



US Dept of Energy: Off-Road Equipment & Vehicles Workshop

Hydrogen On-Site Supply & Refueling

Al Burgunder

September 24, 2021

Making our world more productive





- The leading industrial gases and engineering company
- 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
- Proven critical project execution knowledge in diverse geographies
- Best-in-Class Safety Performance

~80,000

employees

Achieving our full potential, individually and collectively

2 million+
customers

Establishing a more diverse and balanced portfolio

100+

countries

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

6,500+

active patent assets
worldwide

Leading with innovative products, solutions and technologies

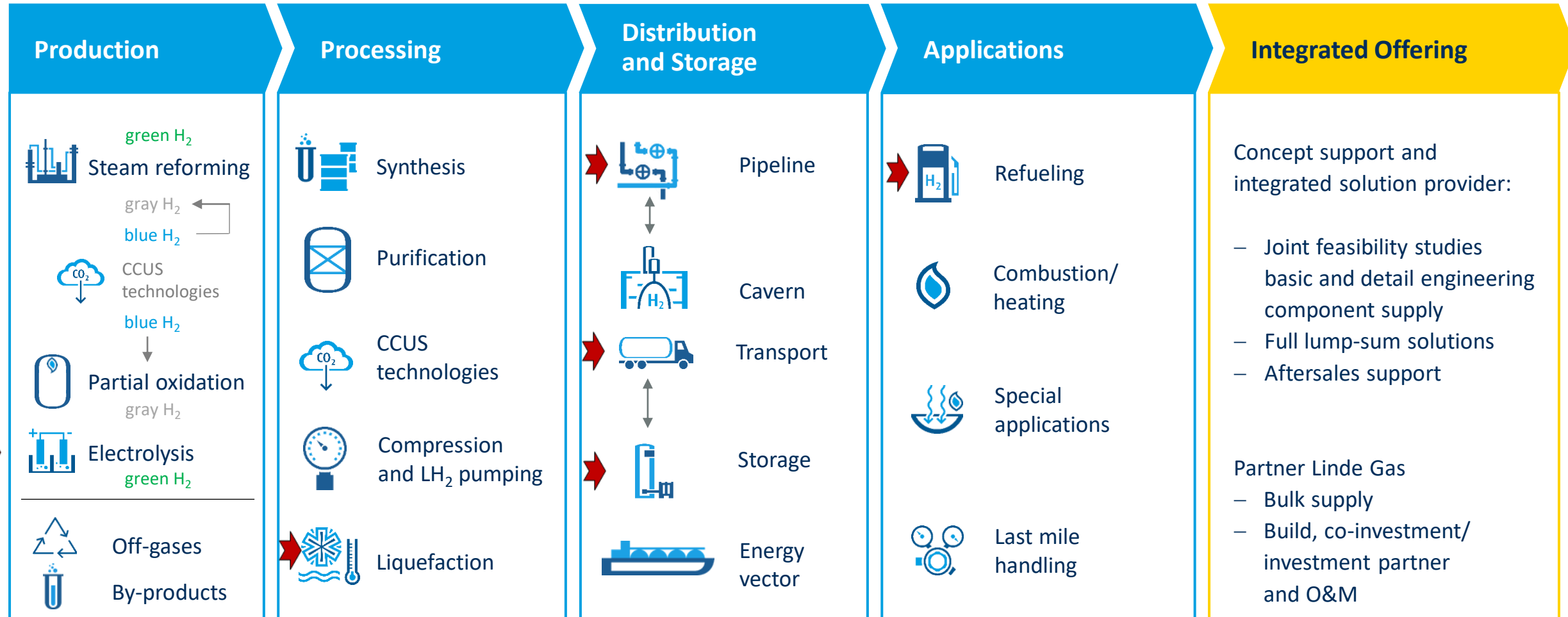


Linde's Hydrogen Value Chain

Technology elements for all steps available



Linde's hydrogen value chain



Linde Hydrogen Solutions

Onsite Hydrogen Production using Steam Methane Reformation



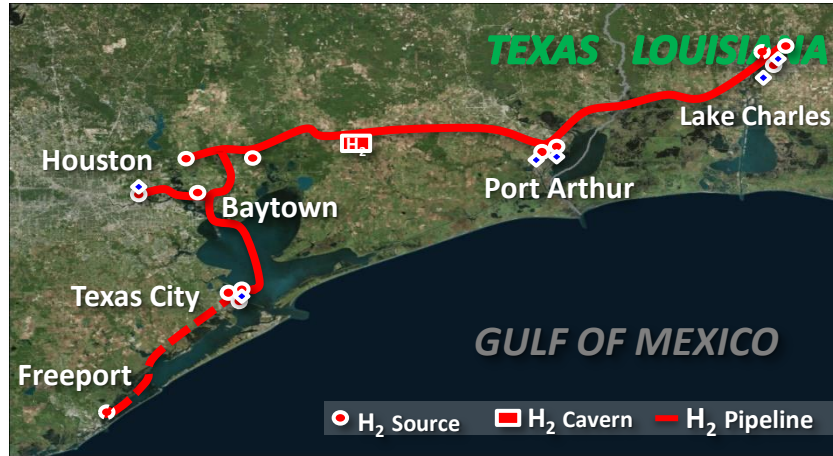
Product	SMR HYDROGEN PRODUCTION			
Capacity	300 Nm ³ /h	<16,000 Nm ³ /h	<32,000 Nm ³ /h	>32,000 Nm ³ /h
Brand	HydroPrime MIN	HydroPrime MID	HydroPrime MAX	HYCOMP/HYMOD
Market & Application	Glass, Fueling, Special Chemicals, Electronics	Oil&Gas, Chemicals, Fueling	Oil&Gas, Chemicals	Oil&Gas, Chemicals
Degree of Standardi-zation	Containerized	Standardized Mechanical Modules	Standardized Mechanical Modules	Standardized Plant Design modules
	High	Med-High	Medium	Customization



PSA Purification System

Production of gaseous hydrogen at +200 psi

Hydrogen Pipelines



Hydrogen Pipeline Supply

- Easy, high-pressure source (700+ psi)
- Possible direct connection to power generation systems
- Fuelcell applications may require purification depending on source (H₂O, hydrocarbons, etc)
- Limited number of hydrogen pipeline across the US



Linde's hydrogen liquefaction

Product portfolio - Lowest total cost of ownership



0.25 tpd LH₂
Japan

0.5 tpd
China

1 tpd
India

Small Size (He Brayton Cycle)



≥ 5 tpd
6x in Japan
2x Leuna, Germany

15 tpd
Canada/Korea

4 x 30+ tpd
U.S.

up to 500 tpd



Medium Bulk Size
(H₂ Claude Cycle)



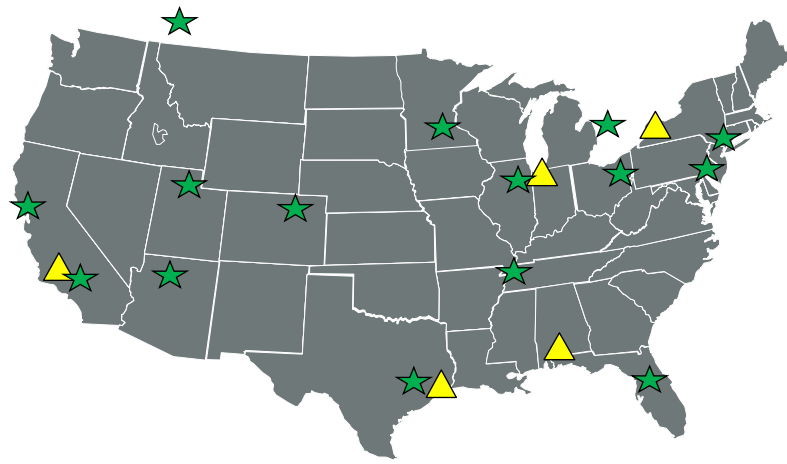
Future
Large-scale

Liquid Hydrogen Supply Option



Delivered Liquid Hydrogen

- Readily available
- Requires site storage and dispensing systems
- Tank size based on fuel consumption and delivery factors
- Smaller capital commitment



- ▲ 5 hydrogen liquefiers
 - More than 150,000 Kgs/day
- ★ 15 gas hydrogen trans-fill stations
 - 180 bar & 500 bar gas pressure





Unrivalled 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**

Sourced by-product H₂ from PSAs

Through processing



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

Vast experience in **H₂ compression or liquid pumping to desired pressure**

To storage and distribution



220+ Liquid and Gaseous H₂ trailers

1000+ km H₂ pipeline

H₂ storage Cavern

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

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

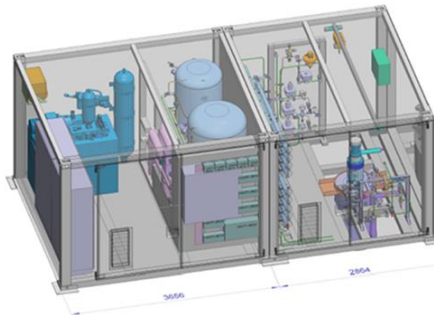
Hydrogen Fueling Technology

Experienced provider of compression & cryopump technologies



Linde Hydrogen FuelTech

Leading technologies



CP – Cryopump (LH2)



IC – Ionic Compressor (GH2)

Global projects

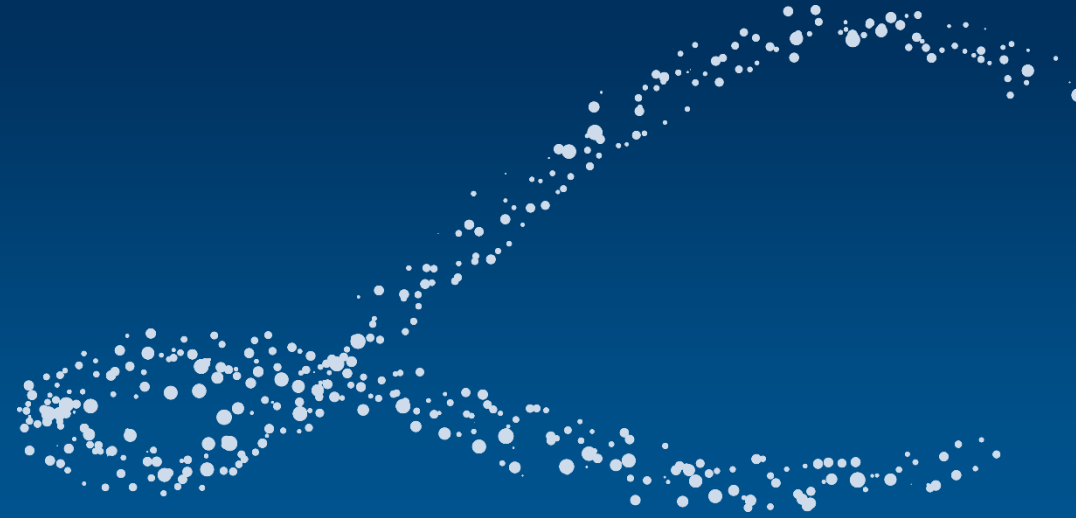


Leading expertise and know-how

- ✓ More than 200 fueling stations installed worldwide
- ✓ More than 1.5 million successful hydrogen fills of cars, buses and forklifts
- ✓ Supplier of the world's first hydrogen station for a passenger train
- ✓ Supplier of the world's biggest hydrogen bus depot in California to date

Vision For An Integrated Solution





Thank you!

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