Making our world more productive

Linde Clean Hydrogen

Enabling the energy transition

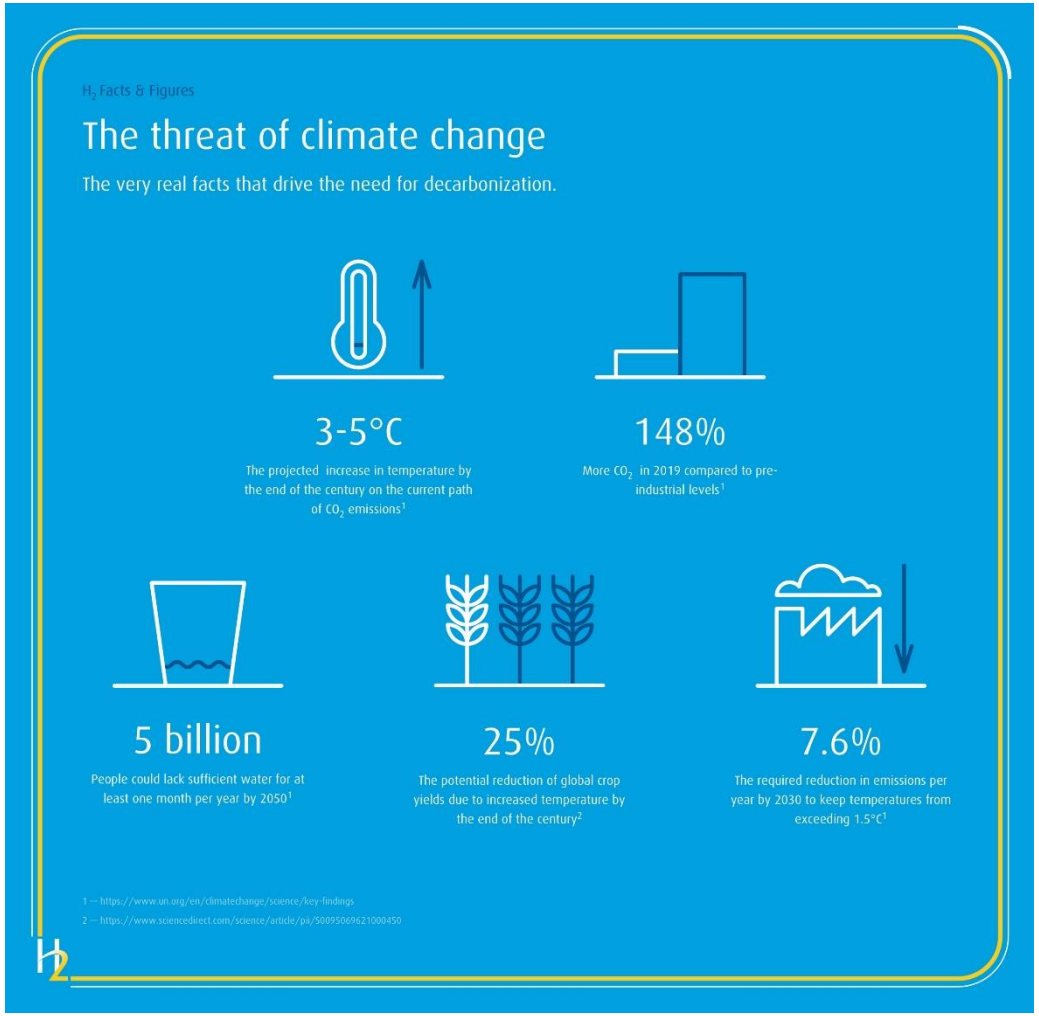
www.lindehydrogen.com

Climate change mitigation
Limiting global warming to below 2°C

Decarbonization as part of the solution for climate change

According to the European Commission, scientists warn that without urgent action, global warming is likely to exceed 2°C above pre-industrial levels by 2060, which will have devastating effects on our planet's ecosystems and cause irreversible damage.

United Nations' Paris Agreement aims to prevent the rising temperatures through a reduction of greenhouse emissions, increase in the share of renewable energies and improvements in energy efficiency.



The role of hydrogen in the energy transition

Empowering renewables, decarbonizing the economy

Hydrogen as an enabler of the zero-emissions goal

Hydrogen is a flexible energy carrier: it can be used to store excess renewable energy; it can be transported through an extensive network of pipelines and trucks; and it can be applied to a plethora of applications to lower their carbon footprint up to zero emissions.

When used in a fuel cell, for instance, hydrogen (H2) produces only water vapor.

The Hydrogen Council forecasts the hydrogen market to be valued at $100bn by 2030.

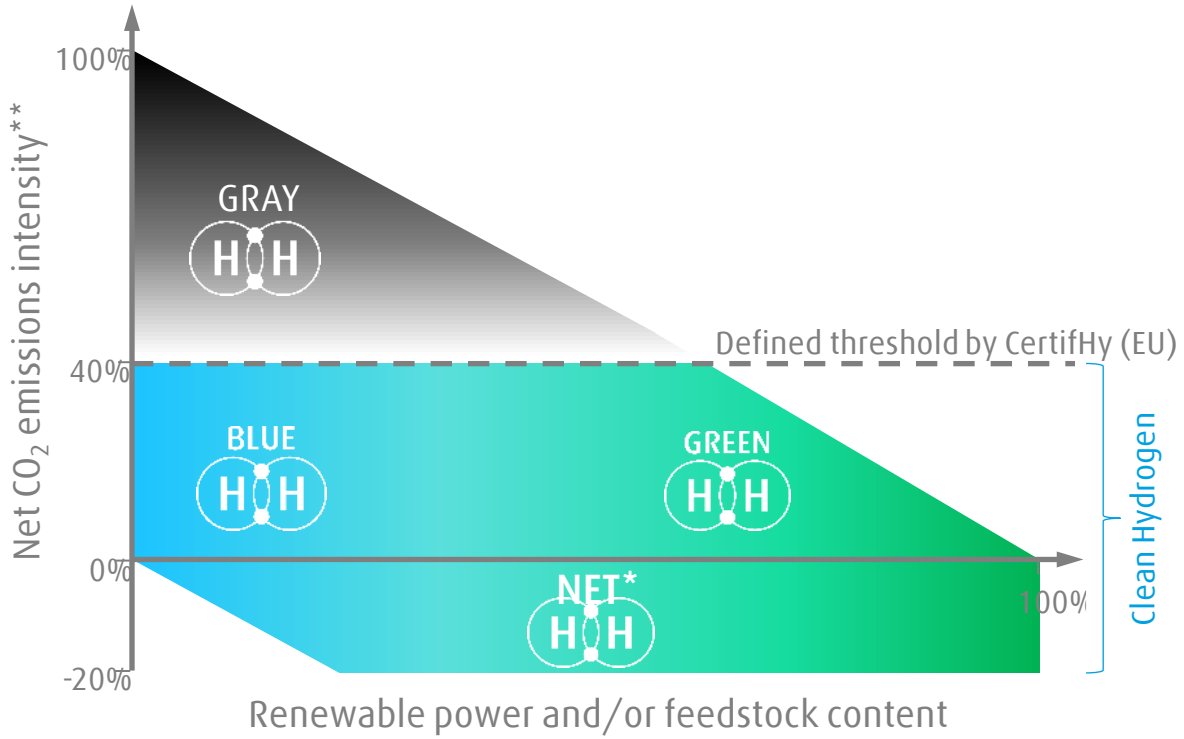
The hydrogen colors
From gray, to blue to green hydrogen

The steppingstones in the path to green hydrogen

Hydrogen can be of many colors, depending on its net carbon dioxide emissions' intensity, production method and feedstock content, as illustrated by the chart.

At Linde, we have been harnessing the power of hydrogen for over 100 years and we make continued investments in effective and economic ways to deliver gray, blue and, ultimately, green hydrogen.

Sustainable H2 production classification – a visual guide.



*NET = Negative Emissions Technology | **Direct & indirect emission (SMR = 100%)

Source: Linde

Introduction to Linde

- The leading industrial gases and engineering company, combining technology and operational excellence
- Formed in 2018 with the merger of Linde AG and Praxair, Inc – two world-class companies with nearly 140 years of shared history and successful achievements
- BOC, a Linde company, is the largest provider of industrial, medical and special gases in the UK and Ireland
- Best-in-Class Safety Performance

Our Mission

We live our mission of **making our world more productive every day**. Through our high-quality solutions, technologies and services we are making our customers more successful and helping to sustain and protect our planet.

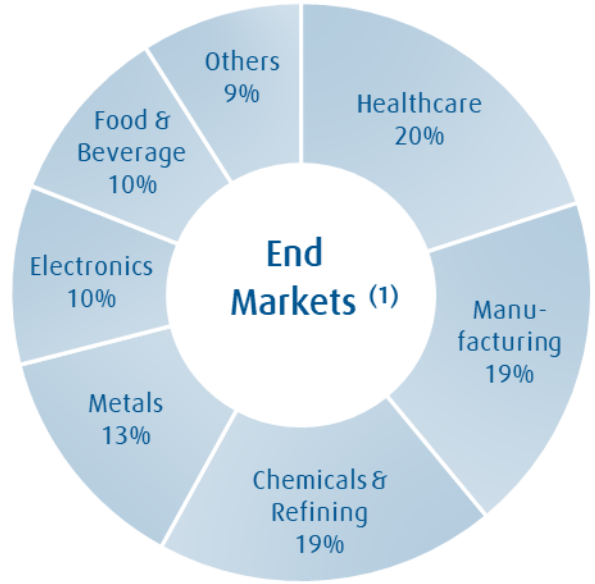
100+
countries
Enabling strong, complementary positions in all key geographies and end markets

~75,000
employees
Achieving our full potential, individually and collectively

$27 billion
2020 sales
Established presence where customers are and where their operations are growing

6,500+
active patent assets worldwide
Leading with innovative products, solutions and technologies

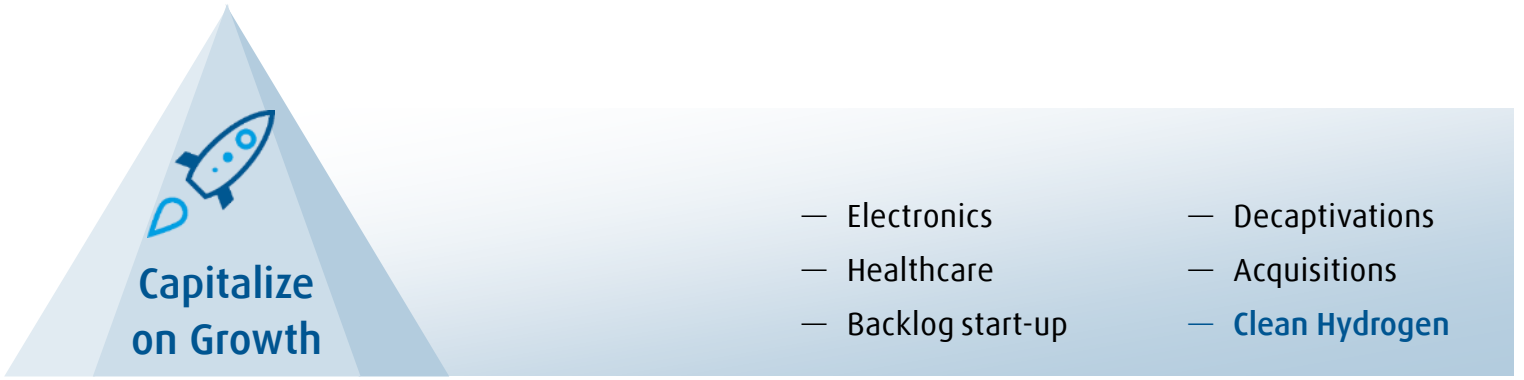
2020 SALES



(1) Total sales excluding Linde Engineering

Introduction to Linde
Clean Hydrogen as Growth Pillar for Linde

Sustainable value creation



Linde as a clean hydrogen advocate
Leading by example

Fostering clean hydrogen

Linde is a steward of sustainability and an industry leader in clean hydrogen. We are founding members of the Hydrogen Council and the H2 Mobility and actively advocate for clean hydrogen policies and initiatives through more than 20 industry and government sponsored organizations around the world.

We lead by example and are taking steps towards decarbonizing our own operations. Our SD 2028 Targets include lowering our greenhouse gas emissions intensity by 35%, investing at least $1 billion in decarbonization initiatives and dedicating at least 1/3 of our R&D budget to decarbonization.

Hydrogen Council

H2Accelerate

Hydrogen Europe

H2 MOBILITY WASSERSTOFF TANKEN

H2Global

UK HFCA

FCHEA Fuel Cell & Hydrogen Energy Association

European Clean Hydrogen Alliance

HYDROGEN FORWARD

FCH | FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

California Hydrogen Business Council
Hydrogen Means Business in California!

Cooperation with

Bundesministerium für Wirtschaft und Energie

U.S. DEPARTMENT OF ENERGY

Unique setup enables smooth transition to clean hydrogen

Leveraging our experience, technology and reach

Production and Processing

Sourcing from Natural Gas and Biogas

150+ SMR & PSAs

Steam Reforming (SMR) With Carbon Capture and PSA

40+ Compressors

H_2 Processing

Sourcing from Renewable Energies

80+ Plants

Electrolysis

170 TPD

H_2 Liquefaction

Storage and Distribution

1000 km

H_2 Pipeline

World's First

High-purity H_2 Cavern

Largest Fleet

Liquid and Gaseous H_2 Distribution Trailers

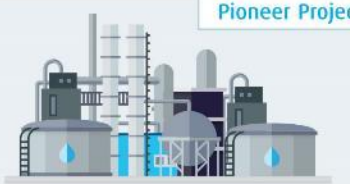
Cryogenic Tanks and Cylinders

Applications

200 Stations

Mobility – From Cars to Trains

Pioneer Projects



Industry Feedstock: Refineries, Steel, Chemicals, Ammonia

Largest P2X Plant

Power Buffering

Building Heating

Gearing up for clean hydrogen

How Linde supports customers and industry partners

Hydrogen production with electrolysis

Global green gas solutions at industrial scale using ITM Power's modular PEM electrolysis technology and Linde's world class EPC expertise and technologies.

Hydrogen Refueling Stations

Highly efficient and fast fueling concepts for cars, trucks, trains, forklifts and buses. Worldwide leader in installed H2 refueling stations.

Renewable energy storage

Experienced partner in the development of energy parks. Operating the first commercial high-purity H2 cavern for over a decade.

Carbon capture, utilization and storage

Linde offers proven CCUS technologies and is part of numerous R&D alliances to leverage government funding.

Infrastructure

Approximately 1000 km of H2 pipeline. Decades of experience in operating high-purity, high-pressure H2 pipelines. Largest global hydrogen liquefaction capacity and distribution fleet of liquid and gaseous trailers.

Industry feedstock

Trusted supplier of heavy industries, such as steel, chemicals and refining, Linde is well equipped to support the transition to a low carbon production.

Hydrogen production with PEM electrolysis

GLOBAL GREEN GAS SOLUTIONS | ITM LINDE ELECTROLYSIS

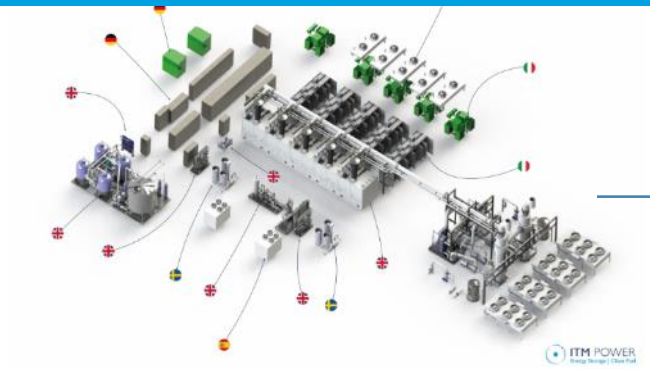
World class technology for energy storage and green industry feedstock

Energy storage

Example: Energie Park Mainz

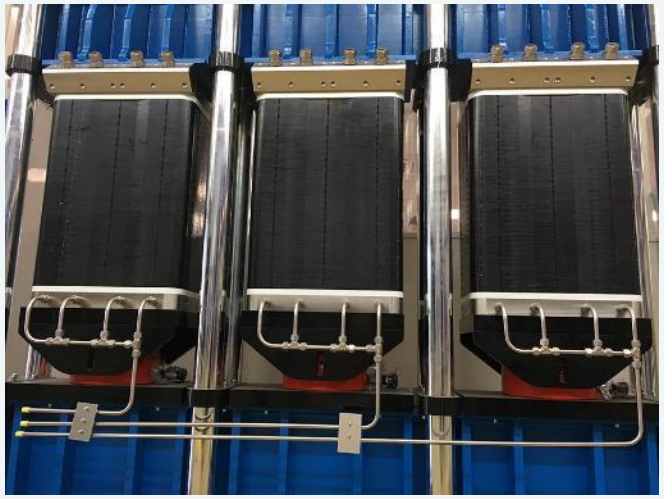
- Largest P2G plant, converting wind power into green hydrogen through electrolysis
- On-site production and storage of GH2
- 800 kg storage (25 MWh)
- Running since 2015

Industry



Example: Shell REFHYNE project

- 10 MW (Phase I) + 100MW (Phase II) electrolysis system for H2 generation
- H2 purification to 5.0 purity, suitable for load and grid balancing
- Integrated into general refining operations and displacing of gray hydrogen



Detail of modular PEM electrolysis system

- Each module independently controllable
- Ability to phase maintenance
- Developed for >100MW plants
- Small footprint

Hydrogen refueling stations (HRS)

Fueling tomorrow

Leading expertise and know-how

- Nearly **200 HRS** installed **worldwide**
- More than 1.5 million successful fueling of cars, buses and forklifts
- Only provider of **LH2 90 MPa stations**
- Supplier of the world's **first** hydrogen station for **passengers' trains**
- Supplier of the **world's biggest hydrogen bus depot** in California

Global projects

Berlin

Tokyo

Emeryville, CA

Cutting-edge technologies

CP – Cryopump (LH2)

IC – Ionic Compressor (GH2)

Renewable energy storage

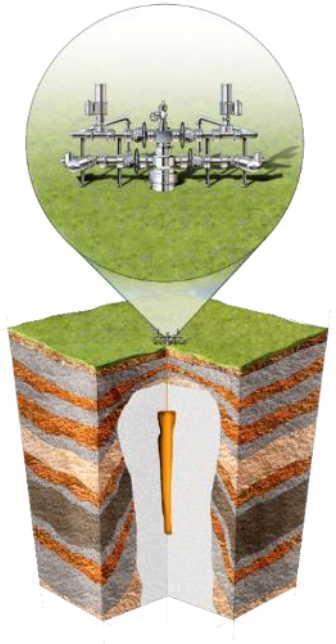
Empowering renewables

Wind to Gas to Power

Energy Park in Mainz.
In operation since 2015.

Solar to Gas to Fuel

Bulwer island, Queensland, Australia.
Planned operation start by 2021.



World's first high-purity H2 commercial cavern

- 10+ years of successful operation
- 2 years to solution mine: geophysical and execution expertise is key
- Total capacity of 2.5 Bcsf (6,000 MT)
- Working capacity equivalent to 10 days production from a world-scale SMR
- Essential for storing off-peak energy and thus create supply reliability

Carbon capture, utilization and storage (CCUS)

Lowering GHG emissions

CO_2 capture in IG production
from SMR, ammonia, ethylene, steel & ethanol plants

Various **pre-combustion capture** as well as **post combustion capture technology options** available

CO_2 production for the **merchant market** & **large industrial consumers** (e.g. urea production)

CO_2 capture & utilization
for customer applications

CO_2 mineralization in concrete
Ready-mix & precast concrete application

CO_2 utilization in Greenhouses
Linde OCAP pipeline in The Netherlands

CO_2 utilization for water pH control & remineralization
Linde SOLVOCARB technology for wastewater & drinking water

CO_2 capture & utilization technology
for IG production & customer applications

Linde DRYREF™
dry methane reforming for chemicals production with external CO_2 import

Linde post-combustion capture & purification
for hard to decarbonize industries (e.g. cement, steel)

Linde oxyfuel combustion capture & purification
for industry decarbonization (e.g. power, cement, glass)

Industry feedstock

Using clean hydrogen to reduce carbon footprint

Refineries

Using clean hydrogen in the production of clean fuels will decarbonize refining processes and reduce emissions.

Steel

Clean hydrogen can be used to replace coal and NG during the steel production process, substantially reducing the carbon footprint.

Renewable fuels and Methanol

The carbon footprint associated with the production of both can be lowered when using clean hydrogen.

Ammonia

Ammonia can be produced sustainably and directly from clean hydrogen.

Infrastructure

Unrivaled H2 network: global reach, strong local presence

From production

Operation of **150+ steam methane reformers and PSAs**

80+ electrolyzers installed

Joint Venture with **ITM** Power

Through processing

Largest H2 liquefaction capacity in the world with 170 tons/day

Vast experience in **H2 compression**

To storage and distribution

Largest Fleet of Liquid and Gaseous **H2 trailers**

1000 km H2 pipeline

World leader in cryogenics. **20,000+ cryogenic tanks supplied***

Solutions for **on-site production**

* more than 20,000 cryogenic tanks for liquefied gases supplied since 1960

Success stories

World's 1st stationary HRS for fuel cell trains, Bremervoerde

- Operation of 14 H2 trains (Alstom Coradia iLint model)
- Up to 1600 kg H2 per day
- On-site storage of up to 1800 kg GH2
- Hydrogen supply through Linde GH2 trailers
- On-site production: expansion ELY with wind power supply
- Commissioning in 2021

One of Europe's largest H2 Bus refueling stations, Cologne

- Commissioned in August 2020
- Capacity of up to 20 bus refills per day
- Featuring a new high-pressure storage technology developed by Linde, which allows for multiple back-to-back fillings
- Located in Cologne, Germany
- Project sponsored by the German Federal Ministry of Transport and Digital Infrastructure

Linde Builds World's Largest PEM Electrolyzer

- The new 24-megawatt electrolyzer will produce green hydrogen to supply Linde's industrial customers through the company's existing pipeline network.
- Located at Linde's plant in Leuna, Germany.
- Due to start production in the second half of 2022.

Thank you for your attention

Think Hydrogen. Think Linde.

Making our world more productive