



Hydrogen extraction from hydrogen blended natural gas. Linde solutions.

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April 22, 2021

Making our world more productive



Linde.

A leading global industrial gases and engineering company.



Gases Business

World-class gases supply and operations of over 1,000 plants.

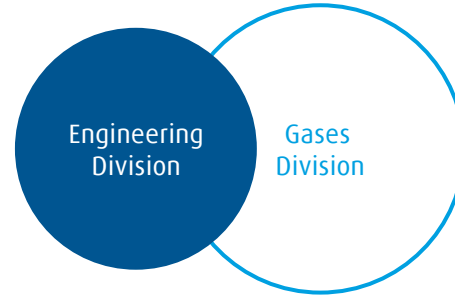


- Operating in >100 countries
- Established presence where customers are and where end users' operations are growing.
- Linde's industrial gases are used in countless applications, from oxygen for hospitals to high-purity & specialty gases for electronics, hydrogen for clean fuels and much more.



Unique setup

Close to the customer with an integrated business model



2020 sales USD 27.2 billion



Engineering Business

Technology-focused with more than 4,600 plants built.



- Development and optimization of gases production, processing, separation and liquefaction technologies.
- Maximization of plant lifecycle productivity, efficiency and service life.
- Proven critical project execution knowledge in diverse geographies.

We serve a large variety of end markets including chemicals & refining, food & beverage, electronics, healthcare, manufacturing and primary metals.

Linde Engineering

A market leader in all segments.



Air separation plants



Hydrogen & syngas plants



Adsorption & membrane plants



Petrochemical plants



Natural gas plants

Production of plants
for Linde Gas and 3rd party customers

Providing chemistry and energy related
solutions to 3rd party customers

The perfect fit for your needs

Inspiring and advancing innovative technologies

Manufacturing and execution excellence

Adsorption and membrane plants



Product portfolio

The **pressure swing adsorption (PSA)** and **temperature swing adsorption (TSA)** systems are suitable for a vast number of applications in almost all industries, including:

- **Hydrogen** recovery and purification
- **Oxygen** and **nitrogen** generation
- **Carbon dioxide** recovery and removal (**carbon capture**)
- **Helium** recovery and purification
- **Valuables** recovery (C_{2+}/C_{3+})
- **HHC** removal and natural gas conditioning

The **membrane units** can favorably be used for:

- **Hydrogen** and **helium** recovery
- **Natural gas sweetening**
- **Hydrogen/carbon monoxide** ratio conditioning
- **Hydrogen** extraction from hydrogen blended natural gas

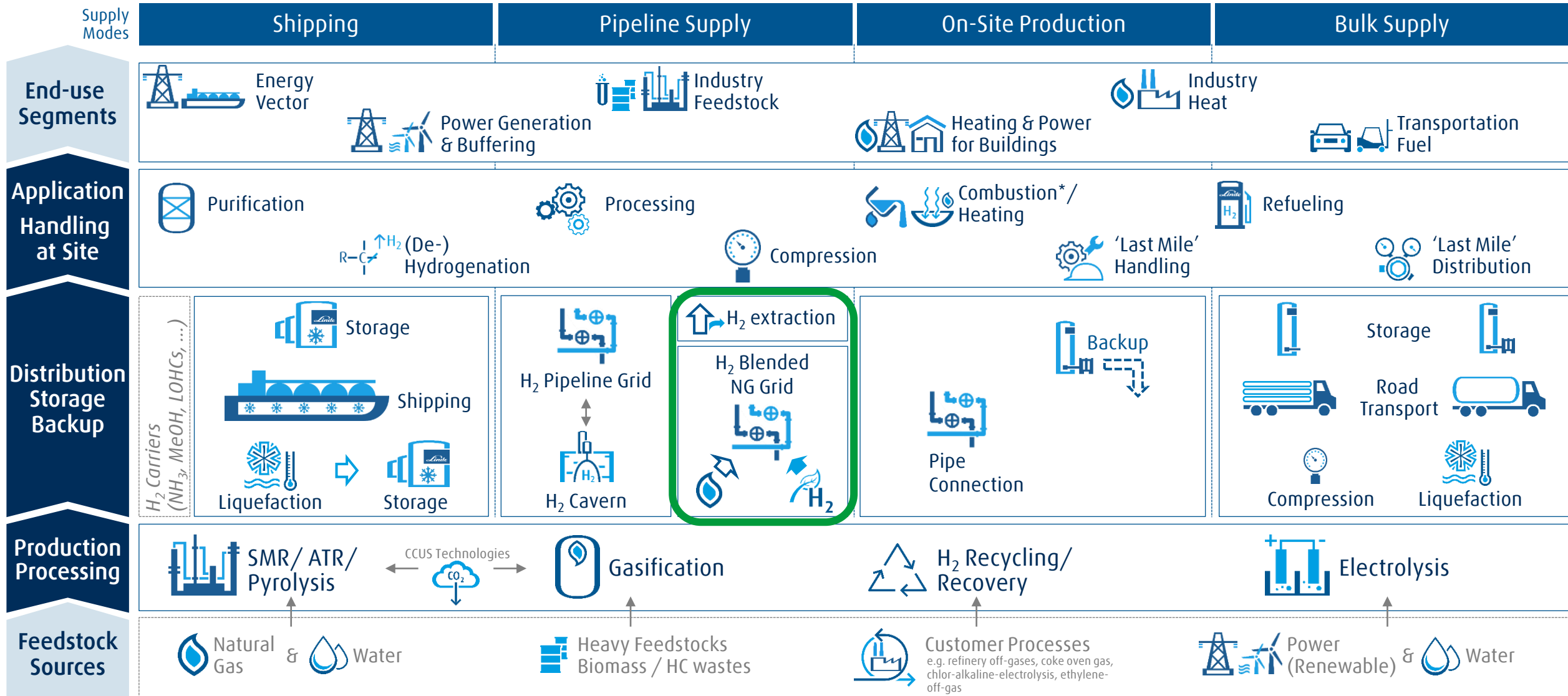
Key features

- Tailormade (hybrid) solutions
- High product purity and recovery rates, low operating costs
- Outstanding reliability and on-stream availability
- Excellent aftersales services

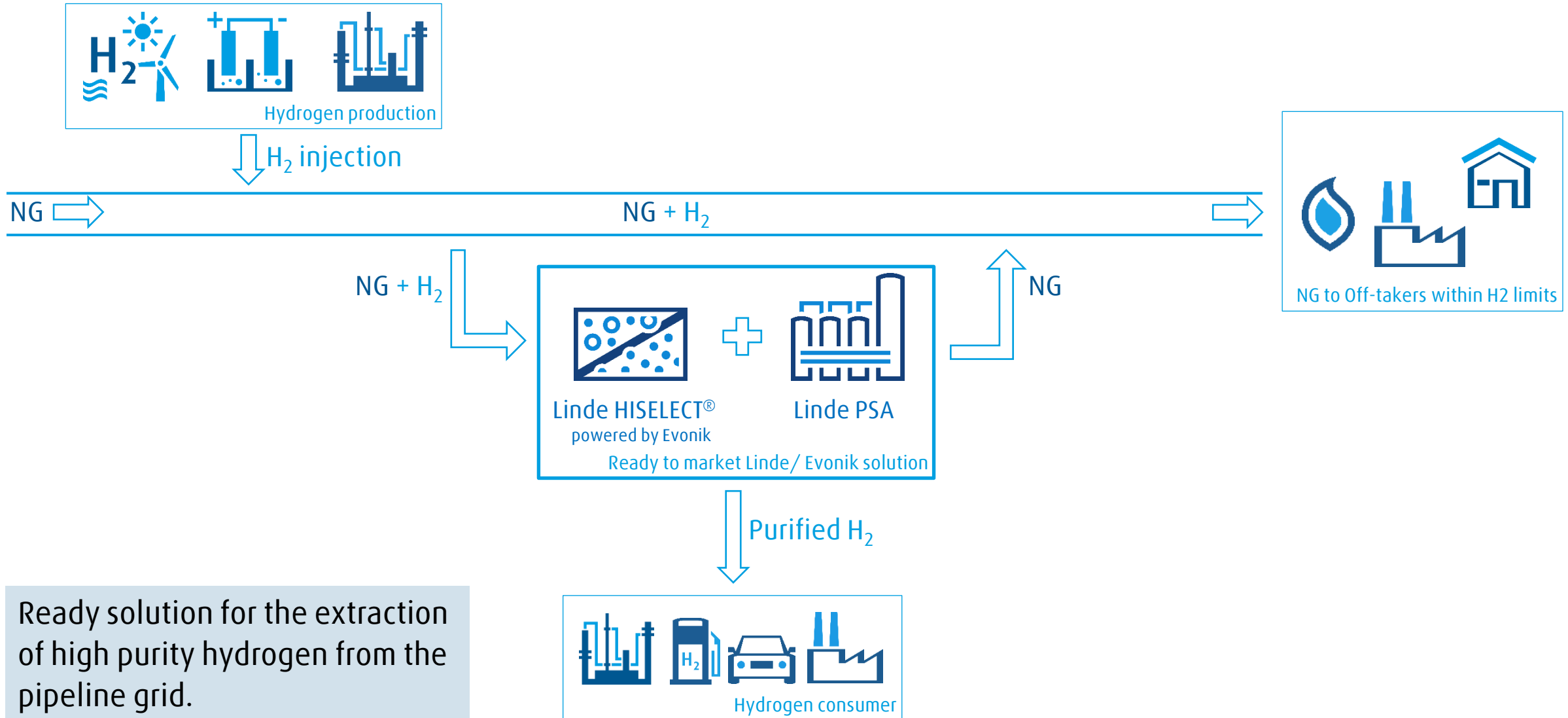


Hydrogen Economy – from industrial gases perspective.

Hydrogen value chain and industrial gases supply modes.



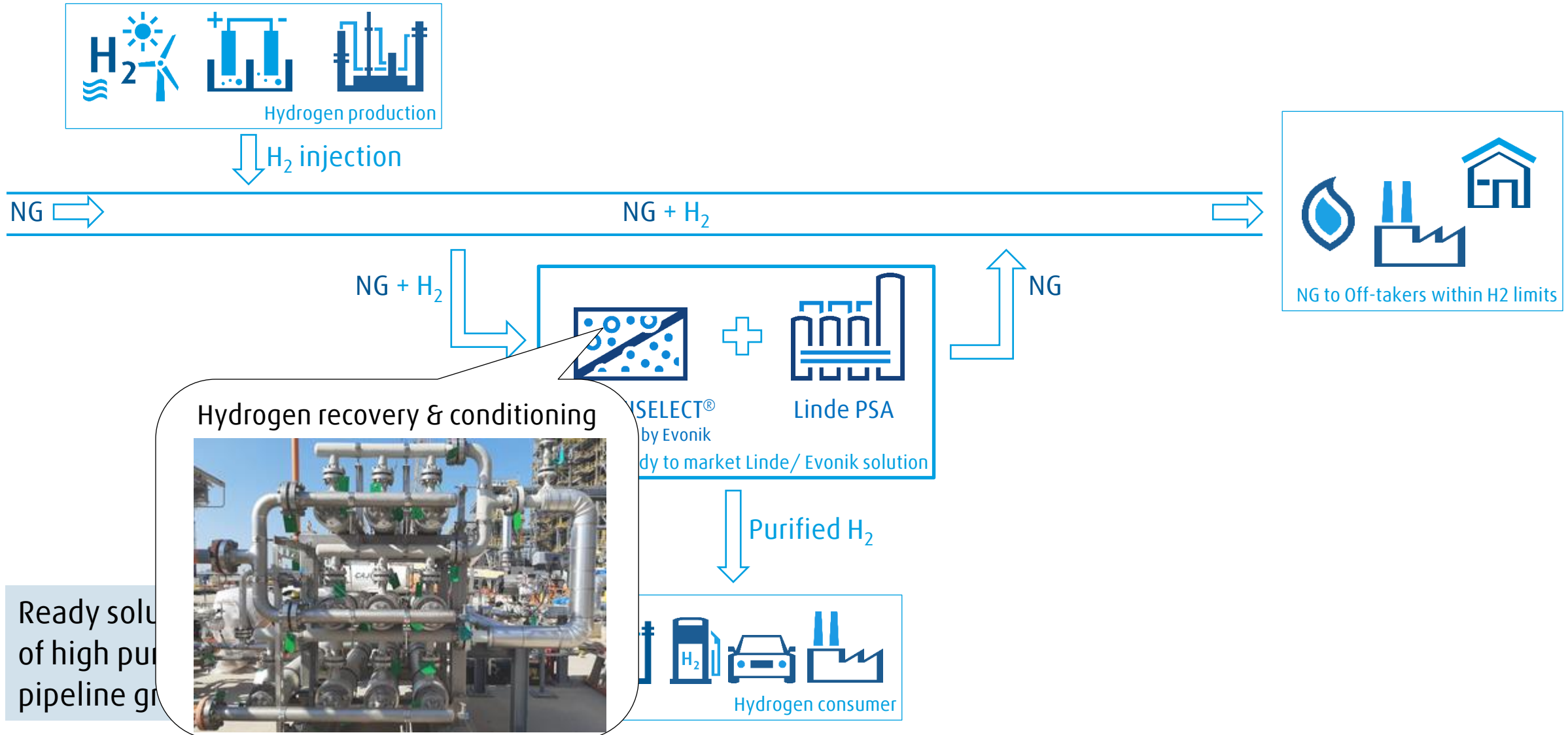
Hydrogen extraction from hydrogen blended natural gas. Basic concept.



Ready solution for the extraction of high purity hydrogen from the pipeline grid.

Hydrogen extraction from hydrogen blended natural gas.

Basic concept – (1) Membrane Pre-treatment.





Monomer
Polymer



Hollow
Fibers



HISELECT®
Membrane
Technology



Combining Gas
Processing
Technologies



Process
Engineering
Excellence

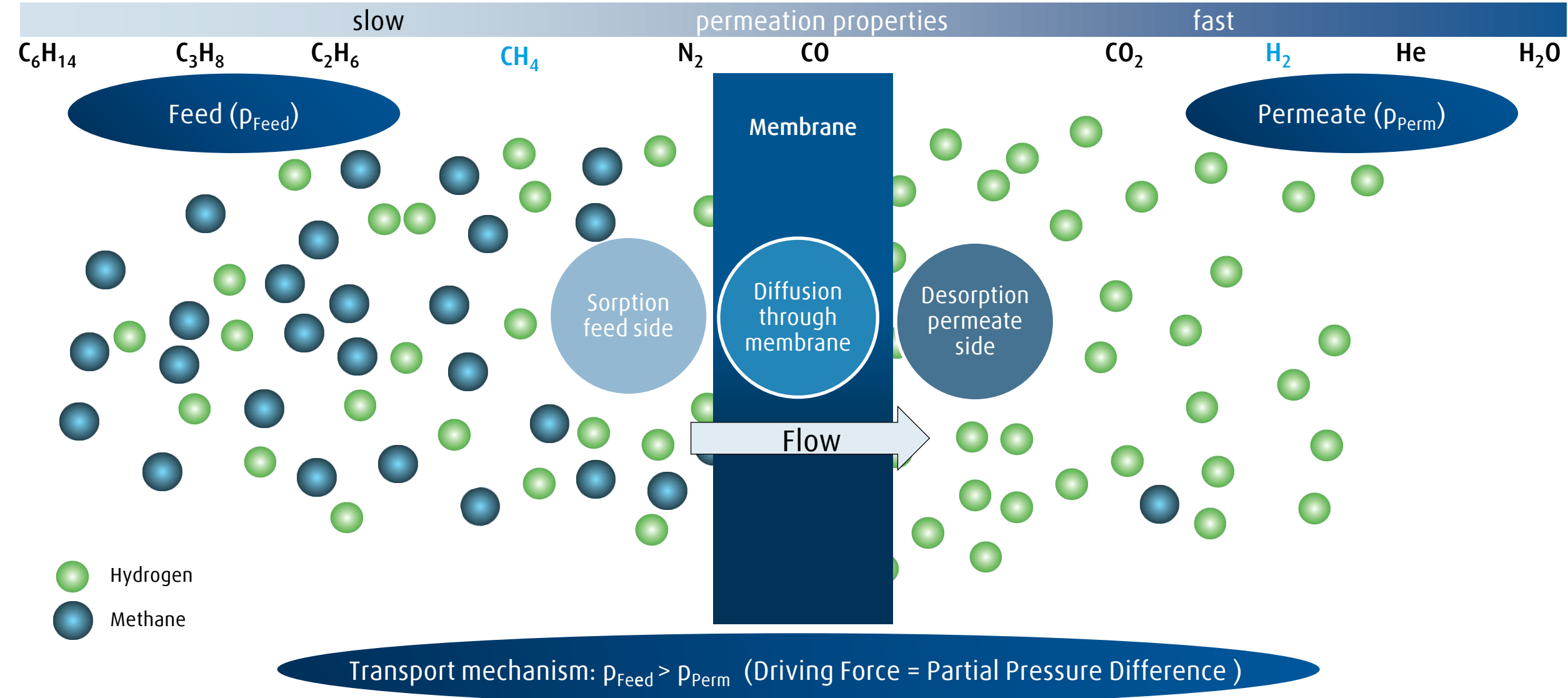


Customised Gas
Processing Plants

Leveraging synergies by integrating the HISELECT® powered by Evonik high-performance membranes into Linde's gas processing technology portfolio

HISELECT® Membranes

Membranes are often characterized by their selectivity and permeability

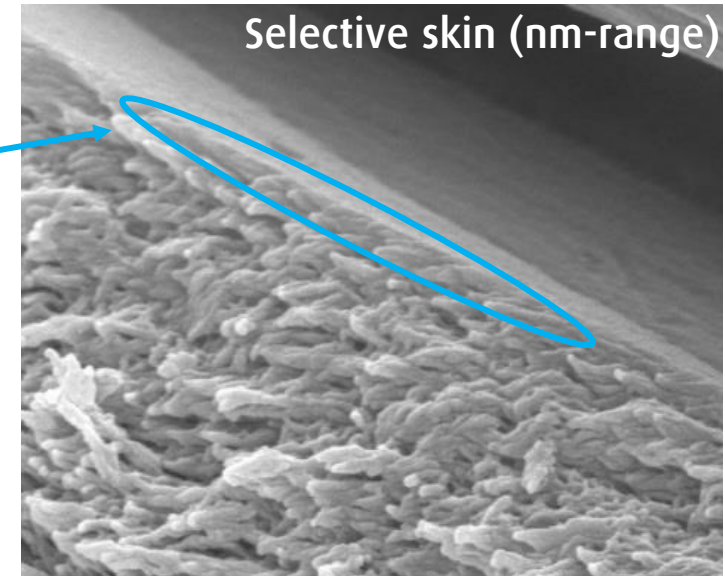
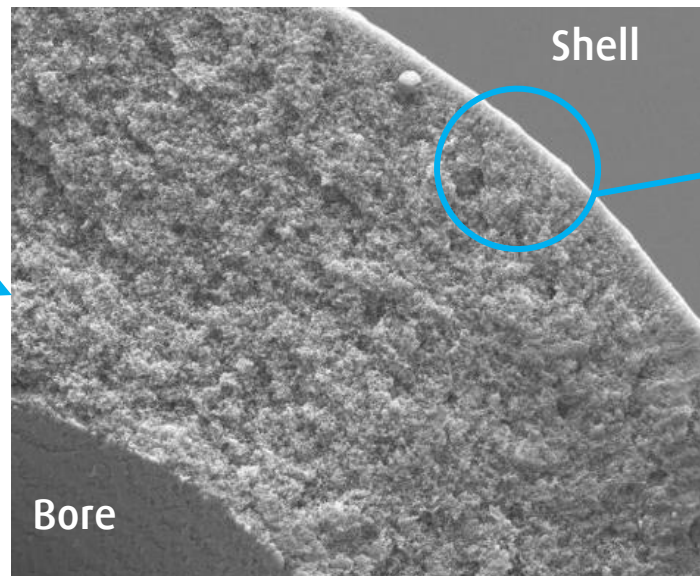
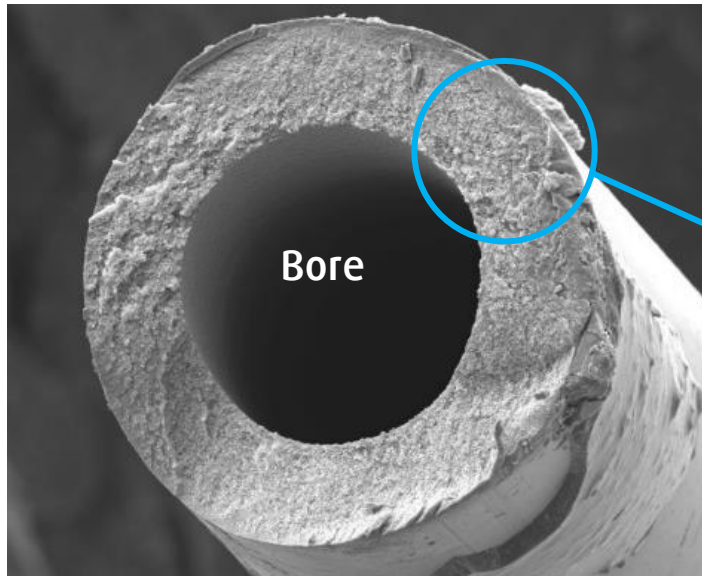


General Information about HISELECT® Membranes

The fiber inside HISELECT® Membranes



- Hollow fiber membranes
- Small tubes
- Thin selective skin on support structure
- Feed is shell side



Linde HISELECT® membrane

How it works



Linde HISELECT X 86 cartridge

High specific surface area of hollow fibres

Efficient due to counter current flow

High stability against mal-operation

Stable against HHC and trace components

Feed pressures up to 200 bar

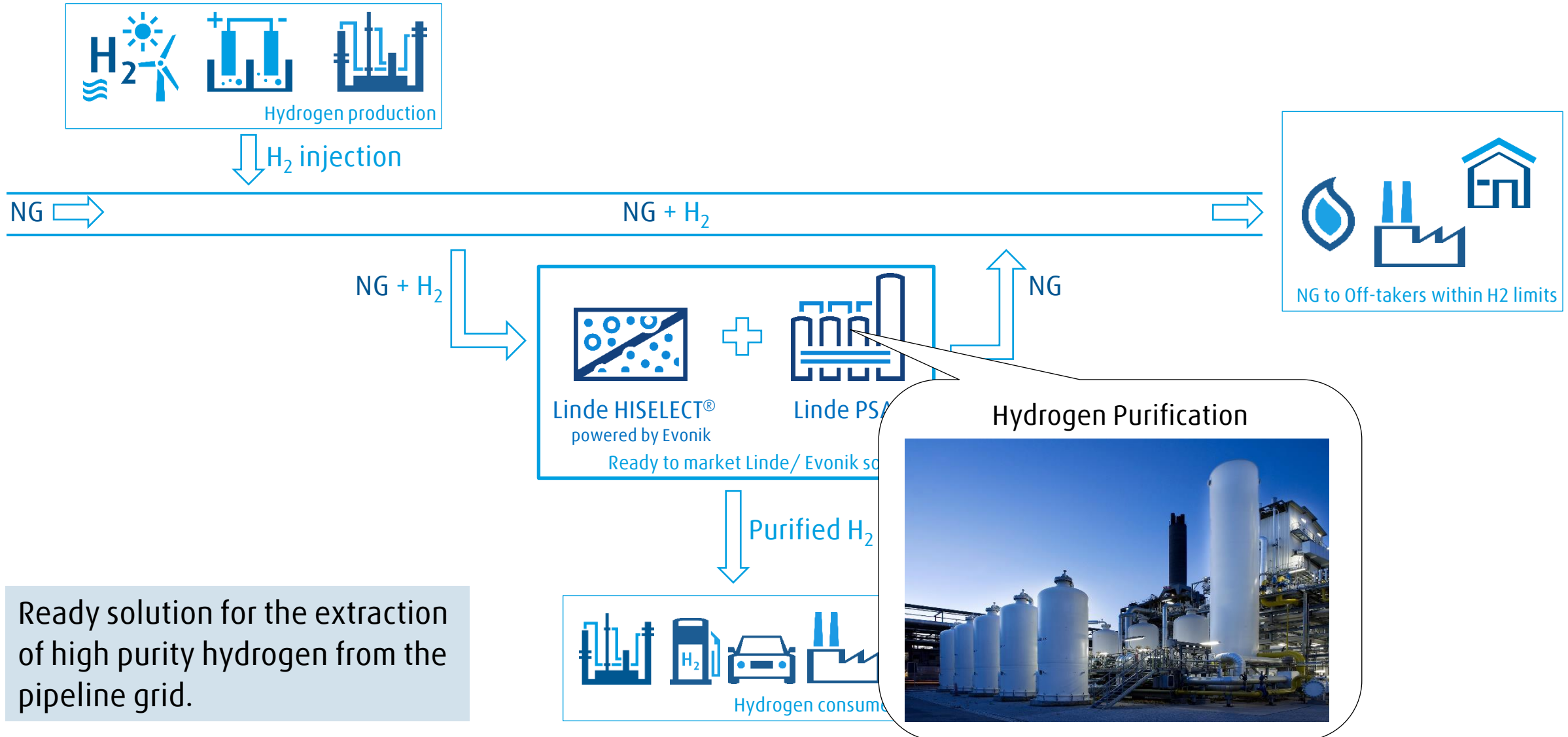
Plug-in replacements

Plug-in replacements for all standard 8" membranes make further adaption unnecessary.



Hydrogen extraction from hydrogen blended natural gas.

Basic concept – (2) Hydrogen Purification.



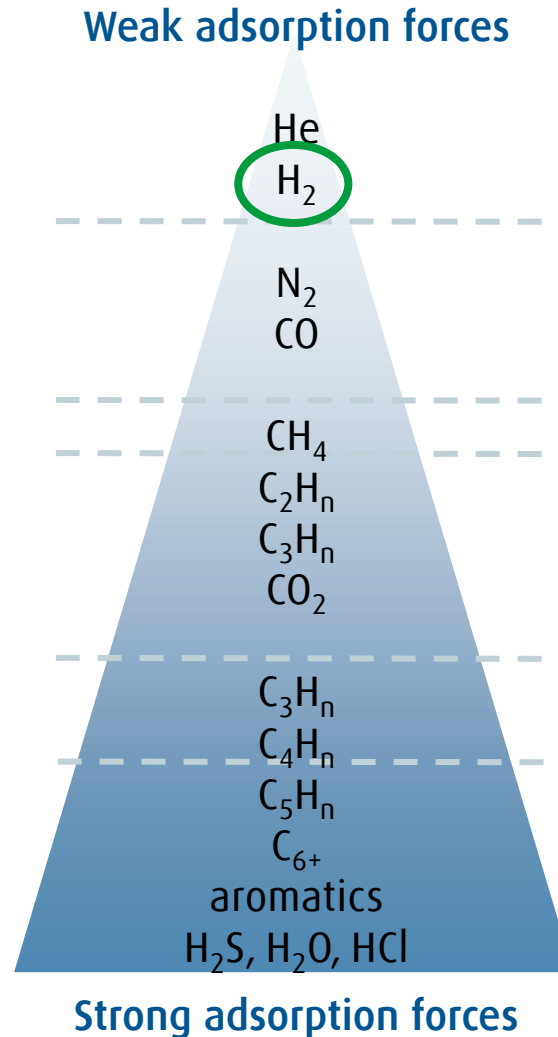
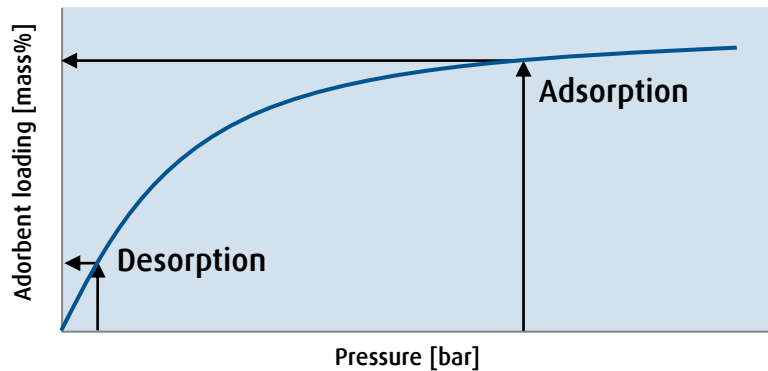
H₂ extraction from natural gas

Gas separation and purification by adsorption

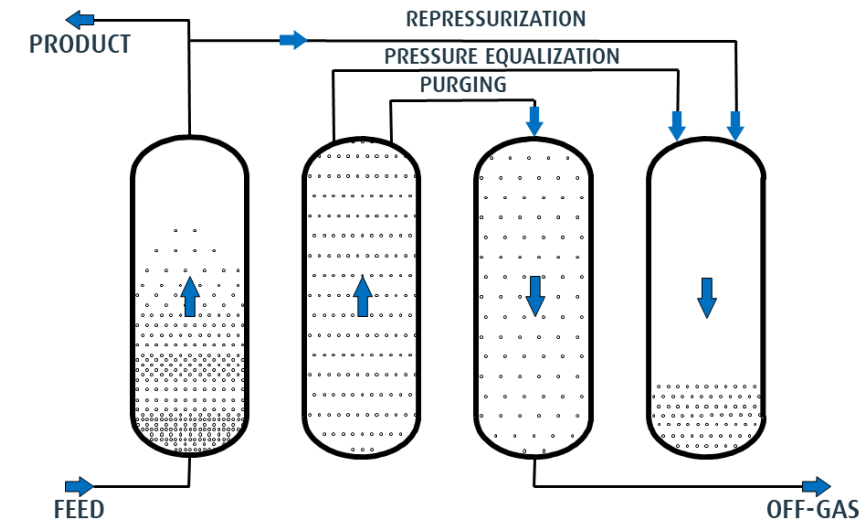


What is adsorption?

- **Attachment of molecules** (adsorptives) to the active surface of a solid (adsorbent)
- **Discontinuous process**: desorption follows adsorption



- **Simultaneous separation** of a multitude of components to achieve highest product purities → various adsorbents
- **Continuous process**: multiple adsorber vessels + intelligent interconnection + process control



- **Single train product capacity** from around 300 up to 400.000 Nm³/h

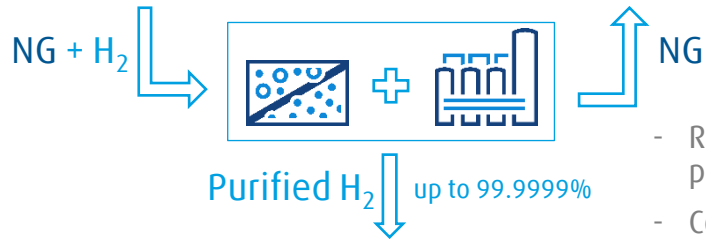
Hydrogen extraction from hydrogen blended natural gas.

Four major use cases & example applications – tailored to the requirement.



Extraction of purified H₂

NG + H₂ ⇒



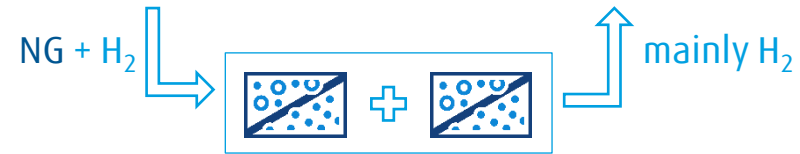
Purified H₂ ↓ up to 99.9999%



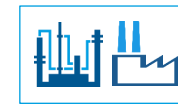
- Replacement of on-site H₂ production or H₂ bulk supply
- Connection of H₂ refueling stations
- Dedicated extraction of H₂ for subsequent liquefaction and shipping

H₂ removal for (pure) NG supply

NG + H₂ ⇒



NG ↓ w/ low H₂ content

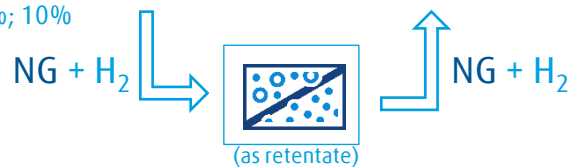


- Protection of chemical sites & plants from H₂

Depletion of H₂

NG + H₂ ⇒

e.g. C_{H₂} = 30%; 10%



NG + H₂ ↓ e.g. C_{H₂} = 10%; 1%

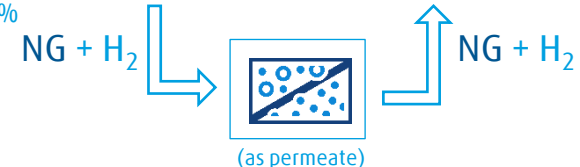


- Protection of NG fuel-driven pipeline compressors from H₂
- Protection of chemical sites & plants from H₂
- Depletion of H₂ in branched pipeline networks

Enrichment of H₂

NG + H₂ ⇒

e.g. C_{H₂} = 10%



NG + H₂ ↓ e.g. C_{H₂} = 30%



- Enrichment of H₂ in branched pipeline networks

H₂ extraction from natural gas

Summary



H₂ can be extracted in pure form from H₂ blended natural gas

Wide range of H₂ purities possible, e.g. 99.0%, fuel cell grade, 99.9999%. This enables an application of H₂ as industrial feedstock, transportation fuel, heating, storage & buffering

Various H₂ concentrations in NG can be targeted, e.g. 5-30 % H₂

H₂ intolerant consumers can be effectively protected from elevated H₂ concentrations, e.g. <1%, <0.1%

Ready toolbox for all use cases around H₂ in H₂ blended natural gas:

- Extraction and purification of H₂
- Depletion
- Enrichment





Collaborate. Innovate. Deliver.

Thank you for your attention.

