%[1]
- Reduced wear and long service life; 4x longer maintenance intervals
- Satisfies SAE J-2601
- Compliant with SAE J-2719

IC versions	Outlet pressure	Capacity	Nom. inlet pressure
IC 90/30	< 90 MPa	28 kg/h	0,6-20 MPa
Twin IC 90/60	< 90 MPa	56 kg/h	0,6-20 MPa
IC 50/30	< 50 MPa	28 kg/h	0,6-20 MPa
Twin IC 50/60	< 50 MPa	56 kg/h	0,6-20 MPa
IC/50 HyFlow/150	2/5/15/45 /90 MPa	150 kg/h	0,6/1,5/5/ 15/45 MPa

10/28/2020

[1] compared to conventional compressors

Liquefaction

Multiple technologies available.

- Kryotechnik: 1 to 100 tpd
- Linde Engineering: 15 tpd
- Praxair Engineering: >30 tpd

Leading edge Energy Efficiency

Fueling for all applications / Hydrogen from multiple sources

First LH_2 station in California (USA)

With three times the capacity of all the existing GH_2 stations, we have built the largest public fueling station in Oakland (CA) based on our Cryo Pump technology.

- Linde H_2 station CP 90/40-L with a fueling capacity of 40 kg/hour[1]
- Fully integrated into existing conventional fueling station (First Element)
- High storage capacity of 800 kg (LH_2) to keep up with growing demand
- Very small footprint of 10 m (length) × 3 m (width)
- Simultaneous refueling on a double 700 bar (cars) and 350 bar (buses) dispenser

[1] inlet pressure of 2 bar

Refueling station in Oakland (California)

First hydrogen refueling station in South East Asia

H_2 fueling stations in Malaysia produce hydrogen by means of electrolysis. This flagship project includes 350 and 700 bar dispensing lines.

- Linde H_2 station Twin IC 90/60-L with a fueling capacity of 58 kg/hour
- Fully containerized, highly compact design
- Serves local bus fleet with fueling capacity of 1.200 kg/day (20 hours of operation)
- Max. outlet pressure 900 bar
- Low maintenance, low noise, high reliability

Refueling station in Sarawak (Malaysia)

Future-proof fueling depot for floor-borne vehicles

Fueling station at Daimler's production site in Düsseldorf, Germany, for fuel cell forklifts and tractors and possibly also light fuel cell vehicles like passenger cars.

- Fueling station based on IC 90/30 technology with a capacity of 28 kg/hour
- Fueling of up to 30 floor-borne vehicles per hour
- Extendable to passenger car fueling
- Specially designed dispenser for indoor production site
- High flexibility thanks to two dispensers that can be installed at two different locations

Fuel cell forklifts fueling station

The world's first H_2 fueling station for passenger trains

Linde Hydrogen FuelTech is the supplier of the world's very first H_2 refueling station for passenger trains. The new depot is located in northern Germany and will fuel 12 Alstom Coradia iLint fuel cell trains, each with a 180 kg tank capacity.

- Fueling station based on three Twin IC 90/60 compressors (58 kg/hour each)
- Fueling capacity of 1.800 kg/day (12 fuelings in 24 hours)
- Total GH_2 storage at site is 4900 kg
- 2 × 250 bar dispenser line
- Application of innovative constant pressure tubes to minimize maintenance efforts

Making our world more productive

Enabling the energy transition