Innovation & Experience.
Hydrogen Technology and Infrastructure.

LeadIng.

THE LINDE GROUP

Thomas Zorn

The Linde Group: History

THE LINDE GROUP

1879 Foundation of "Linde Eismaschinen AG" in Wiesbaden, Germany

1895 Carl von Linde patents "process of air liquefaction "

1907 Foundation of Linde Air Products, USA

1929 Acquisition of Güldner-Motoren-Gesellschaft (Diesel engine)

1959 Linde starts production of forklifts

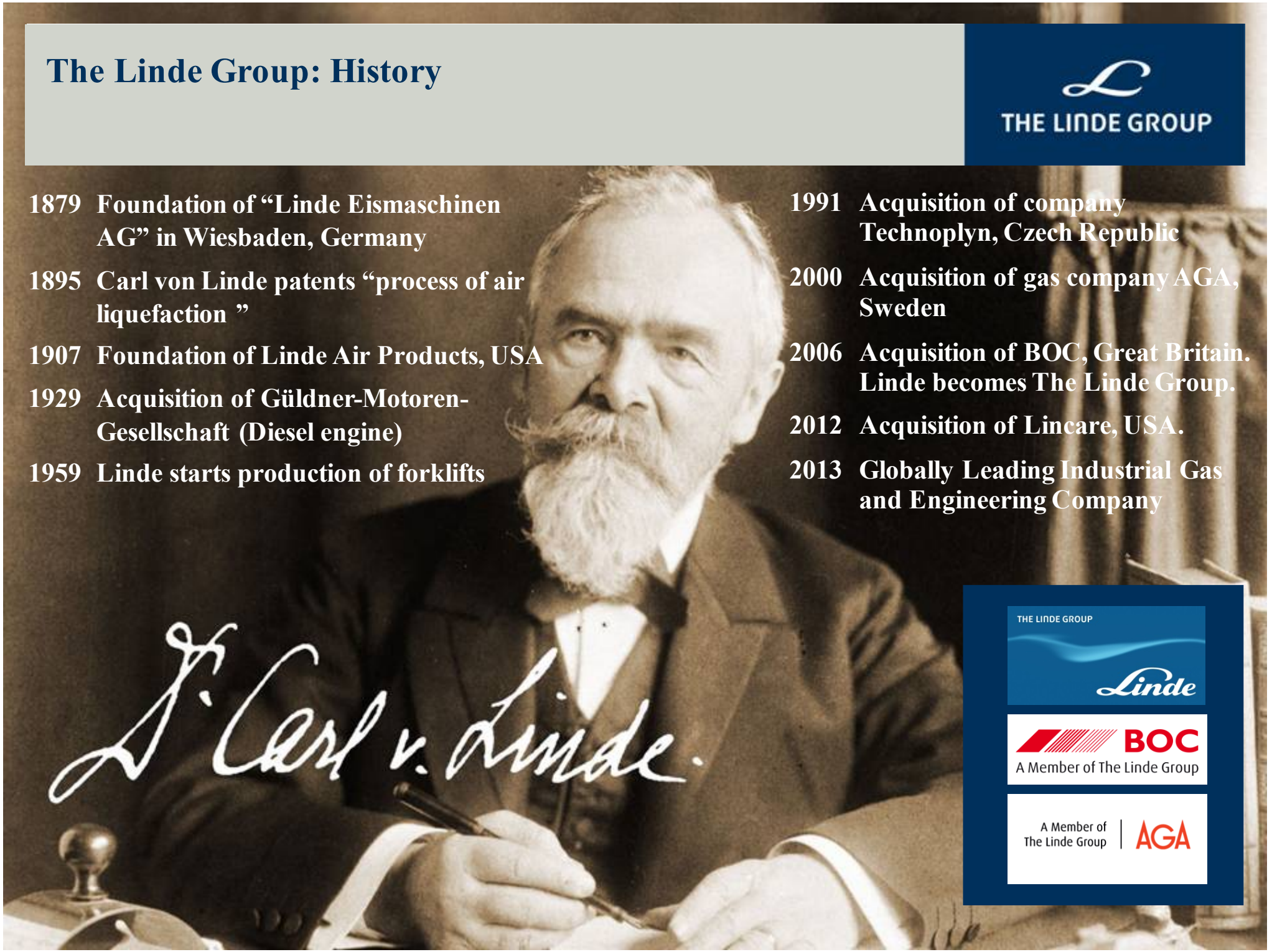
1991 Acquisition of company Technoplyn, Czech Republic

2000 Acquisition of gas company AGA, Sweden

2006 Acquisition of BOC, Great Britain. Linde becomes The Linde Group.

2012 Acquisition of Lincare, USA.

2013 Globally Leading Industrial Gas and Engineering Company



THE LINDE GROUP

Linde

BOC

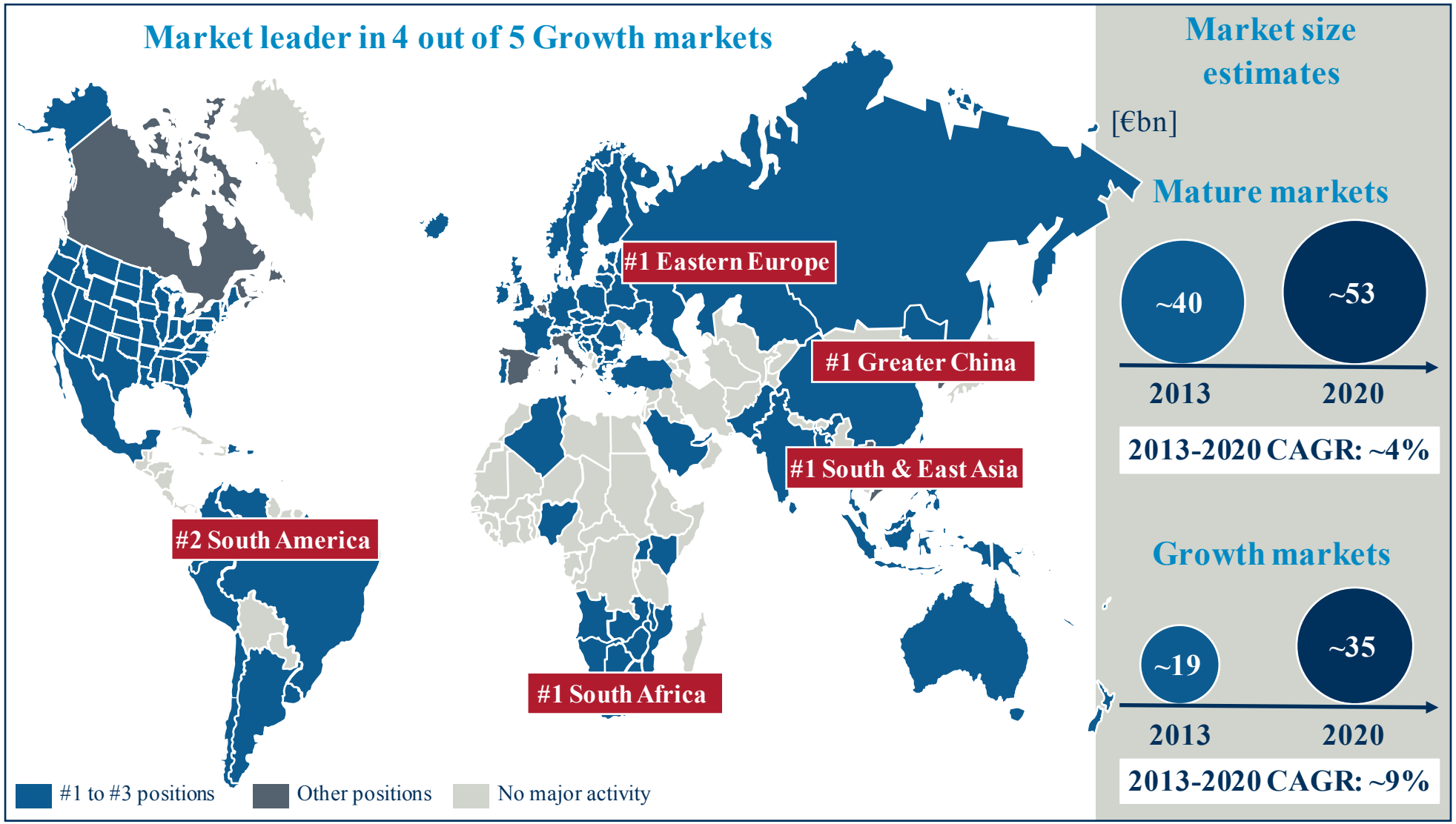
A Member of The Linde Group

A Member of The Linde Group | AGA

Mega trend: Growth markets

> 100 countries, 63’ people and € 16.7 Bn revenue (2013)

THE LINDE GROUP



Source: Linde data May 2013, figures for industrial gases and respiratory healthcare, excl. Japan, equipment and major impacts out of future mega-projects in energy/environment

Mega trends

Leveraging growth with our Gases & Engineering set-up

THE LINDE GROUP

Growth Markets

Energy & Environment

Healthcare

Technology portfolio

Clean energy growth markets for Linde

THE LINDE GROUP

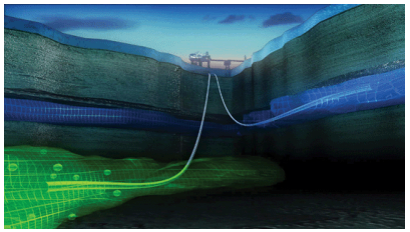
Merchant Liquid Natural Gas (LNG)

- Oil vs. NG spread
- CO_2 reduction

Enhanced Oil Recovery (EOR)

- Maturing oil fields
- High oil prices

Carbon Capture & Storage / Usage



- Regulations
- Funding
- Coal reserves

H_2 as fuel

- Zero emissions
- Drive performance

CO_2 Networks

- Increasing need for CO_2 recycling
- Integrated solutions

Photovoltaic

- Environmental impact
- Efficiency-driven

Application areas for Hydrogen as fuel and Linde's experience

THE LINDE GROUP

Focus areas

Linde's experience

Passenger cars

—> 100 stations delivered
— > 120.000 fuellings

Public transport

—> 10 stations delivered
— > 30.000 fuellings

Material handling

—> 15 stations delivered
— > 1 000.000 fuellings

Backup power

—> 10 units delivered

Linde's experience

Maritime

—2 stations delivered
—Ferry and submarines

Aviation

—Supply of pilot projects
—Market studies

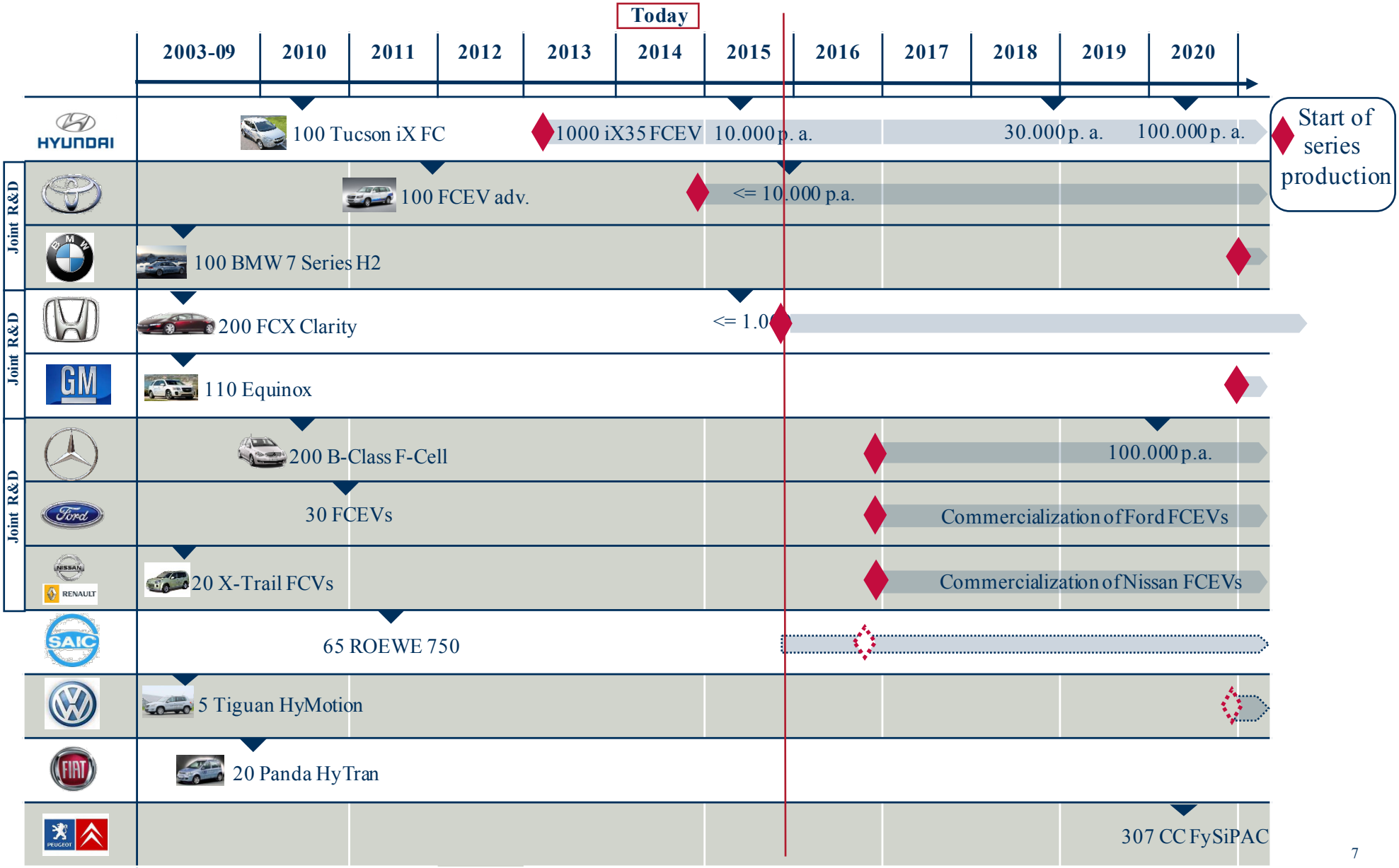
Portable power

—Early market
—Economical advantages

Advanced customer applications

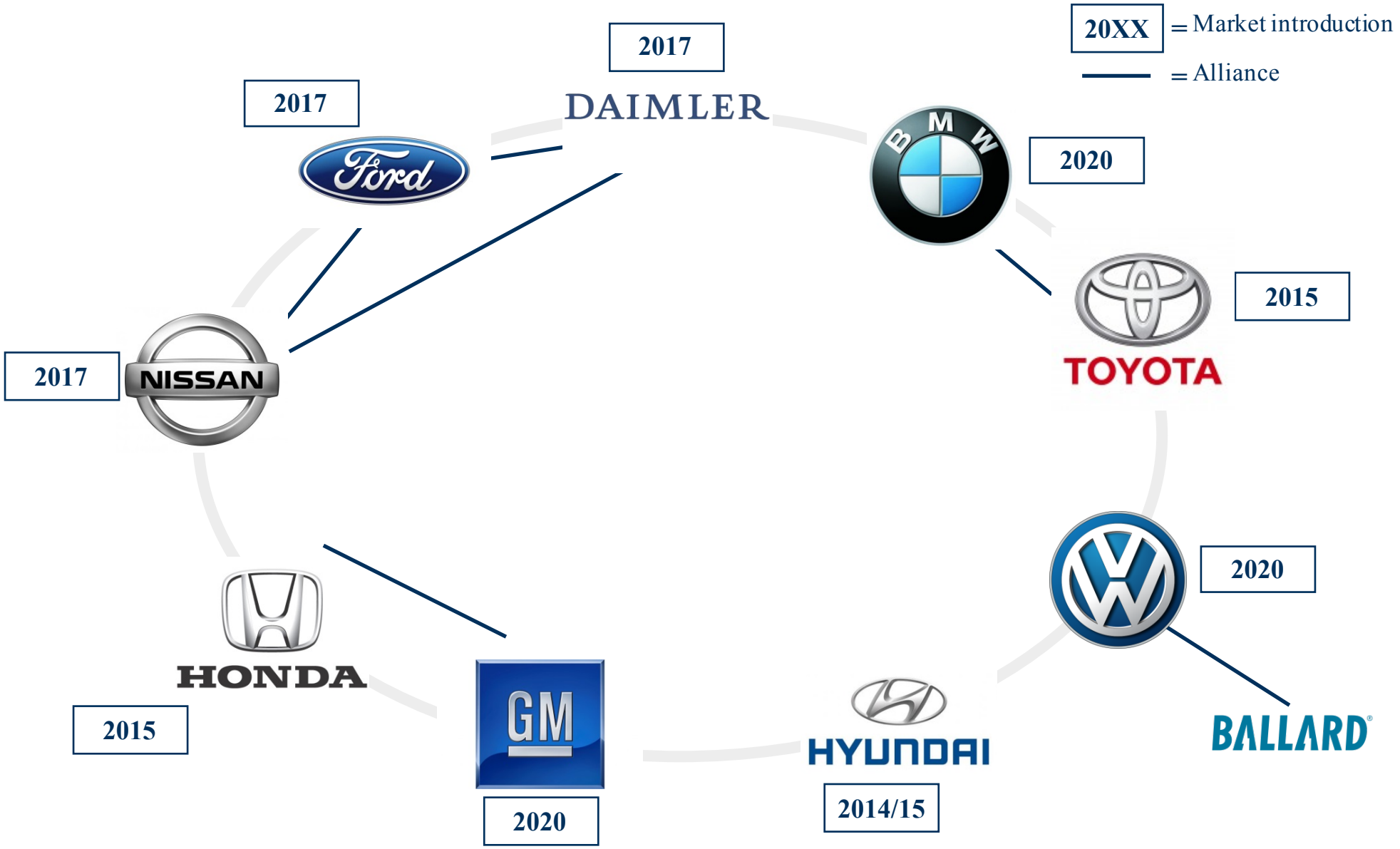
—Multiple projects implemented

FCEV: Project Pipelines



Forming of OEM alliances for FC-development

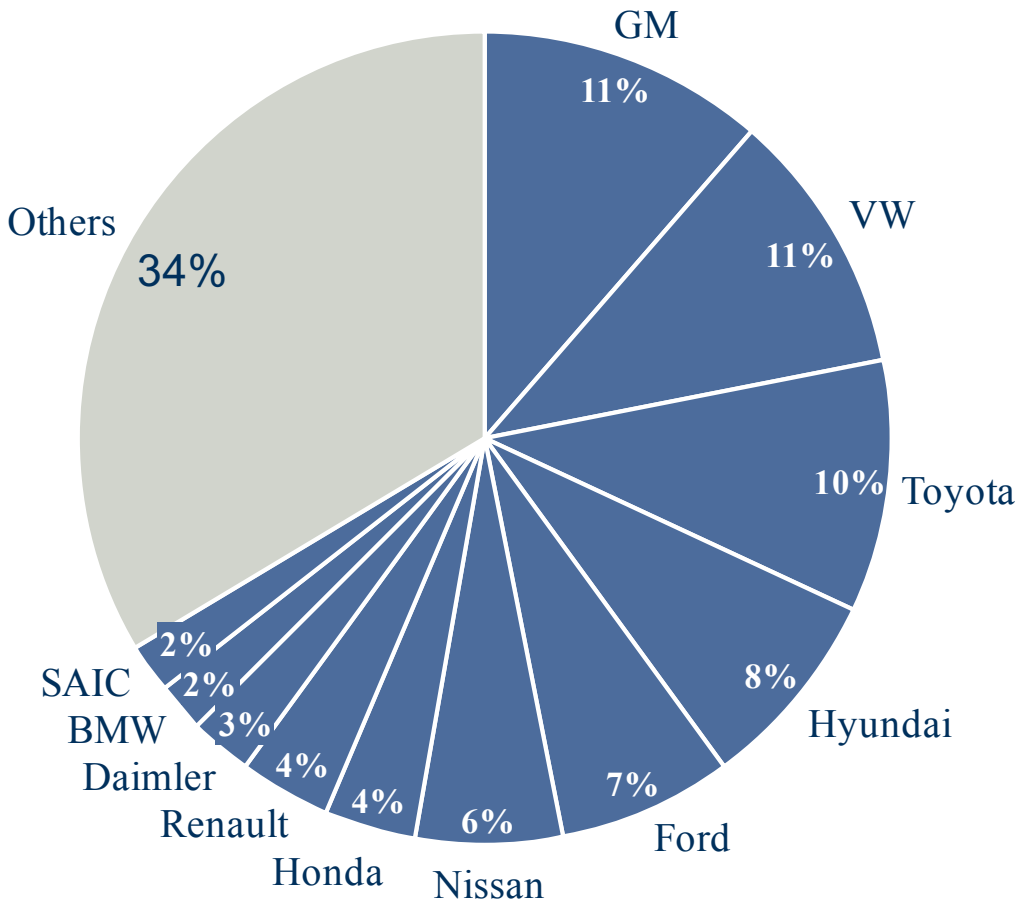
THE LINDE GROUP



Milestones 2012/2013 - OEMs which actively work on FCEVs represent 66 % of today's world market

THE LINDE GROUP

Market share by volume, 2011



Source: "WORLD MOTOR VEHICLE PRODUCTION OICA correspondents survey WORLD RANKING OF MANUFACTURERS Year 2011", OICA

Today numerous initiatives are ongoing in USA, Europe, and Japan.

	North America	Europe	Asia
H2 as fuel	- **Hot Spot California:** CARB Advanced Clean Cars Program / ZEV regulations - First commercial market for **utility fleet vehicles (FLT)**	- **Hot Spot Germany:** Focus of German OEMs due to funding structure (NIP/CEP) - Various other projects in **UK, Benelux, Scandinavia, etc.**	- **Hot Spot Japan & Korea:** Focus of OEMs due to funding structure (METI) - **China fast follower (?)**
H2 infra.	-California H2 Stations Road Map: By 2016: 68 stations.	- 50 HFS Program of BMVBS (NIP) - EU: Clean Power for Transport Directive, Alternative Fuels Strategy	- Japanese HySUT Program By 2015: 100 stations - Korean HFS roll-out scenario

Linde covers the entire hydrogen value chain with in-house technology & developments

THE LINDE GROUP

Production

Decentralization

Conventional
(e.g. SMR)

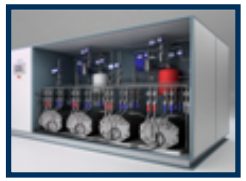
Green
(e.g., BtH*, Ely)

Supply/Storage

CGH_2 storage

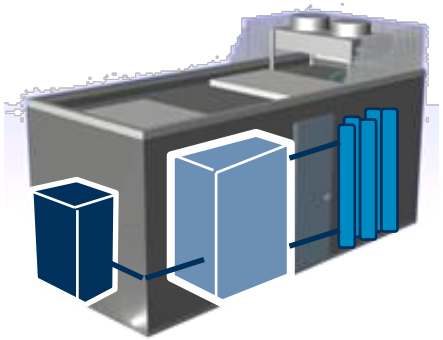
LH_2 storage

Onsite SMR



Onsite Electrolysis

Compression/Transfer



Ionic compressor

Cryo pump

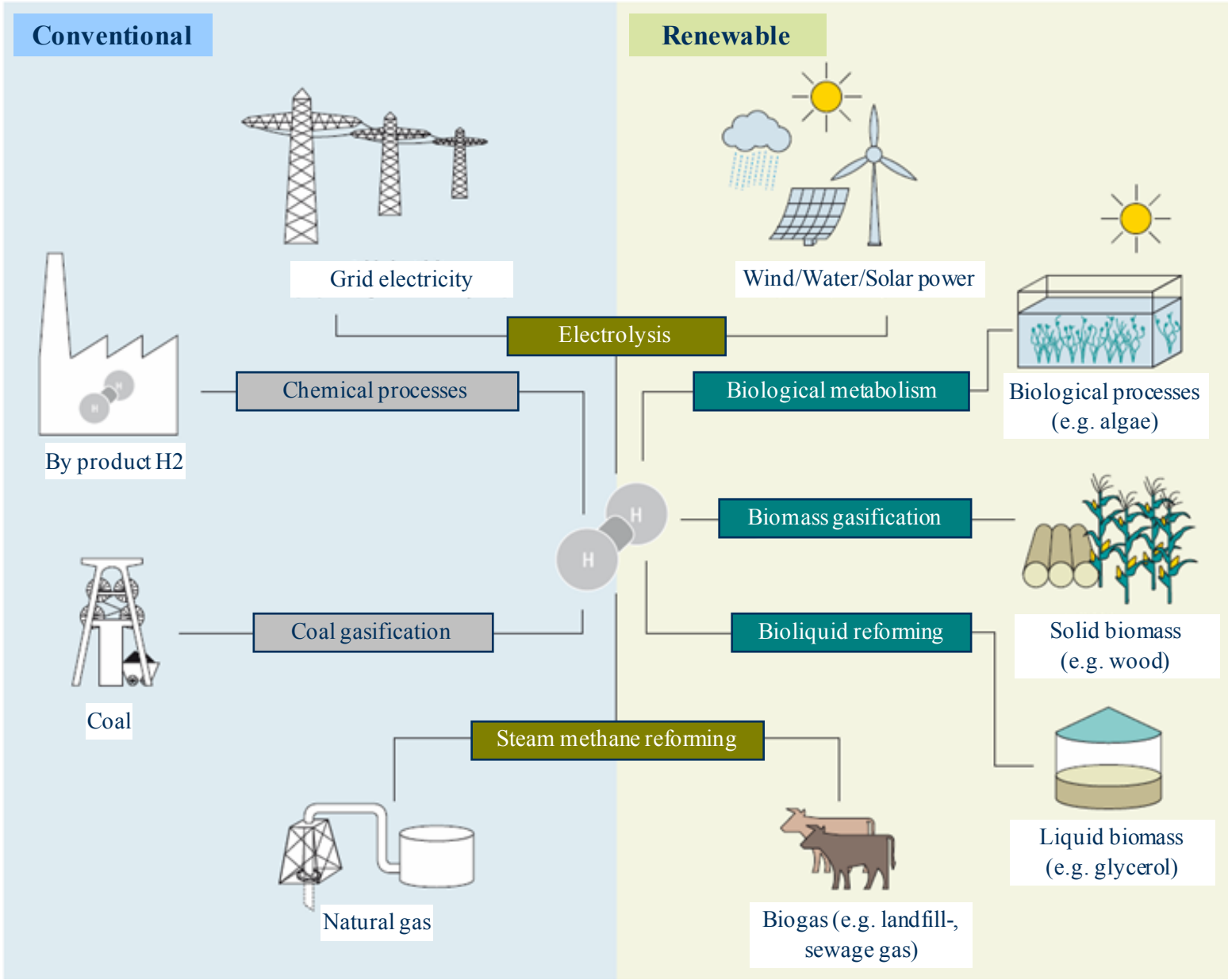
Dispenser

350 bar

700 bar

* Biomass to Hydrogen

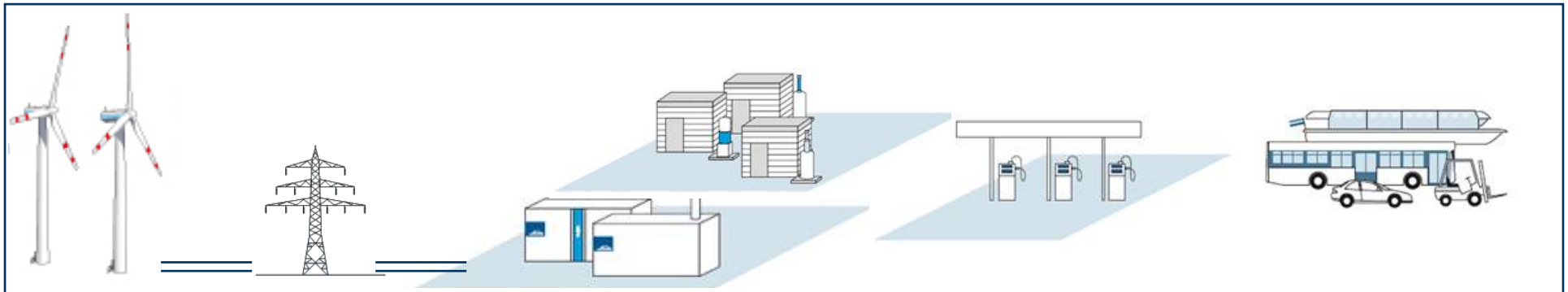
Hydrogen production: Variety of feedstock allows for a broad diversification and CO2 reduction.



Hydrogen production pathways
Focus: Intermittent power to hydrogen

THE LINDE GROUP

Basic flow chart: Wind to hydrogen



Milestones 2014
Opening of power to gas & multi energy station

THE LINDE GROUP

Key facts

- Total, Linde and Enertrag erect a hydrogen refuelling station including electrolysis from windpower and a trailer filling plant at the new Berlin airport.
- Electrolysis provided by Enertrag (500 kW_{el}; hydrogen output ~100 Nm^3/h or 9 kg/h)
- Hydrogen fuelling station operated by Total (350/700 bar; cars and buses)
- Linde will built ionic compression, storage and trailer filling plant to take off excess hydrogen or supply additional hydrogen
- Funding via National Innovation Programme Hydrogen and Fuel Cells

Linde's advanced hydrogen fuelling technologies

The Ionic Compressor

- High throughput of 35 kg/h @ 900 bar[1]
- Energy consumption reduced by 25%[2]
- Very small number of moving parts (liquid piston)
- Reduced wear and long service life
- Four times longer maintenance intervals*
- Fulfils industry standard SAE J 2601

The Cryo Pump

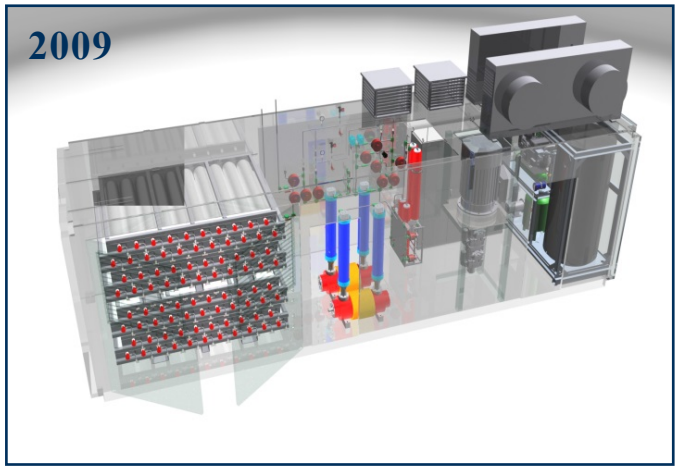
- Very high throughput of up to 120 kg/h @ 900 bar
- Energy consumption reduced by 70%[2]
- Hydrogen with highest purities
- No additional cooling system
- High reliability, little maintenance effort and low costs
- Fulfils industry standard SAE J 2601

[1] For one system. Modular setup allows for higher throughputs.
[2] In comparison to a conventional piston compressor

Progress in Hydrogen fuelling station technology development: Example Footprint

THE LINDE GROUP

Ionic compressor, 700bar station



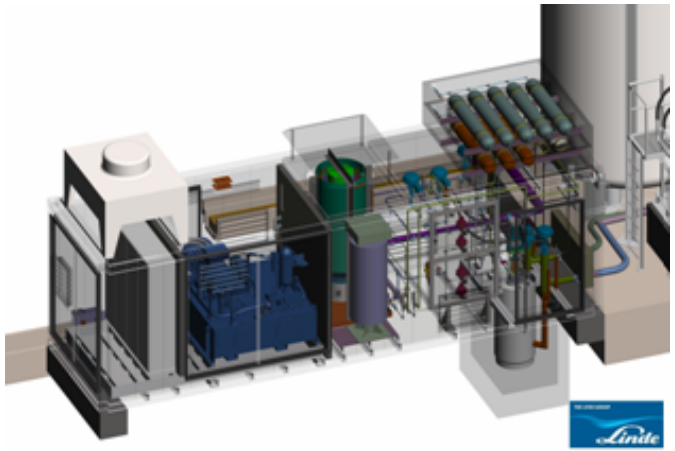
—20 kg/h system, **30ft** to 36 kg/h **14ft** container (potentially 72 kg/h)

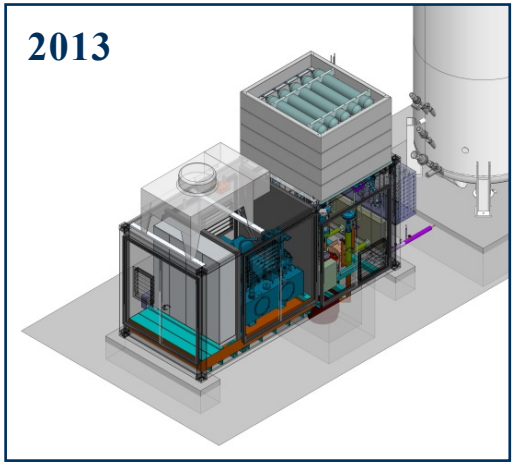
—First implementation:

— Total, Berlin

— Total, Hamburg

Cryopump, 700bar station





—120 kg/h system

—**30ft** container to **20ft** container

—First implementation: Daimler/Linde 20 HFS

The next step in space saving: underground storage

Content

Linde hydrogen refueling solutions.

Reference projects prove technological maturity.

THE LINDE GROUP

Linde reference projects

Key facts

— More than 100 hydrogen stations equipped in 15 countries

— More than 1 000,000 successful fuelings

— Leading supplier of hydrogen fueling technologies

Key learnings

— Technological maturity reached

— High level of standardization reached

  — Standardized fueling protocol

  — Common fueling interface

— User-friendly fueling process

  — 3 min / fueling

  — Touch & feel like con-ventional stations

  — Integration into exist-ing infrastructure

Hydrogen Trailer 500 bar.

THE LINDE GROUP

Project description

— 2010: start of development of a new high-pressure tube trailer composed of modern carbon fiber-wrapped cylinder

— Extension of existing filling plant with modern compression technology from Linde for 500 bar

— 50% public funding from German government

Progress and Status

—Trailer on the road since June 2013

— > 45.000 kg successfully delivered to customer

—> 40 fillings at 500 bar

—Technical requirements: met as specified

Technical Data

— No. of composite cylinders: 100

— Operating pressure: 500 bar

— Hydrogen capacity: 1.100 kg
13.000 Nm^3

— Loading/unloading time: 45-60 min

Green hydrogen
Alternative feedstocks and processes

[1] E.g. sewage gas, landfill gas, mine gas, etc.
[2] With e.g. energy maize, liquid manure, etc. as feedstock for biogas production
[3] Mainly solid biomass like woody biomass, straw, solid & lignocellulosic by-products
[4] Either direct H_2 production or alternatively NH_3 generation as H_2 carrier
[5] Algae biomass can be used as feedstocks for gasification and fermentation theoretically

DLR Cologne, test facility
In operation since December 2012

THE LINDE GROUP

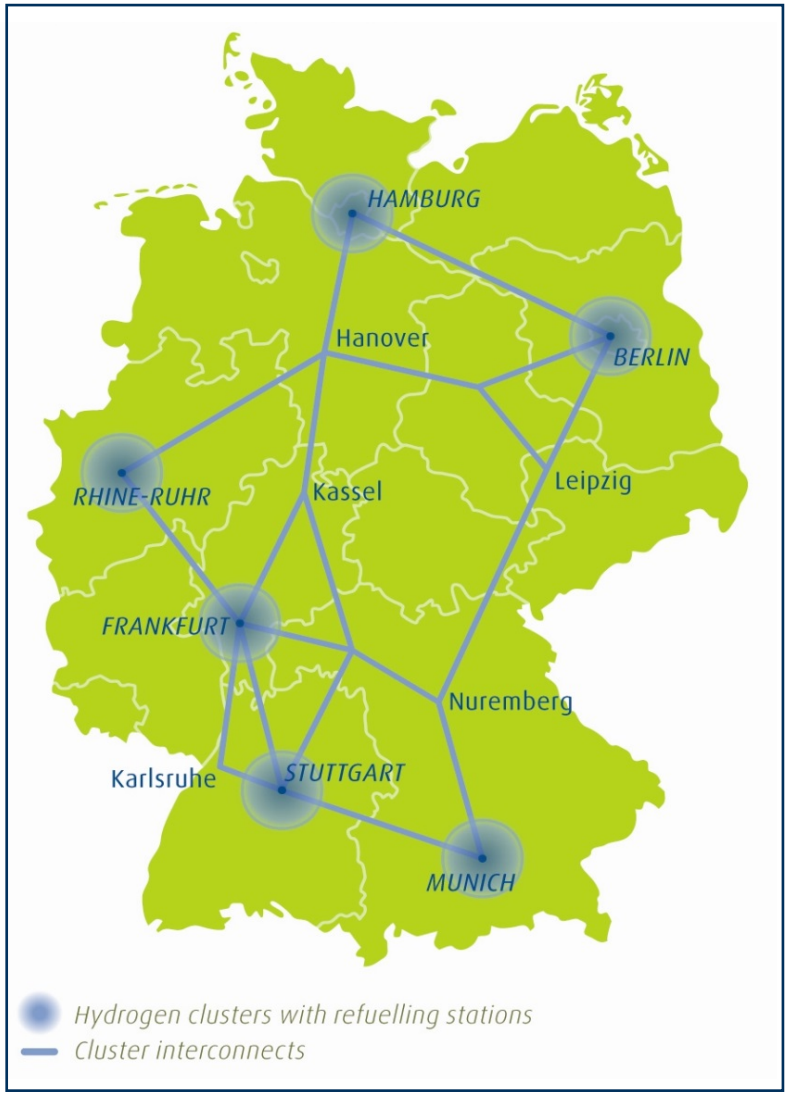
Linde & Daimler invest in 20 additional fuelling stations (as part of the 50 HFS program)

THE LINDE GROUP

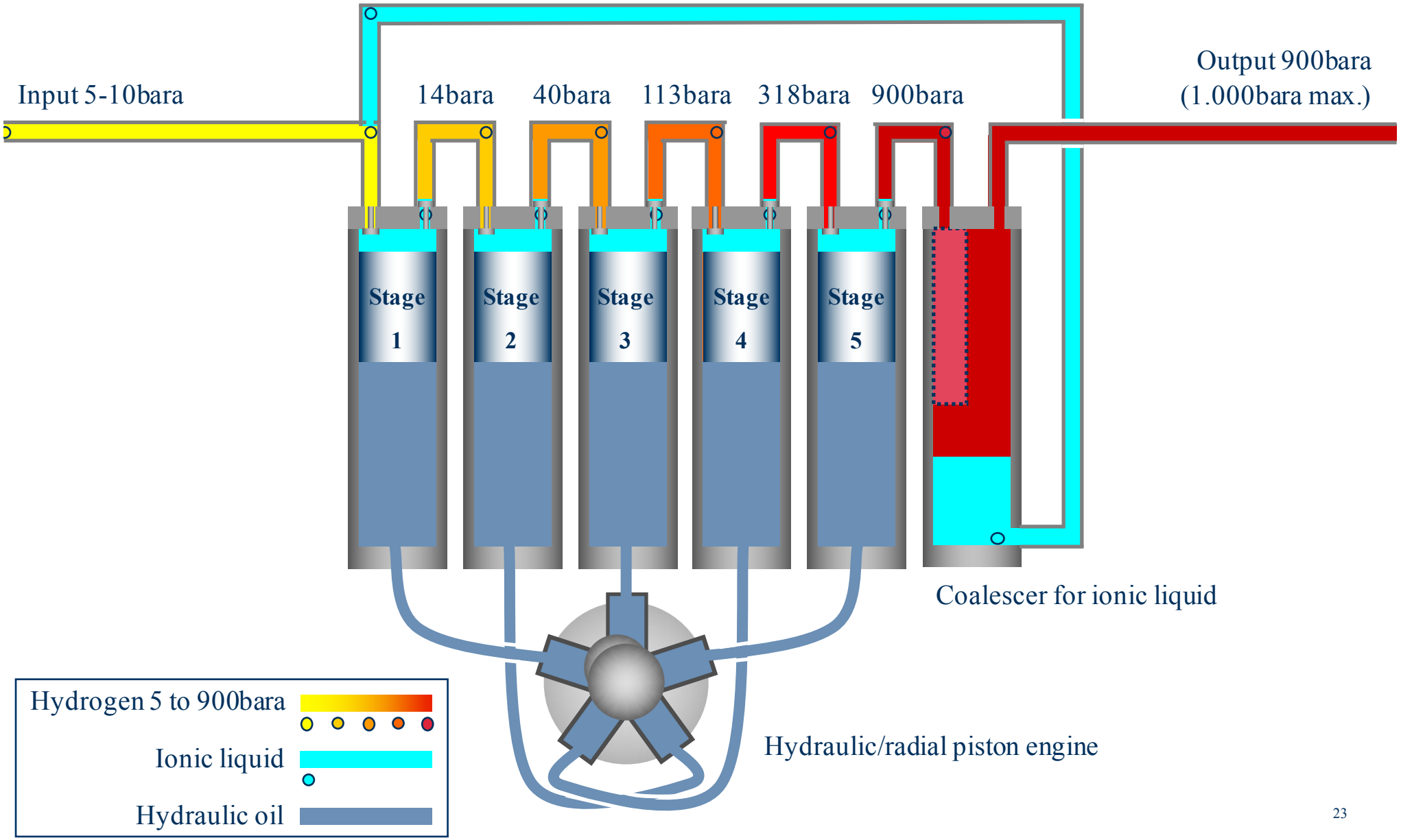
Key facts

- Initiative by Daimler and Linde
- Bridge the gap between demonstration (CEP) and commercialization (H2 Mobility)
- 10 + 10 additional public hydrogen stations in Germany
- Build-up in 2013, 2014, and 2015
- Strengthen existing cluster and establish links
- Will allow to drive through Germany with hydrogen cars

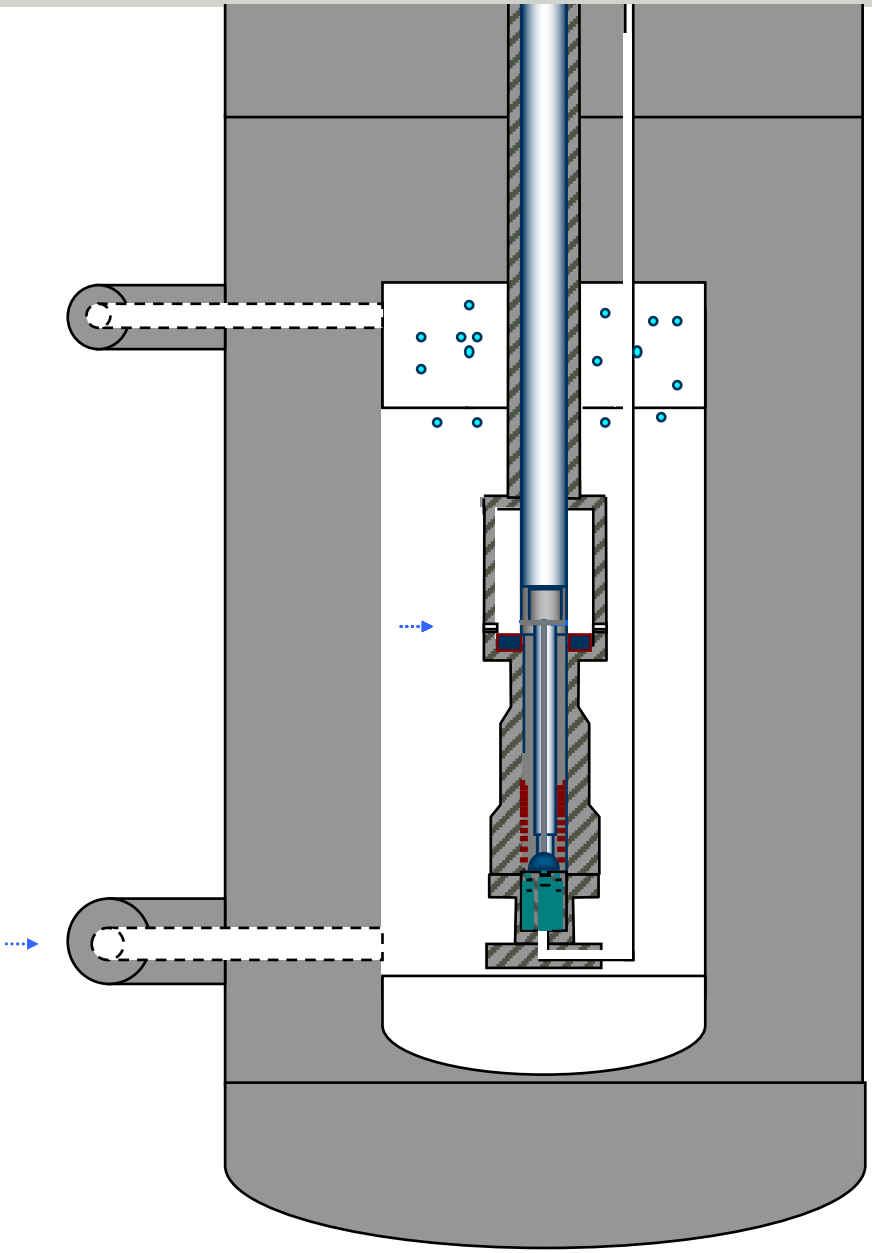
Distribution of stations (preliminary)



Ionic compressor 90MPa - IC90
functionality



Cryo Pump technology



Key facts:

— Super insulated Design

— Slow frequency drive (1,44 Hz),

— Cylinder Volume design for 120 kg/h

— Pump immersed in liquid hydrogen

— Double stage compression with LH2 feeding piston

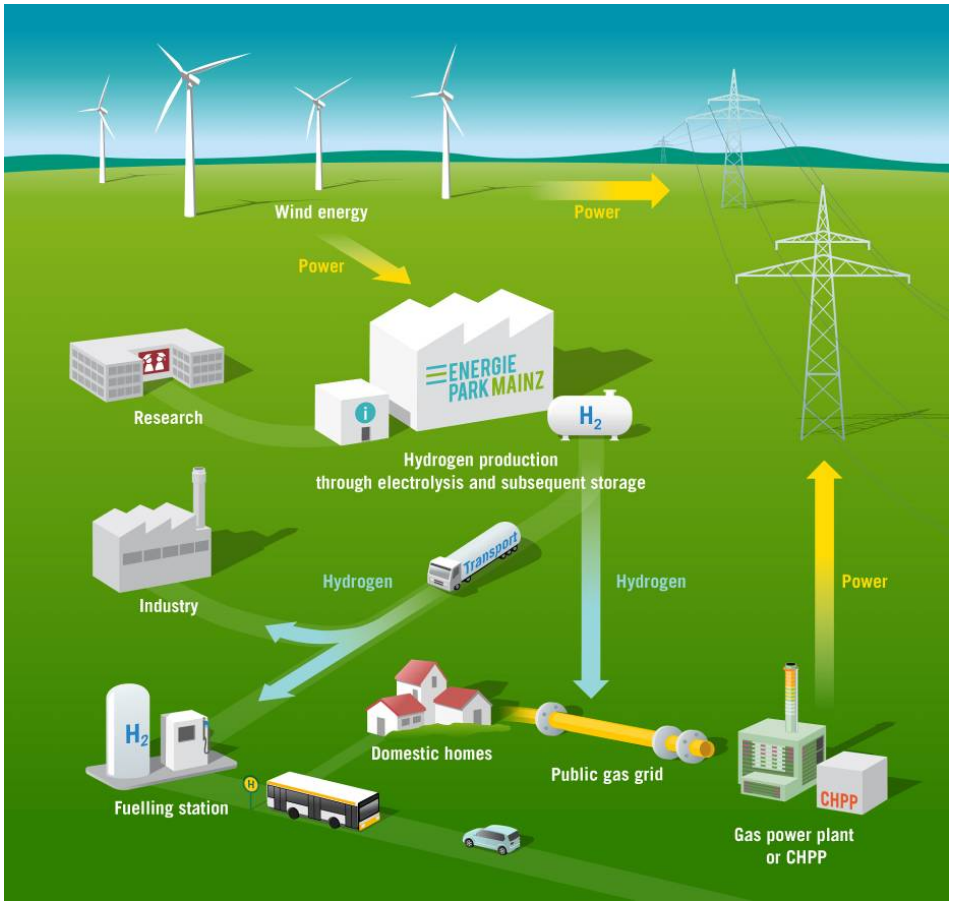
Power-to-gas and hydrogen storage III

„Energiepark Mainz“

THE LINDE GROUP

- Stadtwerke Mainz (SWM, municipal utility), Linde, Siemens and Hochschule RheinMain are planning an electrolysis and hydrogen storage facility in Mainz/Germany
- Total investments EUR 17 m – the biggest project of this kind so far, supported by federal Ministry of Economic Affairs and Technology
- Renewable electricity (up to 6 MW) will come from a wind park
- Hydrogen storage and handling technology by Linde, including proprietary ionic compression technology
- Multiple options for H_2 product which can be …
  - delivered to H_2 fuelling stations
  - fed into the natural gas grid
  - re-electrified in one of SWM‘s gas-powered power plants
- Construction to start beginning of 2014, completion expected in spring 2015

ENERGIE PARK MAINZ



Reference project

Mobile Refueling Truck TrailH2gas™, Europe

Start of operation: **2008**

Dispensing lines: **1 x 700 bar car**
1 x 350 bar car

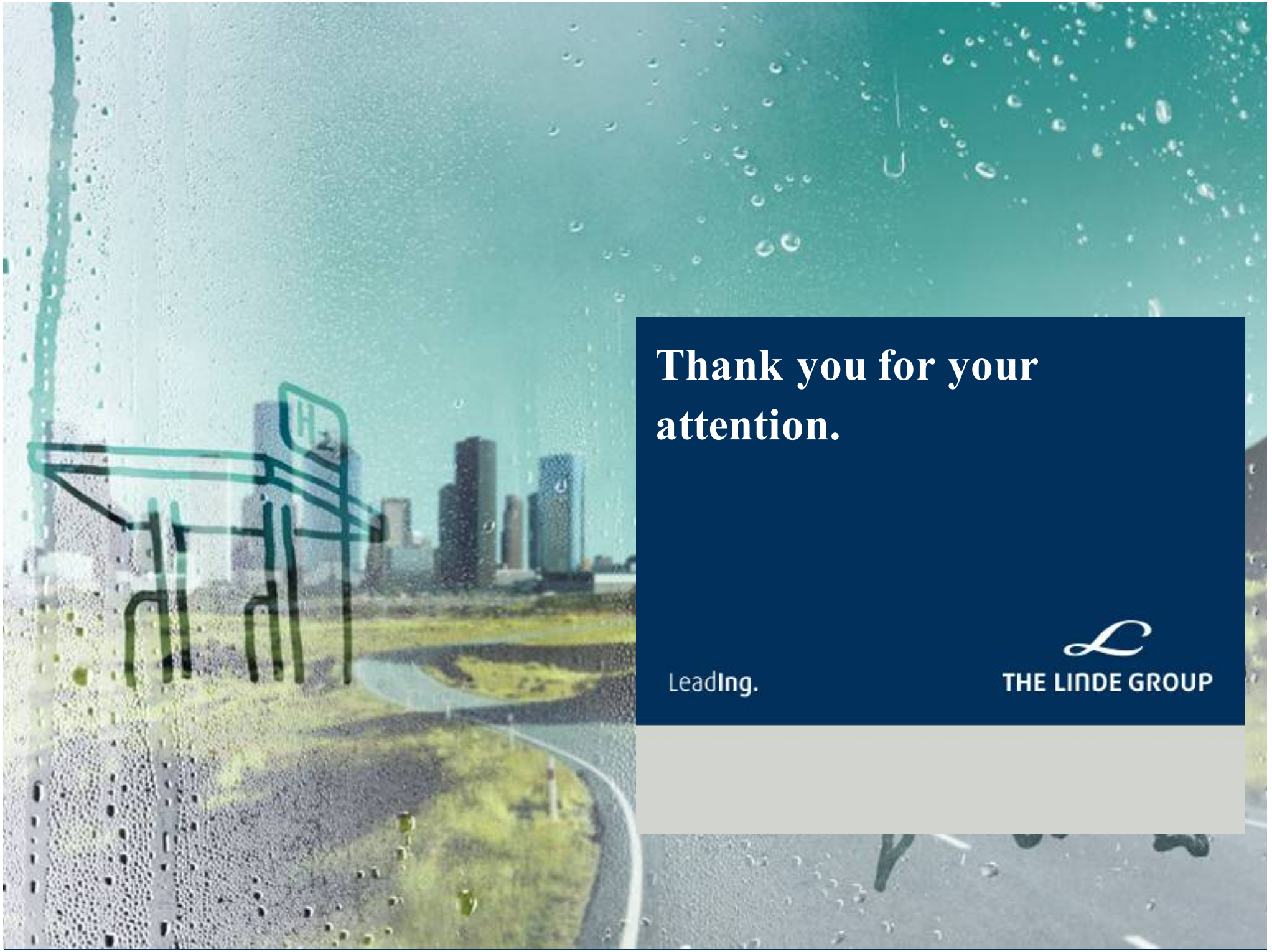
Technology: **Dry Runner**

Main user: **Car OEMs & Customer trials**

Key Features:

Easy and flexible set-up

Event, test & demo refueling


Thank you for your attention.
LeadIng.
THE LINDE GROUP