

CET 2022 - The Converging Energy System

The role of Hydrogen in decarbonization – H₂ as an energy carrier for the future of Europe

Daniel Mateos - Linde

Oskarshamn, September 23rd, 2022

Making our world more productive



Introduction to Linde

Global industrial gas company with focus on sustainability



- 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

\$27 billion

2020 sales

Established presence where customers are and where their operations are growing

~75,000

employees

Achieving our full potential, individually and collectively

6,500+

active patent assets worldwide

Leading with innovative products, solutions and technologies

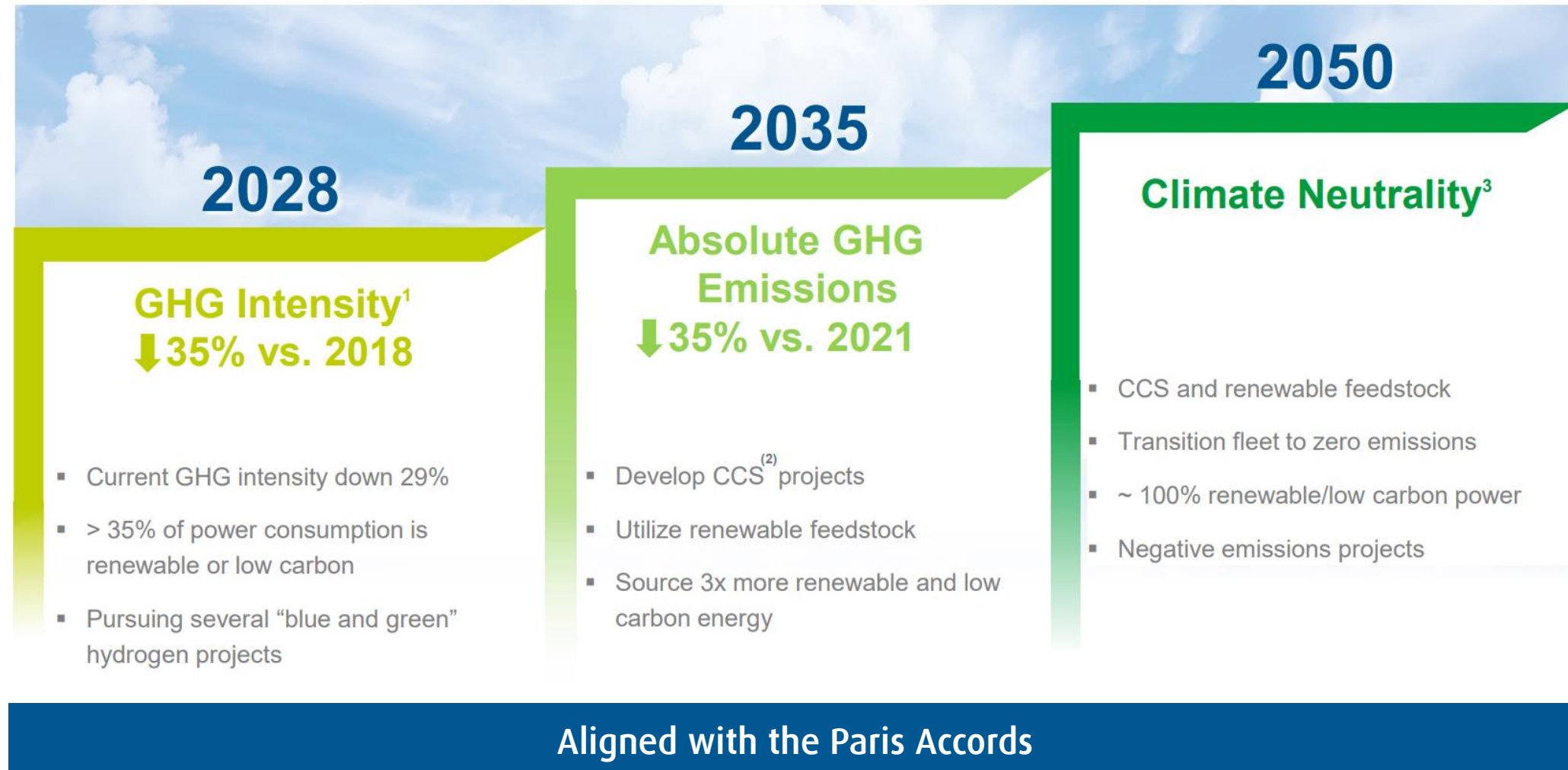
Fostering clean hydrogen

Linde is a steward of sustainability and an industry leader in clean hydrogen. We are founding members of the Hydrogen Council and 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.

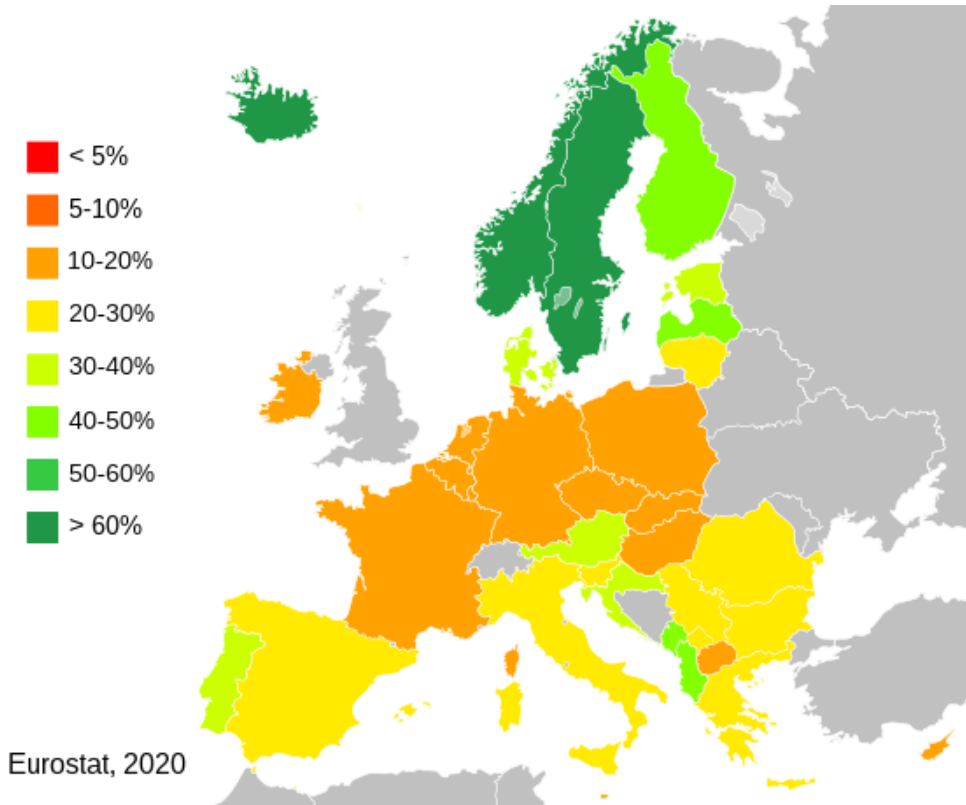
Introduction to Linde

Roadmap to Climate Neutrality



The Converging Energy System

Renewable energies in Europe – Hydrogen as an energy carrier



Share of renewable energy in gross final energy consumption in the European Union (EU-28)

Source: Eurostat, 2020

- Main renewable energies: Solar, wind, hydro & biomass
- Solar & Wind energies: **intermittent** availability
- Hydro & biomass: **Good** for **based load** but limited availability (quantities & locations)
- **High load factors** for Renewable Energy achievable in certain locations **combining** different **renewable** energies
- Nordic countries **privileged** geographical **location** in Europe for **renewable** energies (hydro+wind+biomass) with **high load** factors

But: even optimized load factors → still intermittent availability

→ PtX conversion technologies & energy carriers such H₂ to fulfil intermittent energy profiles & **cost-effective storage** & transportation

Hydrogen key energy carrier in the converging Energy System

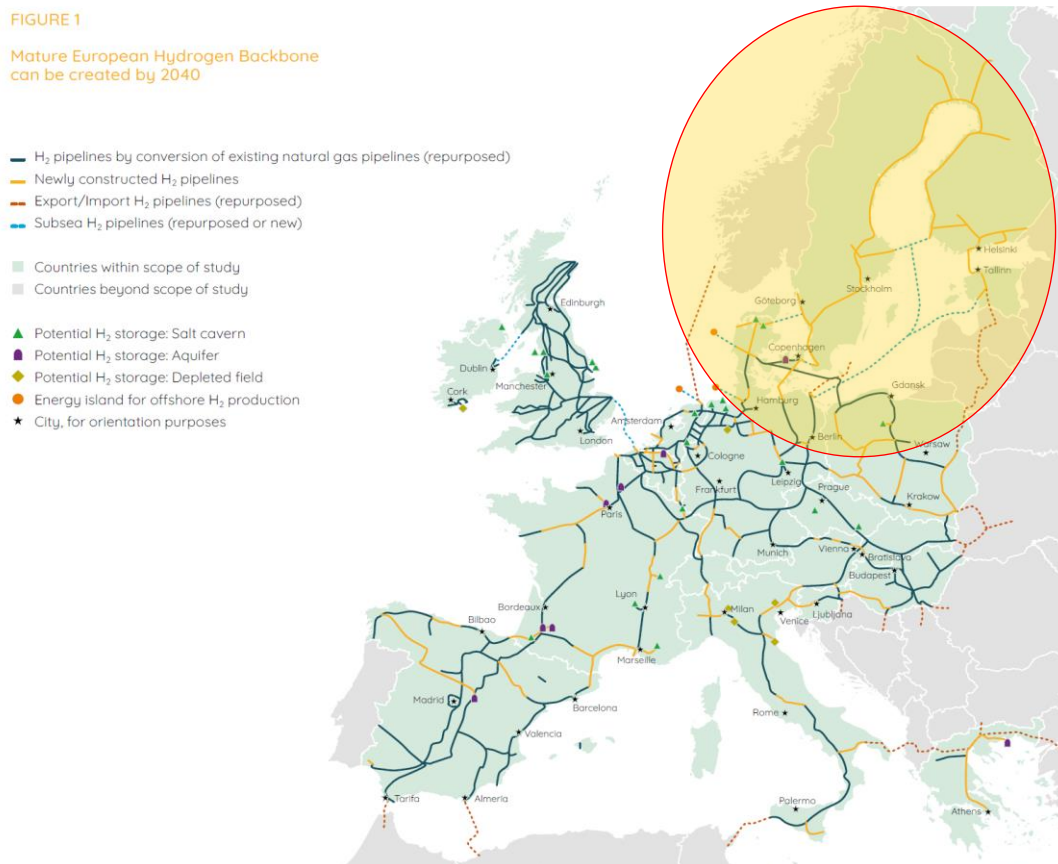
Relevance of Power to X in the European Union.

Nordic Countries and EU H2 roadmap to satisfy local and EU H2 demand.



FIGURE 1

Mature European Hydrogen Backbone can be created by 2040



- **Energy transition supported by EU and local authorities:**
 - Support to the EU regions most affected by the energy transition
 - Example Sweden: EU 's Just Transition Fund JTF to invest in Sweden 's energy transition plan (e.g. steel, mineral & metals industry, fisheries, aquaculture, among others)
 - Future development for H2 pipeline distribution
- **Dedicated H2 pipeline between EU North, Central & South¹:**
 - Approx. 40 thousand km dedicated to H2 until 2040 (new, converted);
 - Transport cost @ 0.15 –0.25 EUR/kg/1,000 km

1) Extending the European H2 Backbone
European Hydrogen Backbone initiative 2021, supported by Guidehouse

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.



Renewable energy storage

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



Infrastructure

Over 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.



Hydrogen Refueling Stations

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



Carbon capture, utilization and storage

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



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.



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.

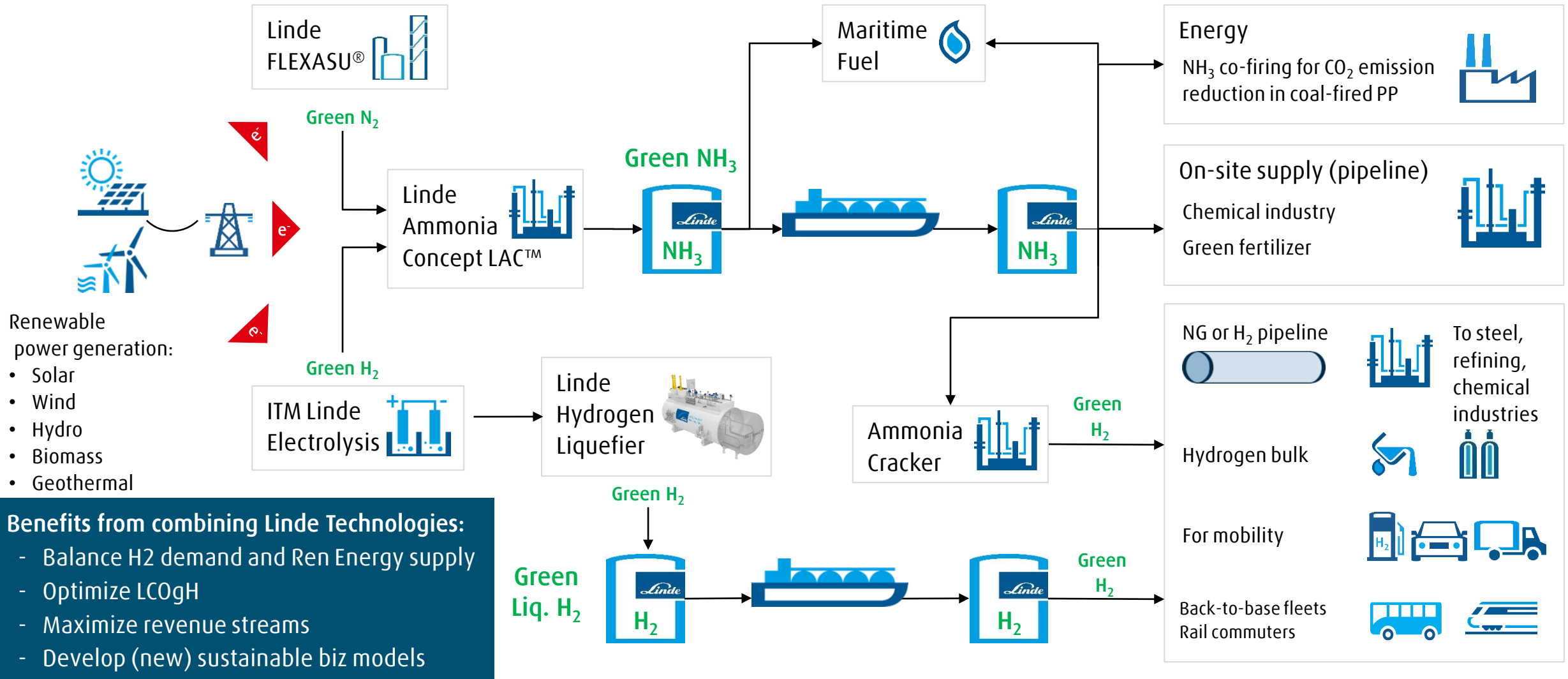


Ammonia

Ammonia can be produced sustainably and directly from clean hydrogen.

H₂ Value Chain for Intercontinental Applications

Example of an integrated production plant for green ammonia used as energy vector



How Linde support the clean energy transition

Technology, Experience & Infrastructure.



Electrolysis

Electrolyzers powered with renewables to produce **green H₂**



Fueling Technology

Efficient and fast **fueling concepts** for road and maritime transport



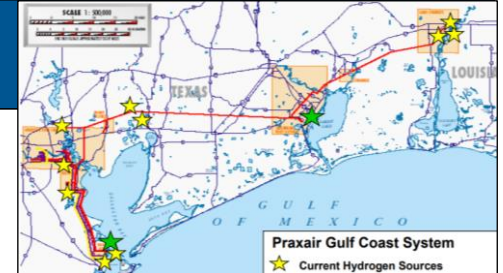
Carbon Capturing for Use or Storage

Turnkey solutions to **capture CO₂**, **store it** or **utilize it commercially**



Grid Infrastructure

Experience in operation of large H₂ network



Liquefying & Storage of Hydrogen

Liquefaction system to produce **LH₂** for ease of **storage & transportation.**



Application Technology

Decarbonization and **performance improvements**



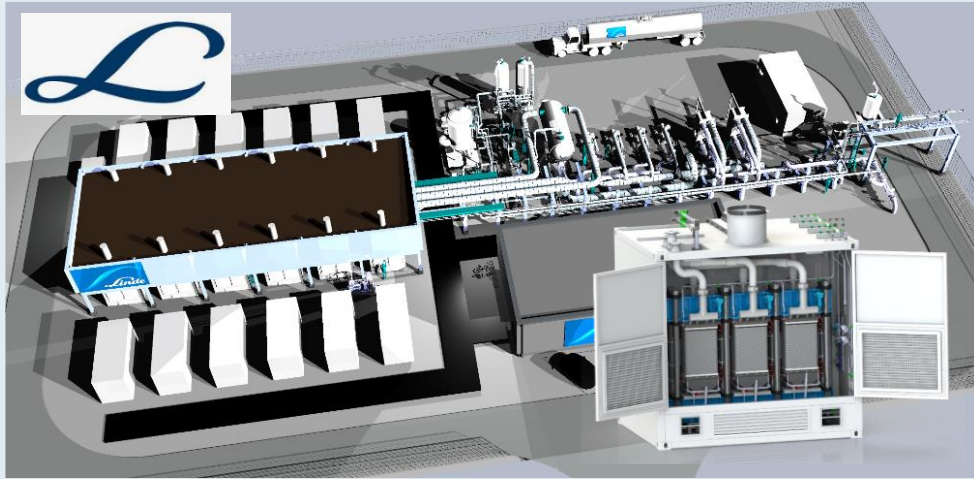
Project Example L-Scale: 24 MW ely + liquefaction @ Leuna / Germany.

Linde Gas 2nd multi-use-case in Europe.

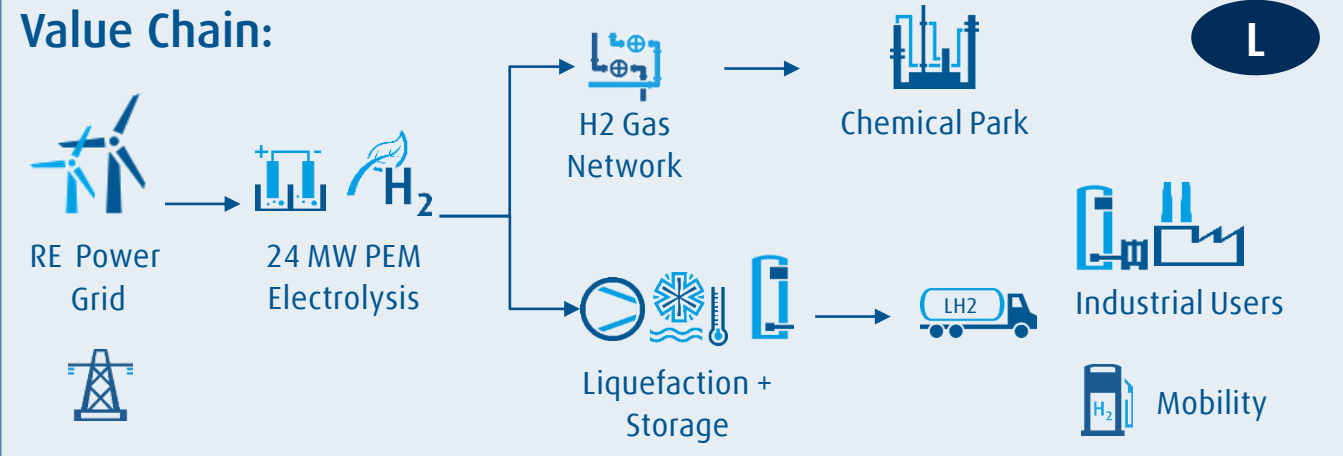
Upon commissioning world-largest PEM-electrolysis plant.



Leuna, Germany, 24 MW → Multi-Use Case



Value Chain:



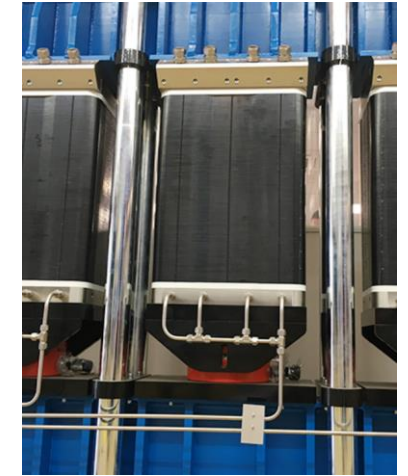
Plant Kind / Capacity: 24 MW electrolysis plant

Plant Concept: 12 x 2 MW “Cube” modules, in building, with balance of system in stick-built approach

Scope responsibility: Linde Engineering is EPC turnkey provider; Linde Gas in BOO role (owner and operator) of electrolysis plant and other process elements; e.g. H2 gas grid, H2 liquefaction, trailer filling

Commissioning Date: Q4/2022

Linde Gas Leuna, Germany, 24 MW. ... and how it looks in reality (Jun 2022).



Tagesthemen 13th of Jun 2022

Project Example L-Scale: 24 MW ely @ Yara Porsgrunn / Norway. Replacing grey hydrogen from SMR for green ammonia production.



Yara Porsgrunn, Norway, 24 MW → Use Case Green Ammonia



Value Chain:



Hydropower
& Grid



24 MW PEM
Electrolysis



Ammonia
Production



Using green ammonia
as fertilizer for fossil
free food production

L

Plant Kind / Capacity: 24 MW electrolysis plant integrated in existing Ammonia Synthesis facility of Yara

Plant Concept: 12 x 2 MW “Cube” modules, in building, with balance of system in stick-built approach

Scope responsibility: EPC – Linde Engineering is EPC turnkey provider

Commissioning Date: 08/2023

Highlight:



Defossilizing the fertilizer value chain, by using Green Ammonia.

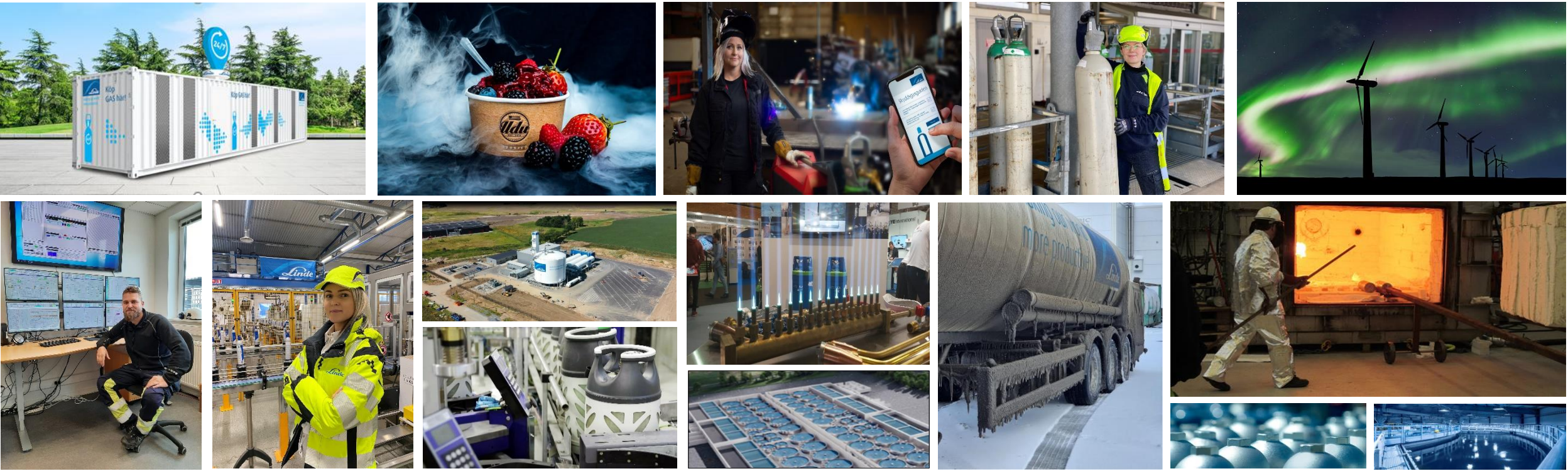
Integration in existing Ammonia synthesis plant, with tailored layout utilizing former compressor building (two floor design).

Summary:



1. **Energy transition supported by EU and local authorities**
2. **Nordic countries privileged geographical location** in Europe for **renewable energies** (hydro+wind+biomass) with high load factors
3. **PtX conversion technologies & energy carriers** such **H2** to fulfil **cost-effective energy** storage & transportation
4. **Green hydrogen derivative** products, such **green ammonia** and **e-methanol & e-fuels** building blocks for the **energy transition**





Thank you for your attention

Daniel Mateos
daniel.mateos@linde.com
www.linde.com



Think Hydrogen. Think Linde.
hydrogen.linde.com

Making our world more productive

