



Overcoming Challenges of a Warming Planet:

- Policies and Technologies to Achieve Green Hydrogen

Al Burgunder Director: Clean Hydrogen
Thursday, October 7, 2021 – 10:00 a.m.

Making our world more productive



The New Linde



- 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
- Group Sales ~\$28B

One Linde

Uniting with a shared Vision, Mission and Strategic Direction, and demonstrating our Values and Behaviors in everything we do

2 million+ customers

Establishing a more diverse and balanced portfolio

100+

countries

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

~80,000 employees

Achieving our full potential, individually and collectively

~\$15 millions

charitable giving and sponsorships in 2018

Supporting our communities through contributions and employee volunteerism

6,500+

active patent assets worldwide

Leading with innovative products, solutions and technologies



Linde 2028 Climate Goals

Compared with a 2018 baseline



Decarbonization can contribute >90% impact in combating climate change

MEMBER OF

**Dow Jones
Sustainability Indices**

In Collaboration with RobecoSAM

Linde has been recognized by The Dow Jones Sustainability World Index Chemicals Sector for 18 consecutive years

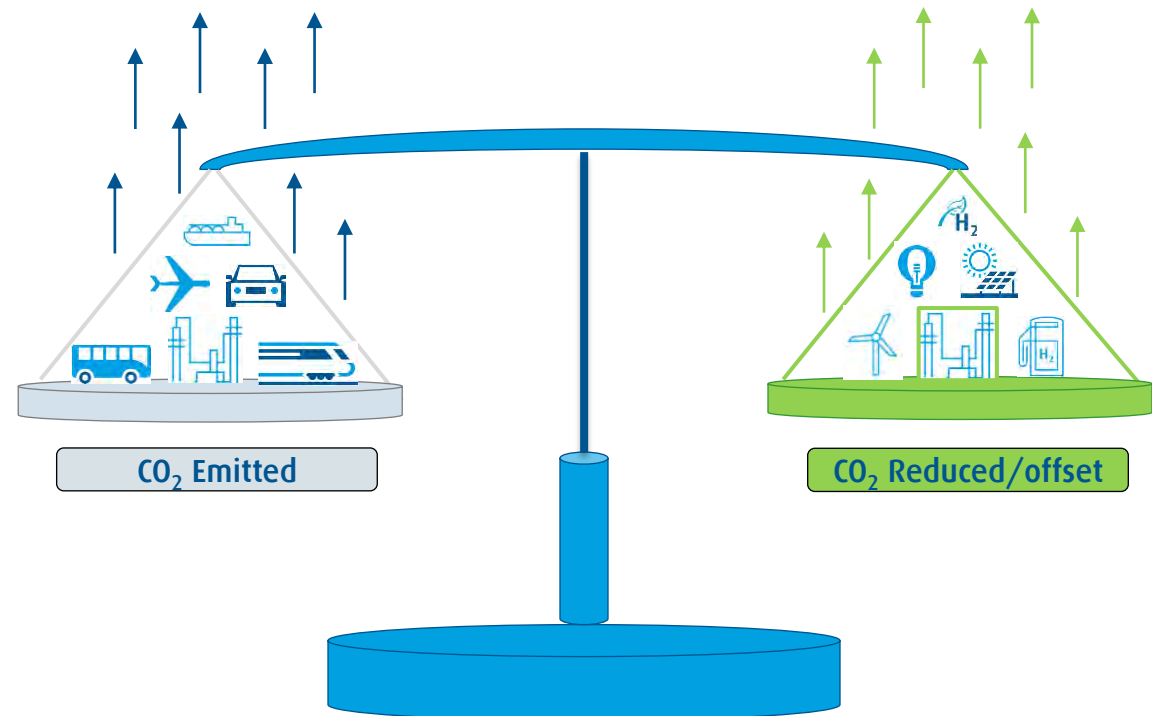
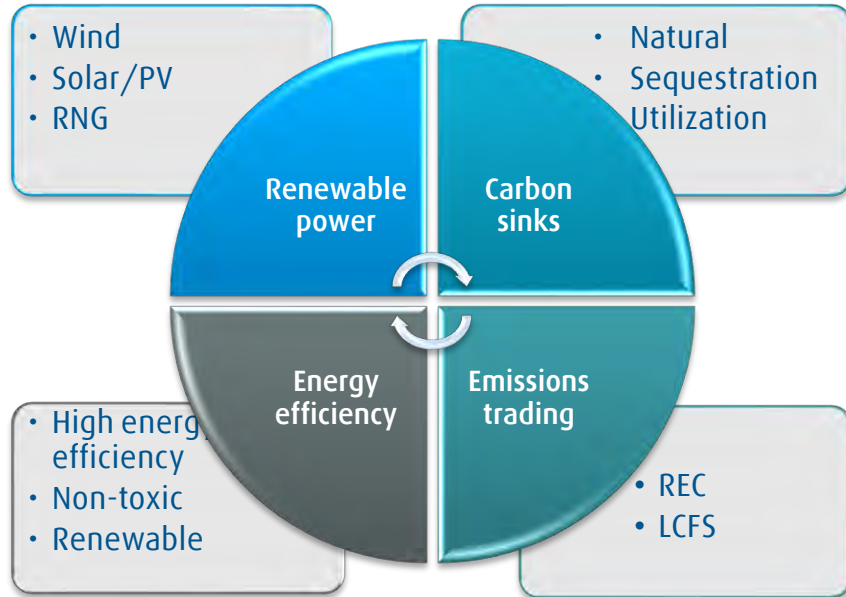


10-year target to lower our Greenhouse Gas (GHG) emissions intensity by 35%

Decarbonization using H₂: Carbon Neutrality



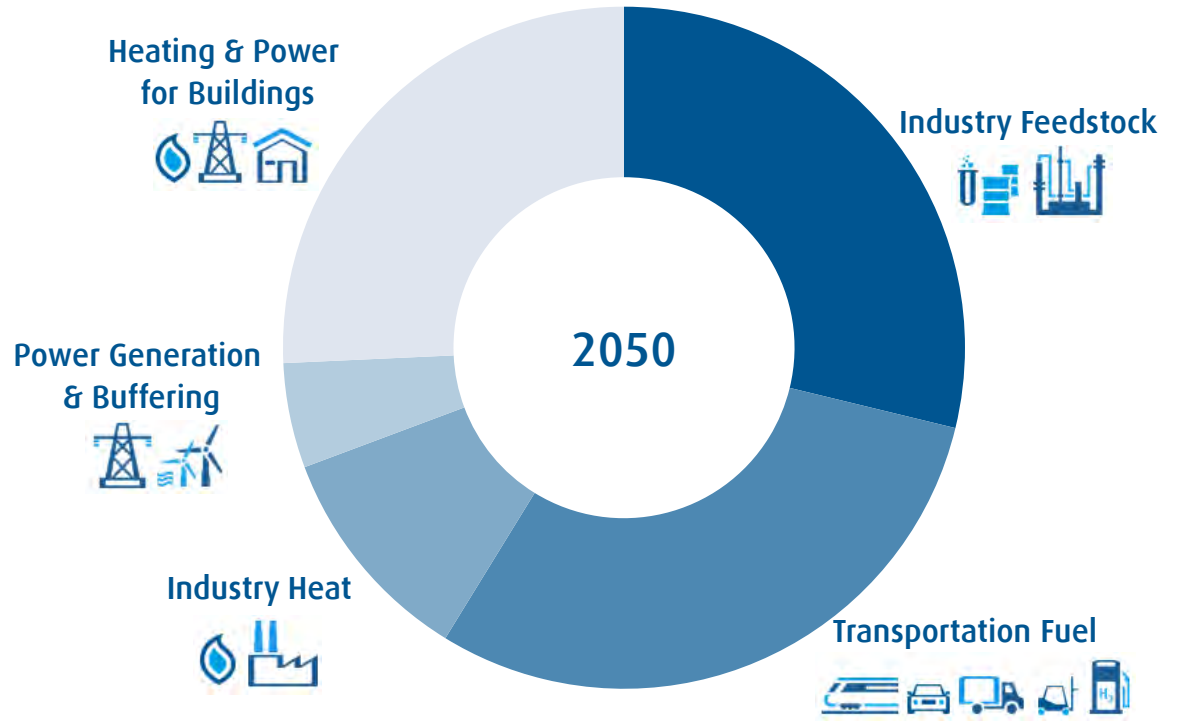
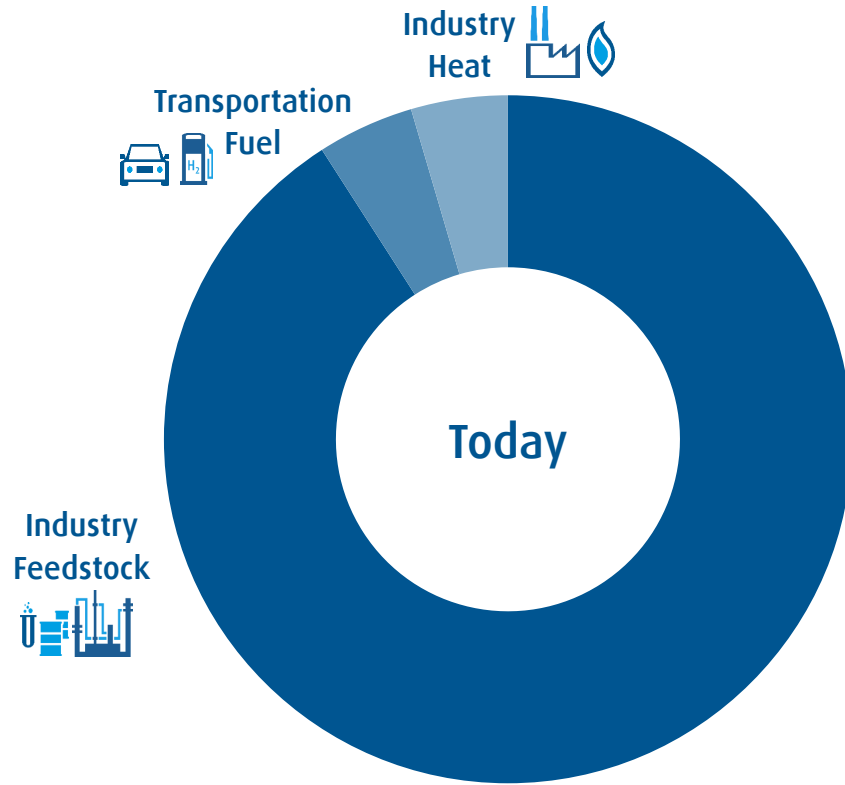
GHG emissions must be counterbalanced and ultimately overtaken by CO₂ Reductions



Hydrogen demand will dramatically expand over next 30 years



Global demand (2018)*:
~115 million tons⁺



* Source: 'The future of hydrogen'; International Energy Agency IEA, iea.org (2019)

** Demands compared to 2015; sources: 'Hydrogen Roadmap Europe'; Fuel Cells and Hydrogen - Joint undertaking, fch.Europe.eu (2019) and 'Hydrogen Scaling up', Hydrogen Council, hydrogencouncil.com (2017)

+ Thereof ~73 m tons pure hydrogen + ~42 m tons hydrogen mixed with other gases*

Conventional to Clean Hydrogen



Conventional: Steam Methane Reforming

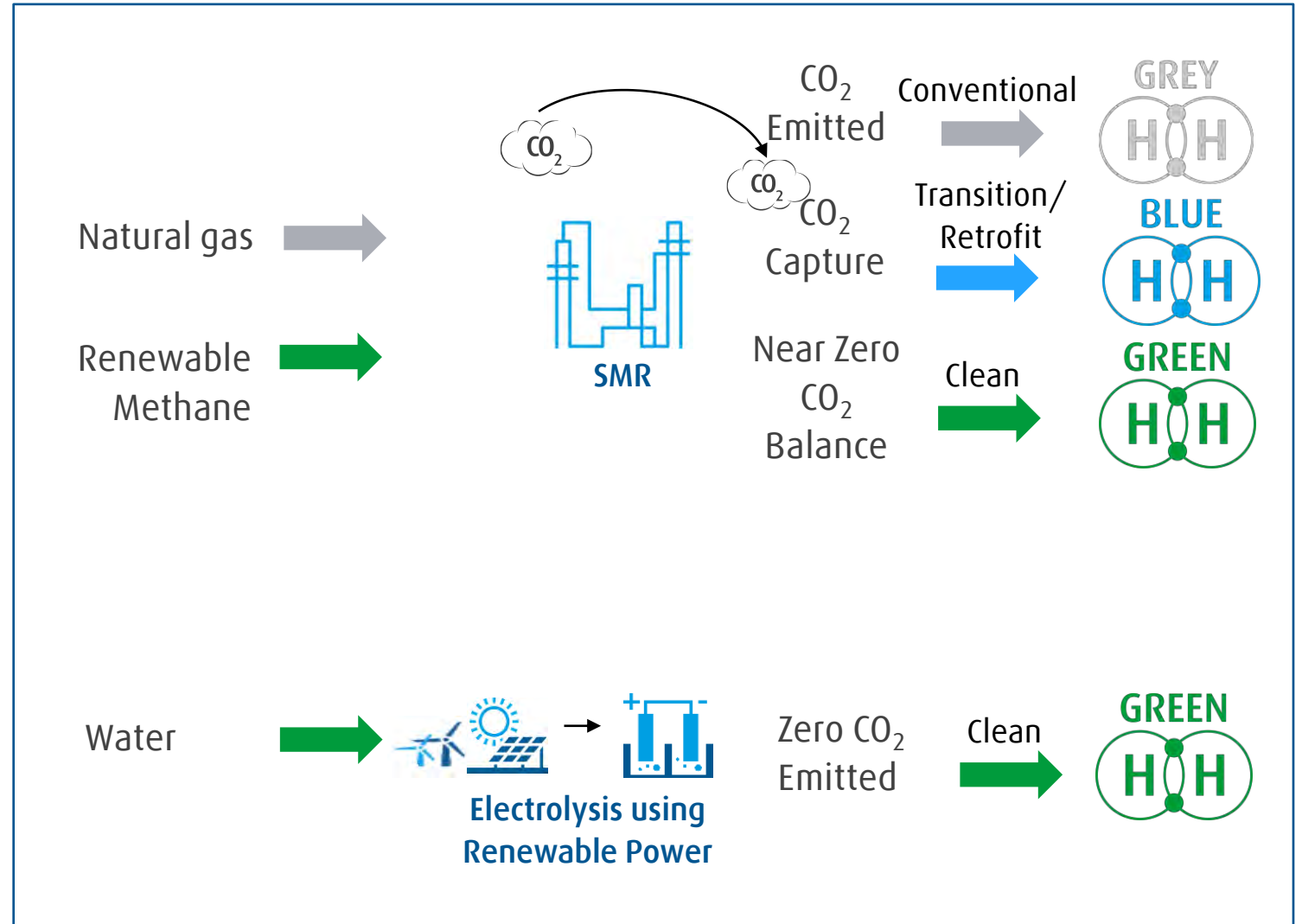
- Efficient, reliable, low cost
- Flexible technology adjustments
 - Carbon capture for sequestration

Transitional: SMR & By-product sources

- Introduction of renewable methane
 - Negative Carbon Intensity
- By-product H₂: chlor-alkali, ethane crackers

Zero Carbon Technology

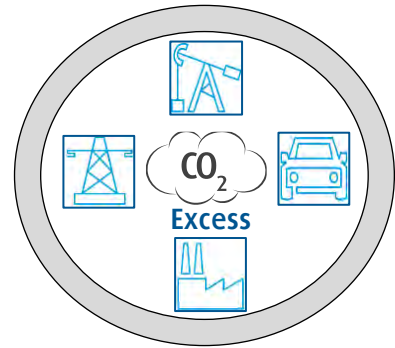
- Renewable electricity + electrolysis



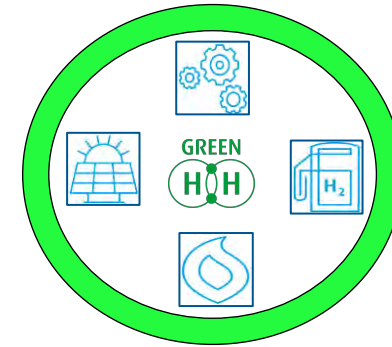
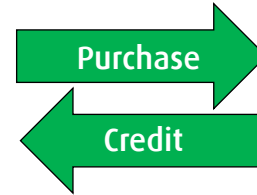
California: Low Carbon Fuel Standard (LCFS)



- Enacted in 2007 to reduce the lifecycle carbon intensity of transportation fuels
 - 3 ways to generate credits
 - Fuel pathway
 - Emission reduction projects
 - ZEV infrastructure
- Adoption driven by:
 - CARB & CEC
 - Subsidies – DOE/CEC funding
 - Providing incentive to the oil, electric, natural gas and auto industries

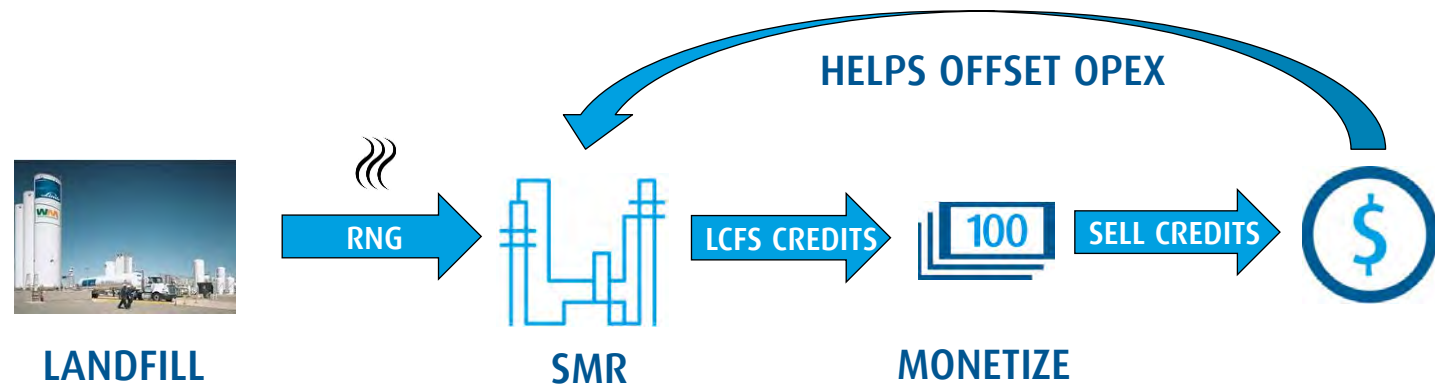


Businesses that sell fuel with carbon intensities **ABOVE** the cap must buy credits



Businesses that sell fuel with carbon intensities **BELOW** the cap can sell excess credits

EXAMPLE: FUEL PATHWAY



"Hydrogen Economy" - The road to Price Parity

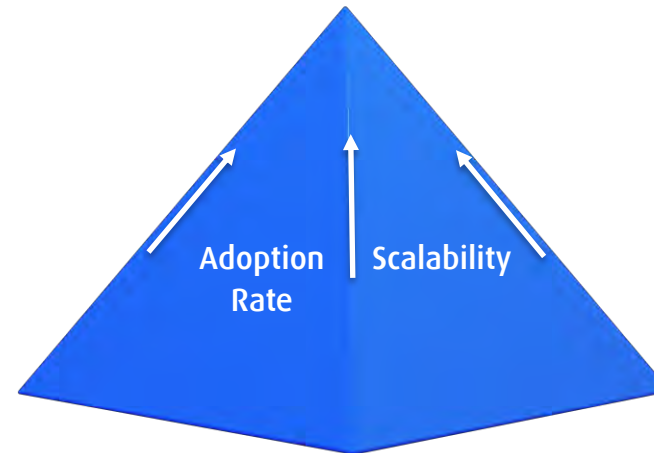


- H₂ Supply
- Renewable energy
- Cost of compliance
- CAPEX



H₂ economy drivers:

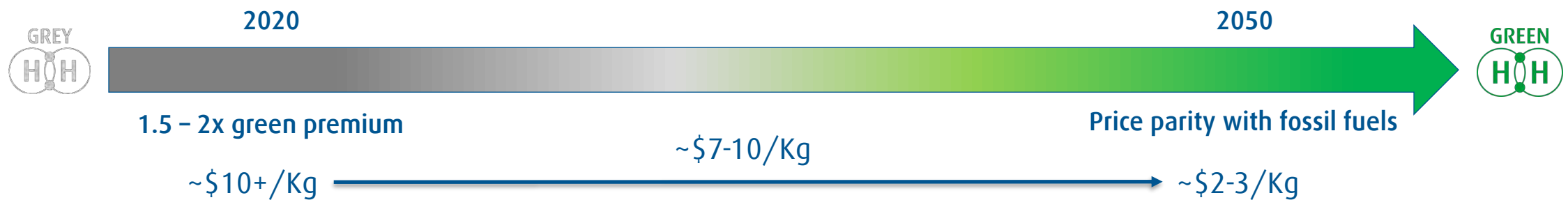
- Governmental policy
- Technical innovation
- Regulatory requirements
- Public perception



- Cost of CO₂



Smart-energy.com



GREET: Quantifiable Carbon Intensity Tracking



➤ Carbon intensity (CI)

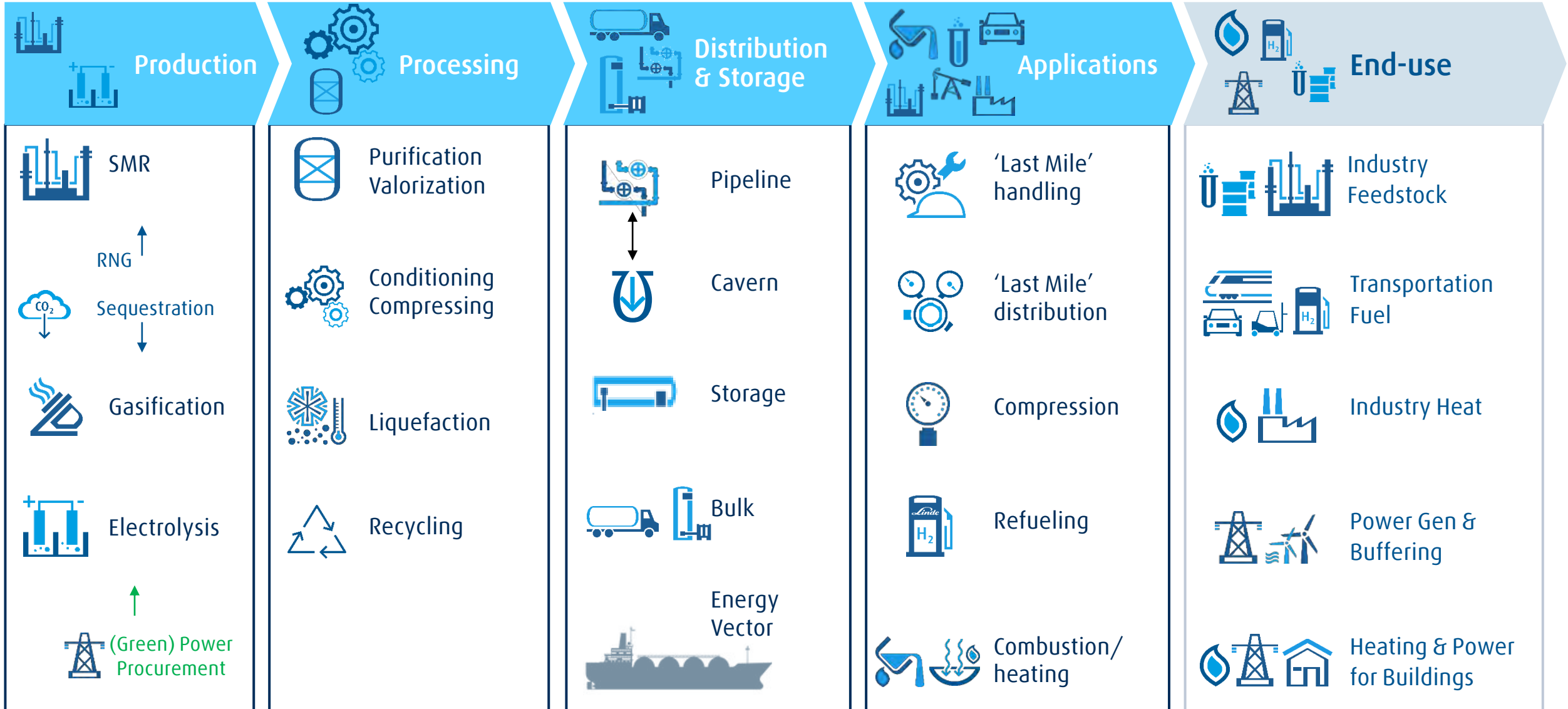
- Argonne National Laboratory developed a “wells to wheel model” to quantify CO₂ emissions of energy supplies
- Measures CO₂ as grams/megajoule or equivalent units

➤ The **GREET** Model provides:

- Common, transparent platform for lifecycle analysis
- Considers production, process, delivery and use
- Encompasses all fuels and vehicle technologies :
 - major transportation sectors (road, air, marine, and rail)
 - other end-use sectors
 - energy systems

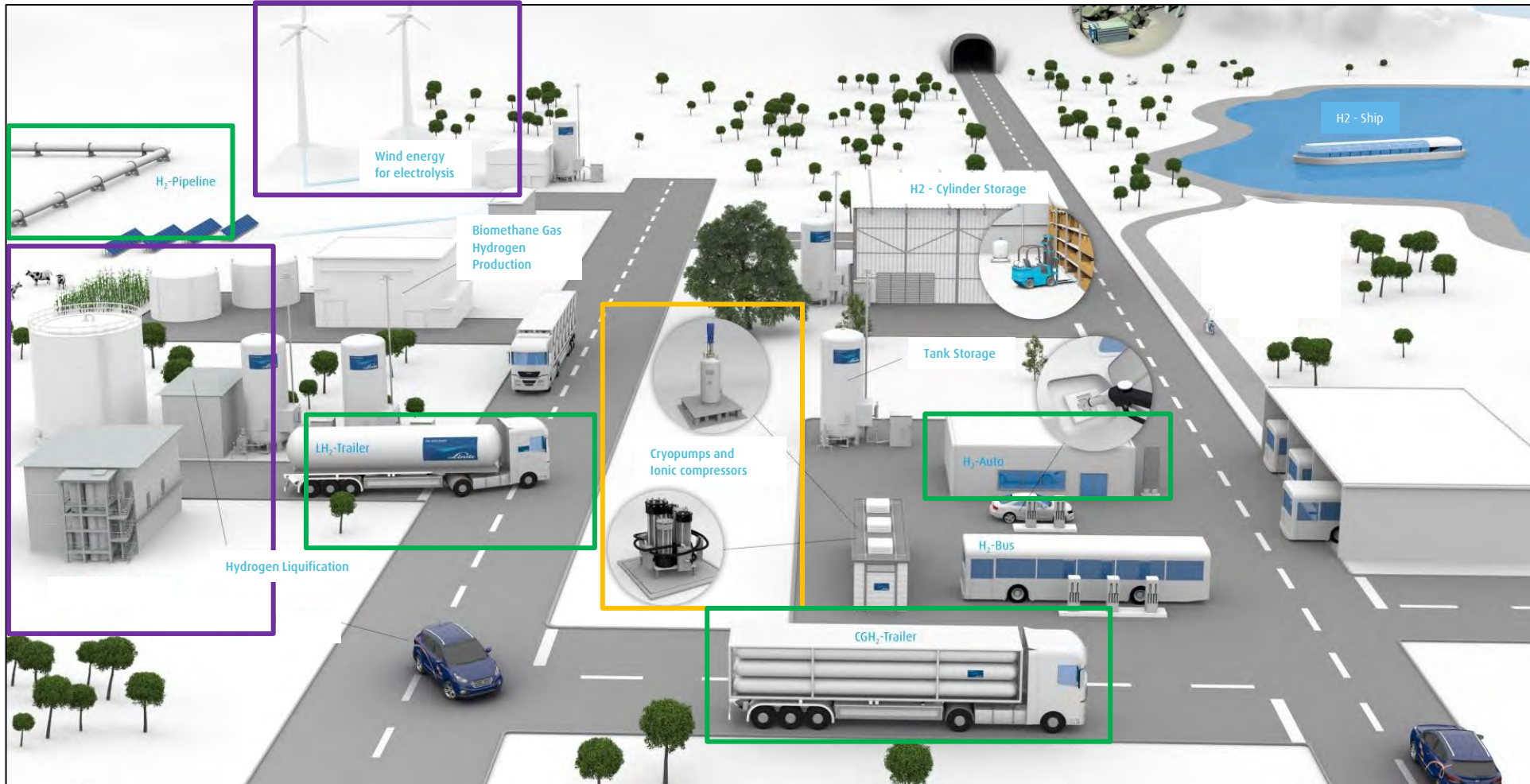


Think Hydrogen, Think Linde: Global Value Chain



Linde's World of Hydrogen

Integrated Deployment Across Multiple Energy Demands



- H2 production**
- renewable production...
 - conventional production

- H2 distribution**
- pipeline
 - trailer transport
 - on-site production

- H2 fueling**
- liquid hydrogen
 - gaseous hydrogen

- Other**
- liquefaction
 - storage
 - project execution
 - service & maintenance



Thank you for your attention.

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