Hydrogen refuelling station – Linde's technologies

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THE LINDE GROUP

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1. The Linde Group – introduction

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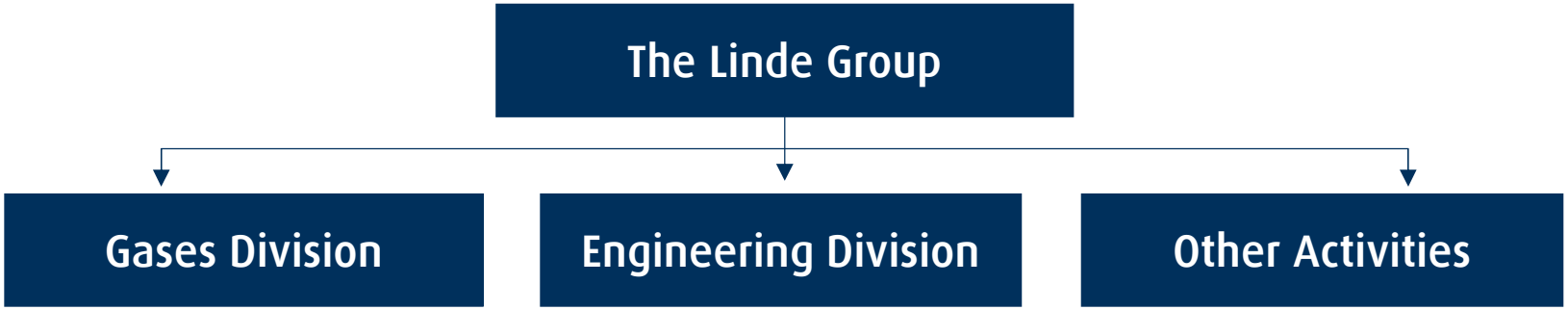
The Linde Group is one of the world leading concerns producing and distributing gases and gas technologies, as well as constructing industrial installations. It employs ca. 52 thousand employees and operates in ca. 100 countries worldwide. The concern has a over century-long tradition.

The Linde Group comprises three divisions: Gases and Engineering (the two core divisions) and Other Activities. The largest division is Gases.



Linde Gaz Polska has been present in Poland since 1993 and still is one of the leading companies in the market, offering complex solutions for gas deliveries and gas technologies. The headquarters is located in Cracow and the production facilities are spread over Poland.

2.1 Introduction to hydrogen refuelling station

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The Linde Group - as a world-leading hydrogen plant engineering company - is one of the driving forces behind the advancement of hydrogen production, distribution and fuelling technologies for mobility applications.

The Linde Group participates in many hydrogen projects and initiatives on hydrogen mobility matured markets.

Our technologies use in hydrogen infrastructure are patented.

Every station is extensively tested before delivery.

Delivery time is 10-12 months.

2.1 Introduction to hydrogen refuelling station

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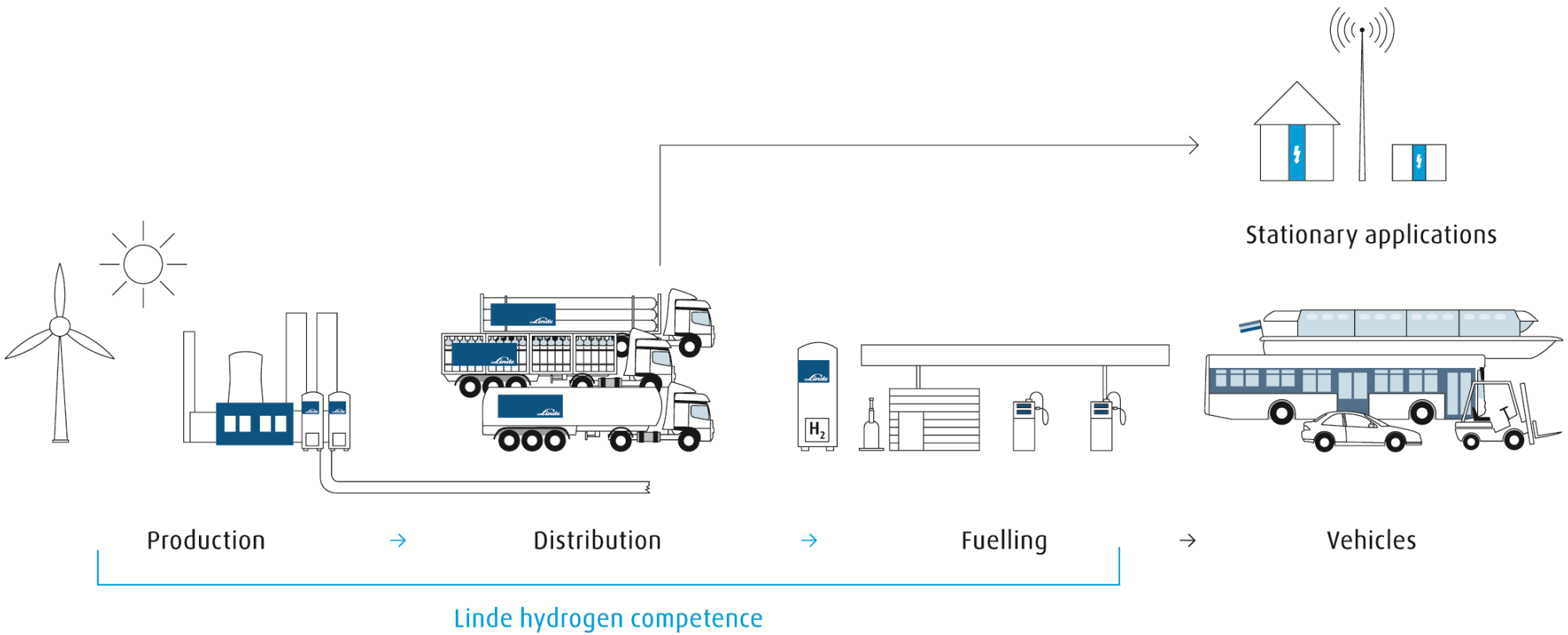
Key elements of hydrogen fuelling station



2.2 Hydrogen production processes

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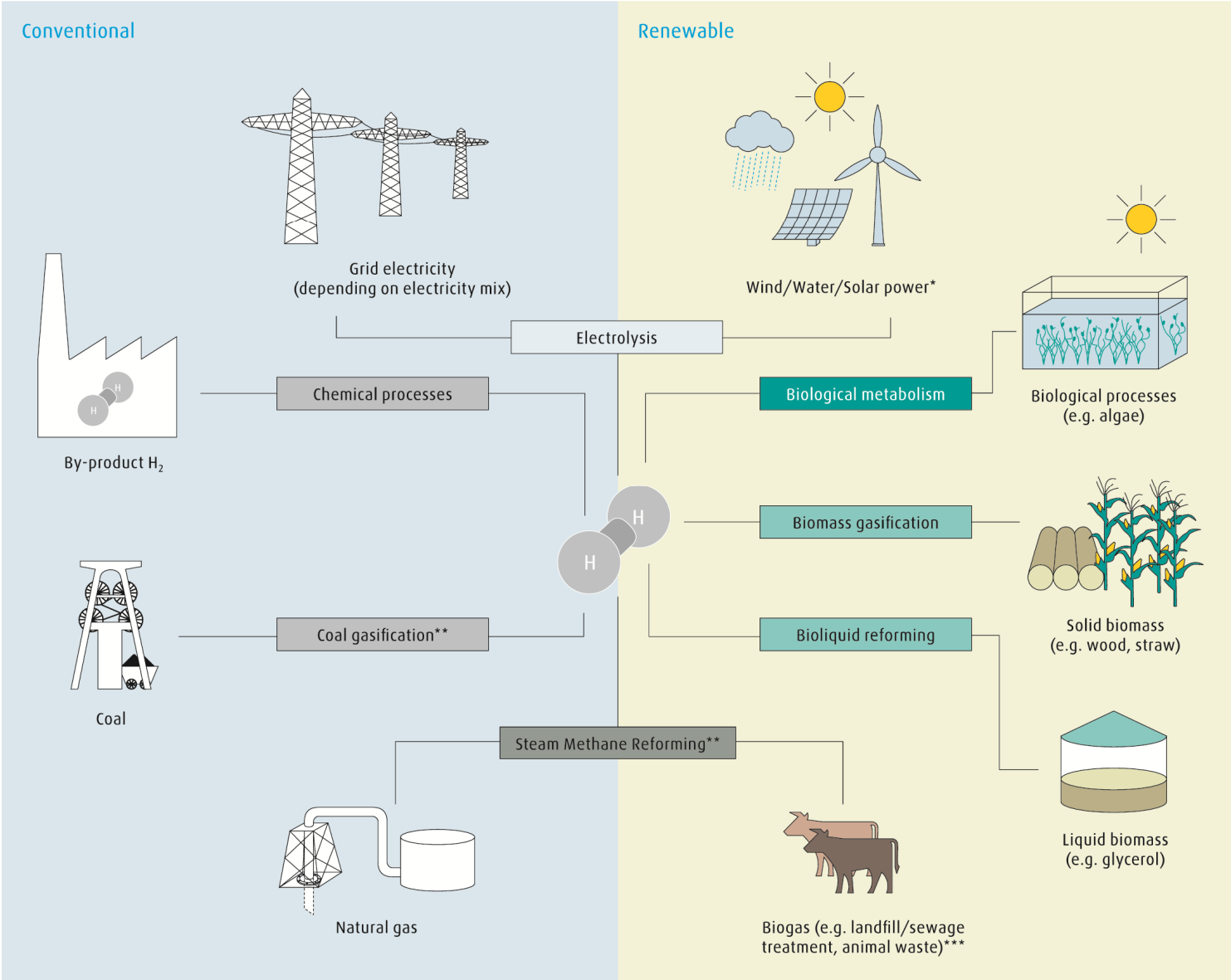
Hydrogen production pathways



*) Intermittent power sources **) With or without Carbon Capture and Storage ***) Requires purification before processing in SMR

2.2 Hydrogen production processes

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Conventional through steam reforming of fossil fuels such as natural gas.

Renewable such as biogenous processes or electrolysis of water with wind power, water power or solar energy.

Though hydrogen as fuel creates no emissions at the tailpipe, the production of hydrogen still generates carbon dioxide (CO2). The highest CO2 reduction can be reached by using renewable energies such as wind power, water power, solar energy and biomass. Definition of green hydrogen has to be determined.

Hydrogen quality standards (as vehicles fuel) are currently under development in SAE International (e.g., SAE J2719 “Hydrogen Specification Guideline for Fuel Cell Vehicles”) and in ASTM International.

2.3 Hydrogen distribution and storage pathways

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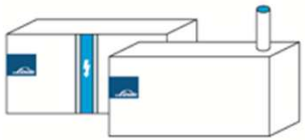
Hydrogen supply methods at a glance

Distribution method	Facts	Advantages	Disadvantages
 CGH_2 trailers	→ Transport at 20 MPa and higher → Capacity: 10,000 Nm^3	→ Economical transport for short → to medium distances	→ Comparatively low capacity (high delivery frequency) → Comparatively large on-site footprint (required space)
 LH_2 trailers	→ Transport at -253 °C → Capacity: 40,000 Nm^3	→ Economical transport for medium to long distances → Comparatively small footprints	→ Comparatively high energy requirement (for hydrogen liquefaction)

On-site production	Facts	Advantages	Disadvantages
 On-site H_2 production – Steam methane reformer – Electrolyser	→ Production through steam reforming or electrolysis → On-site production directly at the station → Typical capacity: SMR: 300 Nm^3/h, electrolyser: 5–100 Nm^3/h (modular)	→ No hydrogen transport costs	→ Comparatively low output/ capacity flexibility → Comparatively large footprint and complex permission process

2.3 Hydrogen storage and distribution pathways

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The methods of hydrogen distribution and storage are closely interconnected.

The main hydrogen distribution concepts based on gaseous and liquid storage systems are **CGH2/LH2 trailers** – road transport.

- **Compressed Gaseous Hydrogen (CGH2)** is stored in pressure-tight containers like cylinders, cylinder bundles, tanks, pipes.

- **Cryogenic Liquid Hydrogen (LH2)** is stored in specially insulated LH2 tanks , at minus 253 deg C.

2.3 Hydrogen distribution and storage pathways

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On-site production - as an alternative to producing hydrogen at one place and then delivering it to the hydrogen fuelling station. Hydrogen is produced and stored directly at the hydrogen fuelling station, eliminating the cost and effort of hydrogen distribution. Two on-site hydrogen production methods are steam reforming of natural gas and electrolysis of water.

The proper method of hydrogen supply to fuelling stations depends on a wide range of various factors e.g.:

- the amount of hydrogen
- the distance between the hydrogen production and fuelling sites
- the required frequency of hydrogen deliveries

2.4 Hydrogen compression technologies

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The compression technology is one of the most important technical elements within a hydrogen fuelling station. The choice of the proper compression technology depends on various factors:

- is the hydrogen feed liquid or gaseous?
- how much hydrogen is needed per hour?
- what is the required pressure?
- what kind of hydrogen vehicles are to be fuelled?
- what are investment and operation costs?

Linde's hydrogen compression technology portfolio is for CGH2 and LH2, for mobile and stationary fuelling of cars, buses and forklift trucks, at pressures from 35 to 70 MPa. Linde achieves a leading TCO (Total Cost of Ownership) position with its ionic compressor and cryo pump technologies.

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The ionic compressor

The basic principle is the replacement of the conventional metal piston with a ionic liquid. The gas is compressed in the cylinder by the up-and-down motion of the liquid column. Ionic liquids are made of molecules that have special physical and chemical properties: no vapor pressure, lubricating properties, no gas solubility, thermal stability and no flammability, high heat capacity.

Linde's ionic compressor virtually eliminates mechanical wear and removes the compression heat directly in the cylinder where it is generated. The result is a compression process independent of the hydrogen supply form, which is physically ideal (almost isothermal compression).

2.4 Hydrogen compression technologies

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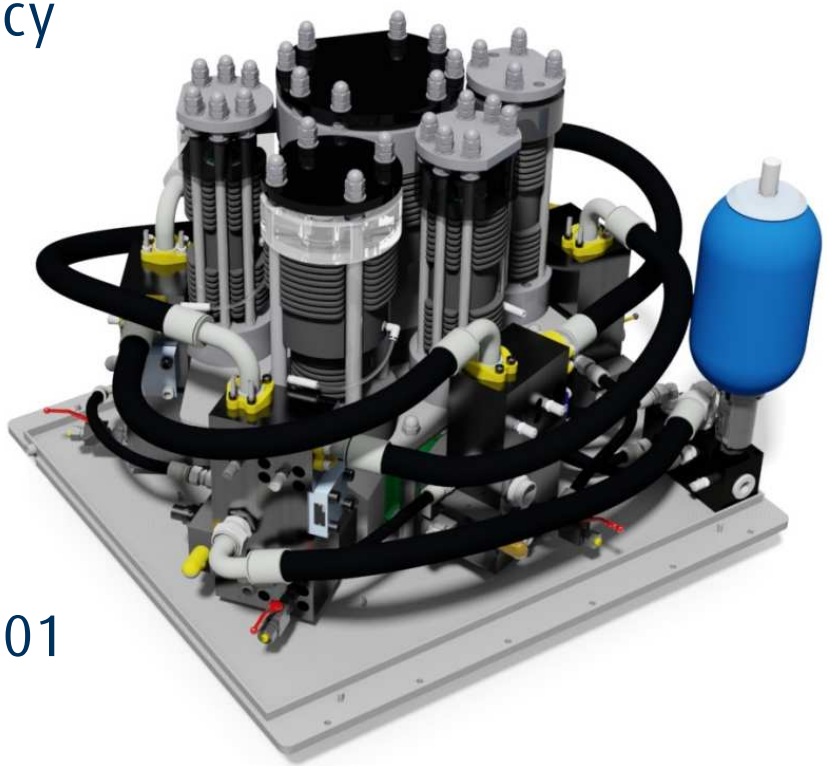
Advantages of the ionic compressor:

- Close to 100 % energy conversion efficiency
- Low energy consumption
- Very small number of moving parts
(due to use of ionic liquid as piston)
- Reduced wear and long service life
- Little maintenance effort and low costs
- Low material costs
- Low noise emission
- Conformity with fuelling standard SAE J 2601



E.g. IC90- output: 25kg/h
- pressure inlet/outlet: 5-200 bar/1'000 bar
- power consumption: 75 kW

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The cryo pump

The process takes full advantage of the direct compression of liquid hydrogen and by this reduces energy requirements at the hydrogen fuel system.

By using the cooling capacity of liquid hydrogen, no additional cooling of the compression process is required, which also reduces space requirements. A specially designed ambient air heat exchanger and temperature conditioning system raises the temperature of the cryogenic gas to -40 deg C. The fuelling can be carried out through a standard hydrogen dispenser.

The cryo pump allows a maximum pressure of up to 90 MPa with a fuelling capacity of up to 120 kg of hydrogen per hour.

The cryo pump is ready for operation at the push of a button, 24 h a day.

2.4 Hydrogen compression technologies

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Advantages of the cryo pump:

- High throughput
- Very low energy consumption
- Hydrogen with highest purity
- No additional cooling system
- High reliability
- Little maintenance effort and low costs
- Low noise emission
- Conformity with fuelling standard SAE J 2601

2.5 Hydrogen high pressure storage system

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- Hydrogen stored at high pressure - ready to immediately use
- 200 bar up to 1’000 bar
- No refill through trailers
- Only 20-30 % of H_2 usable
- Small capacity

2.6 Hydrogen fuelling dispensers

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The dispenser

The last stage of the hydrogen fuelling process takes place at the hydrogen dispenser. The fuel is transferred into the storage tank on board of the hydrogen vehicle.

Linde has various types of fuelling dispensers for cars, buses and forklift trucks.

Hydrogen fuelling dispenser portfolio

	Name	Max. inlet pressure [MPa]	Max. fuelling pressure [MPa]	SAE J 2601[1]	IR com[2]	Max. flow rate [g/sec]
CGH_2 dispenser	→ 25fork	42	31.2	No	No	60
	→ 35HF	50	43.8	No	No	120
	→ 35A	50	43.8	Yes	Yes/option	60
	→ 35B	50	43.8	Yes	Yes/option	60
	→ 70A	90	87.5	Yes	Yes	60
	→ 70B	90	87.5	Yes	Yes	60
LH_2 dispenser	→ LH2 A	0.5 (liquid)	1.0 (liquid)	Not applicable	Yes (wired)	60

[1]) Society of Automotive Engineering (SAE) J 2601, industry-wide fuelling protocol for gaseous hydrogen
[2]) Infrared communication

2.6 Hydrogen fuelling dispensers

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The dispenser with IR communication to measure/read:

- hydrogen pressure
- hydrogen temperature
- vehicle tank capacity

2.7 Hydrogen refuelling station

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Vehicle type:	700 bar car 350 bar bus - optional
Compressor:	IC 90
Max. output:	6 cars/h
Power supply:	105 kW
Supply:	CGH2/ LH2
SAE:	yes

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Italy, Bolzano

The H_2 refuelling station is one of the biggest of its kind. It fuels 6 local city busses and a fleet of semi-public H_2 cars. The hydrogen is produced, stored and supplied on-site making it a self-sufficient system. Additionally the required power comes 100% from hydroelectric plants in the nearby mountains.

H_2 Supply	Compressor	Dispenser	Start of operation
3x electrolyzer	2x IC 90 3x IC 50 (booster)	2x 350 bar bus 1x 700 bar car	2014

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USA, Spartanburg

The BMW factory is the biggest H_2 refuelling station for forklifts worldwide. It needs approximately 1’000 kg H_2 per day and supplies around 350 forklifts through 18 dispensers that are located throughout the facility. The factory is supplied by trailers with liquid H_2.

H_2 Supply	Compressor	Dispenser	Start of operation
LH_2 delivery	6x IC 50	18x 350 bar forklift	2008

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Scotland, Aberdeen

The H_2 bus refuelling station supplies the largest H_2 bus fleet in Europe, maintaining a small footprint. The electrolyzers can power up to 20 busses a day and are designed to extend to H_2 car dispensers. A second H_2 refuelling station is planned by the city in order to become the hydrogen avant-garde in Europe.

H_2 Supply	Compressor	Dispenser	Start of operation
3x electrolyzer	2x IC 90	2x 350 bar bus	2015

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Switzerland, Hunzenschwil

COOP has inaugurated the first H2 refuelling station for trucks worldwide, in line with its corporate goal of a emission-free supply chain. The station is publicly accessible and refuels both fuel cel trucks as well as fuel cell cars. More stations are planned to create a network for fuel cell trucks.

H_2 Supply	Compressor	Dispenser	Start of operation
CGH2 delivery	2x IC 90	1x 350 bar bus 1x 700 bar car	2016

4. The Linde Group – your partner for hydrogen projects

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Everyone doing business with us has access to high quality gases CGH2/LH2, innovative technologies, extensive services, customised solutions.

Turnkey technologies are developed and engineered by our qualified staff.

Safety is our top priority - especially when working with hydrogen.

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Thank you for your attention.

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