A3PS

Rethinking Propulsion.

Country Update on FCH- Activities in Austria

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Workshop Annex 26 -Fuel Cells for Transportation

Austrian Association for
Advancede Propulsion Systems (A3PS)

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A3PS – Austrian Association for Advanced Propulsion Systems

- **A3PS – strategic public- private partnership (PPP)** initiated by the Austrian Ministry for Transport, Innovation and Technology (bmvit) as platform for **strategic cooperation** with **industry** and **research institutions** beyond just funding single R&D-projects

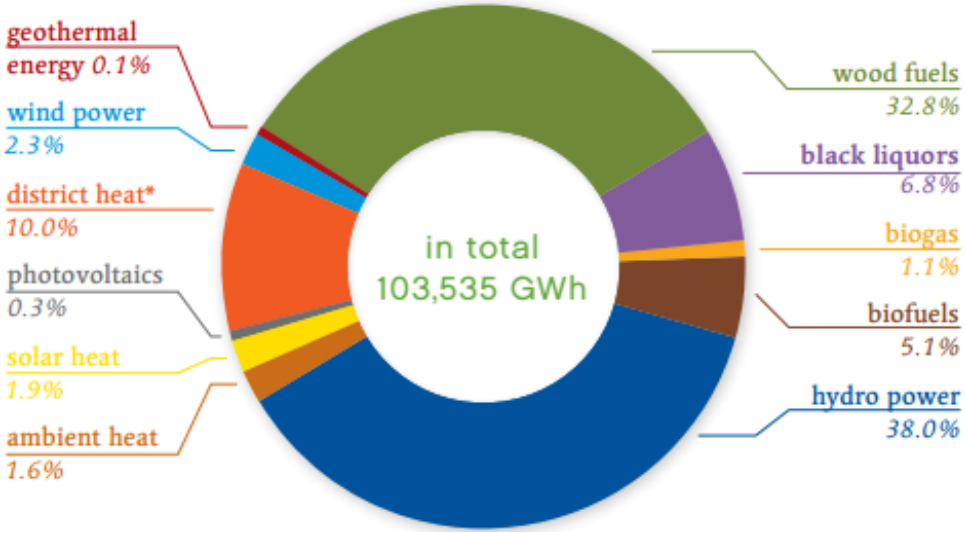
- Targeted platform with the common goal to support the development and market introduction of **advanced propulsion systems and fuels** and the joint mission to develop efficient, competitive and clean vehicles as well as their energy carriers and infrastructure

- Main goal: **strategic cooperation** between **industry, research institutions, public administration** and **policy makers** developing a **joint vision** and **roadmaps** for its **implementation**

Austrian Energy & Automotive Sector

- **Key facts:**
  - Area of 83,859 km² with 8.5 million inhabitants
  - 4.6 million passenger vehicles

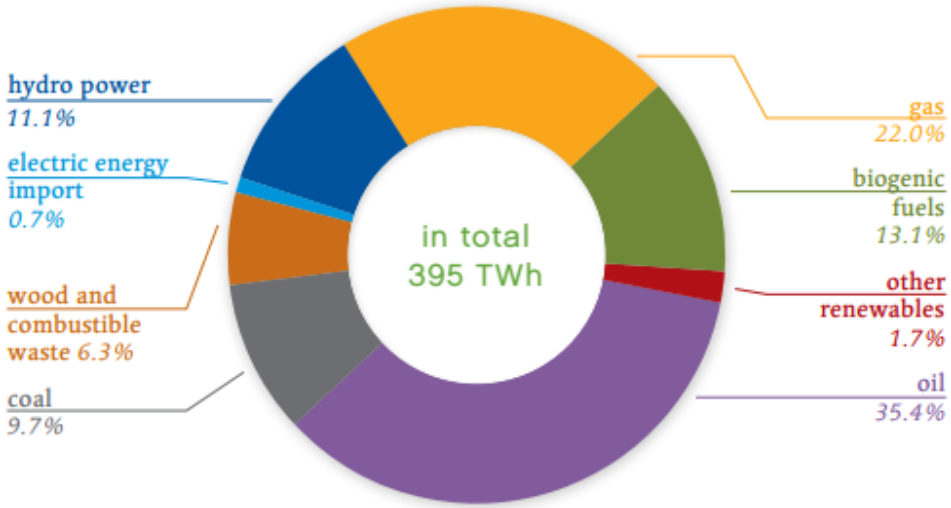
Final energy consumption provided by renewable energy



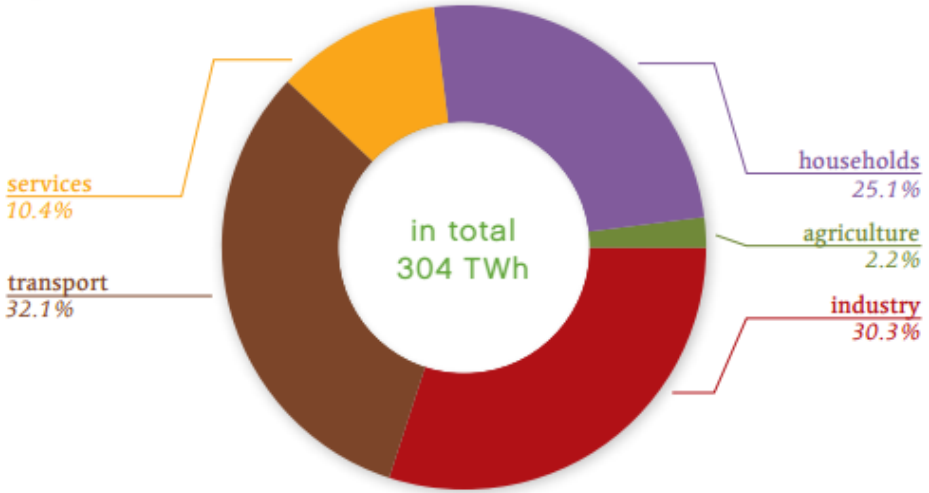
SHARE OF RENEWABLE ENERGY IN AUSTRIA	*percent*
Total share of renewables	32.2%
Share of renewable electricity	65.3%
Share of renewable district heat	45.0%
Share of renewables in transportation	6.6%
Share of other renewables	29.6%

Austrian Energy & Automotive Sector

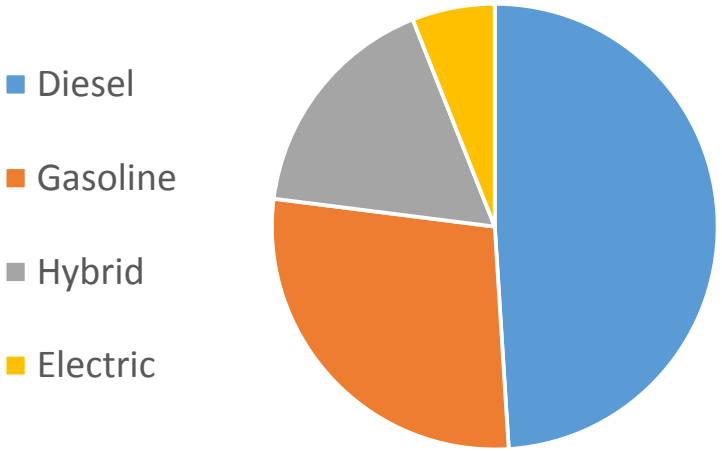
Gross domestic consumption by energy source



Final energy consumption by sector

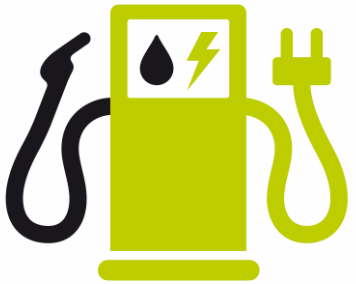


- **Preferences for buying a new car:**
  - Diesel: 49% (52% in 2013)
  - Gasoline: 28% (31% in 2013)
  - Hybrid: 17% (15% in 2013)
  - Electric: 6% (2% in 2013)

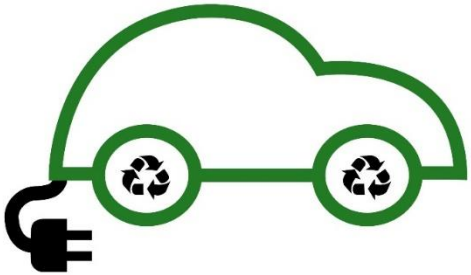


Source: GENERALI- AUTOSTUDIE 2014

Austrian Transport Sector - Vehicles



- **Fleet total*:**
  - Total: 6.4 million
  - Passenger vehicles: 4.7 million
  - EVs (passenger): 3,038
  - HEVs (passenger): 12,194
  - FCVs: 1



- **Total sales during 2014**:**
  - Total: 315,372 (-4.0% to 2013)
  - Passenger vehicles: 237,363 (-4.3% to 2013)
  - EVs (passenger): 1,036 (**+113.4%** to 2013)
  - HEVs (passenger): 1,952 (-7.7% to 2013)
  - FCVs: 1 (+100% to 2013)

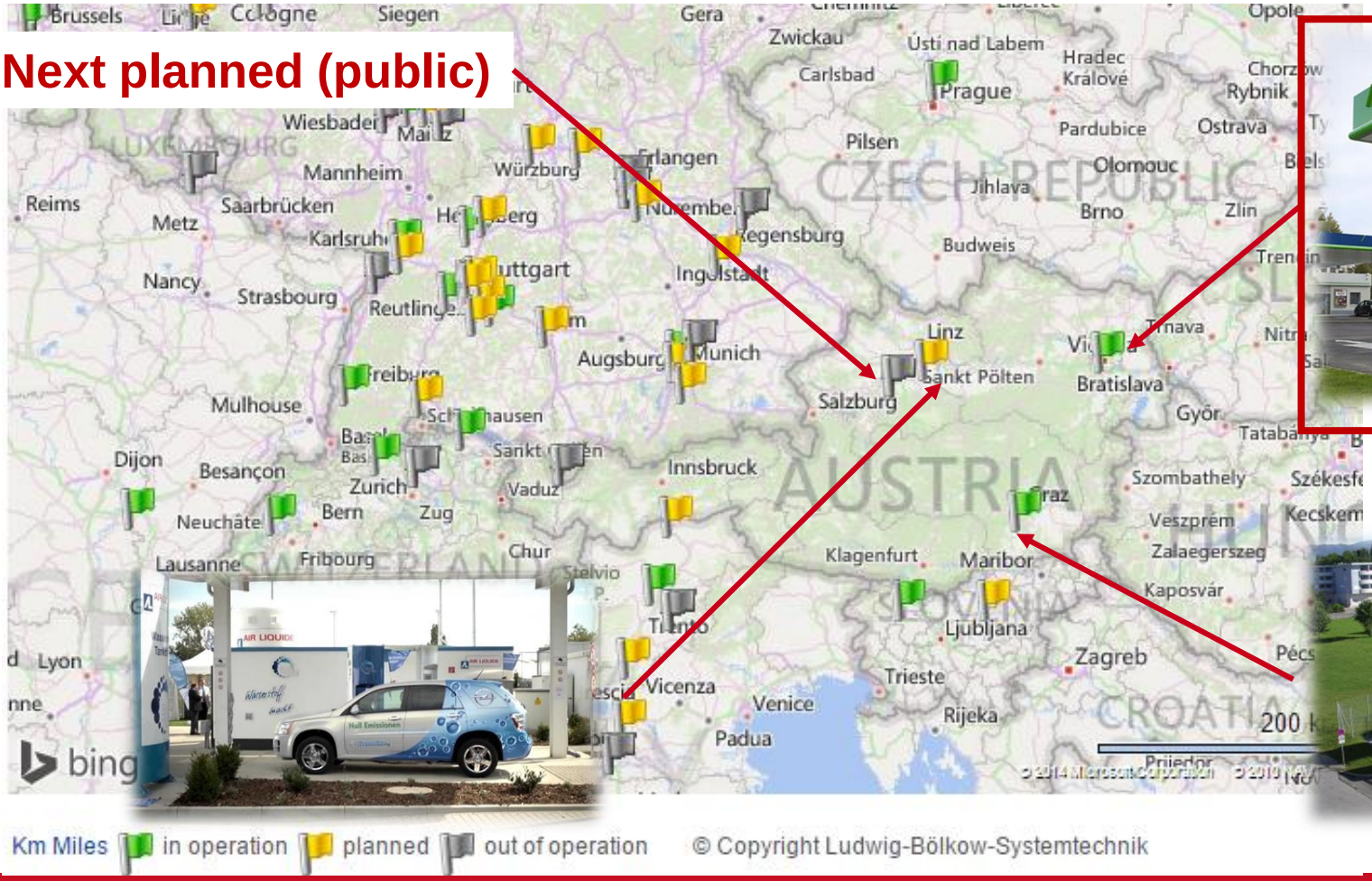
Trend towards e-mobility

* As per End of September 2014

** January till October 2014

Austrian Transport Sector - H_2 - Infrastructure

- Only one public filling H_2-station in Austria (www.h2stations.org)



Hydrogen and Fuel Cells as Key Technologies for Austria

- High potential in Austria to use renewable energy *(35% as per end of 2013 in AUT)* for energy production; energy storage and in mobility

- Strong automotive supply industry with focus on propulsion systems - Automotive sector: 200,000 employees (mainly in the production of drive trains) and a production volume of EUR 21.5 billion (in 2013)

- Austrian industry and research institutions are highly qualified in the field of hydrogen and fuel cells

- All fuel cell and hydrogen components and systems are covered in research and industry

Hydrogen and Fuel Cells as Key Technologies for Austria

Special expertise exists in:

- Hydrogen tank systems (cryogenic and high pressure from Magna for BMW and Daimler and for space applications)
- SOFC-components and systems (Plansee for Bloom Energy, APU from AVL, TU Vienna and Leoben for SOFC-research,..)
- Engineering, development tools & test bench from AVL (PEM/ SOFC)
- Green hydrogen production from biogenic feedstock as well as photovoltaics (Güssing, Profactor, Joanneum, TU Vienna, Fronius)
- Hydrogen refilling stations (in Graz with additional R&D-facilities, in Vienna from OMV building up network to neighboring countries)

FCH- Cluster Austria

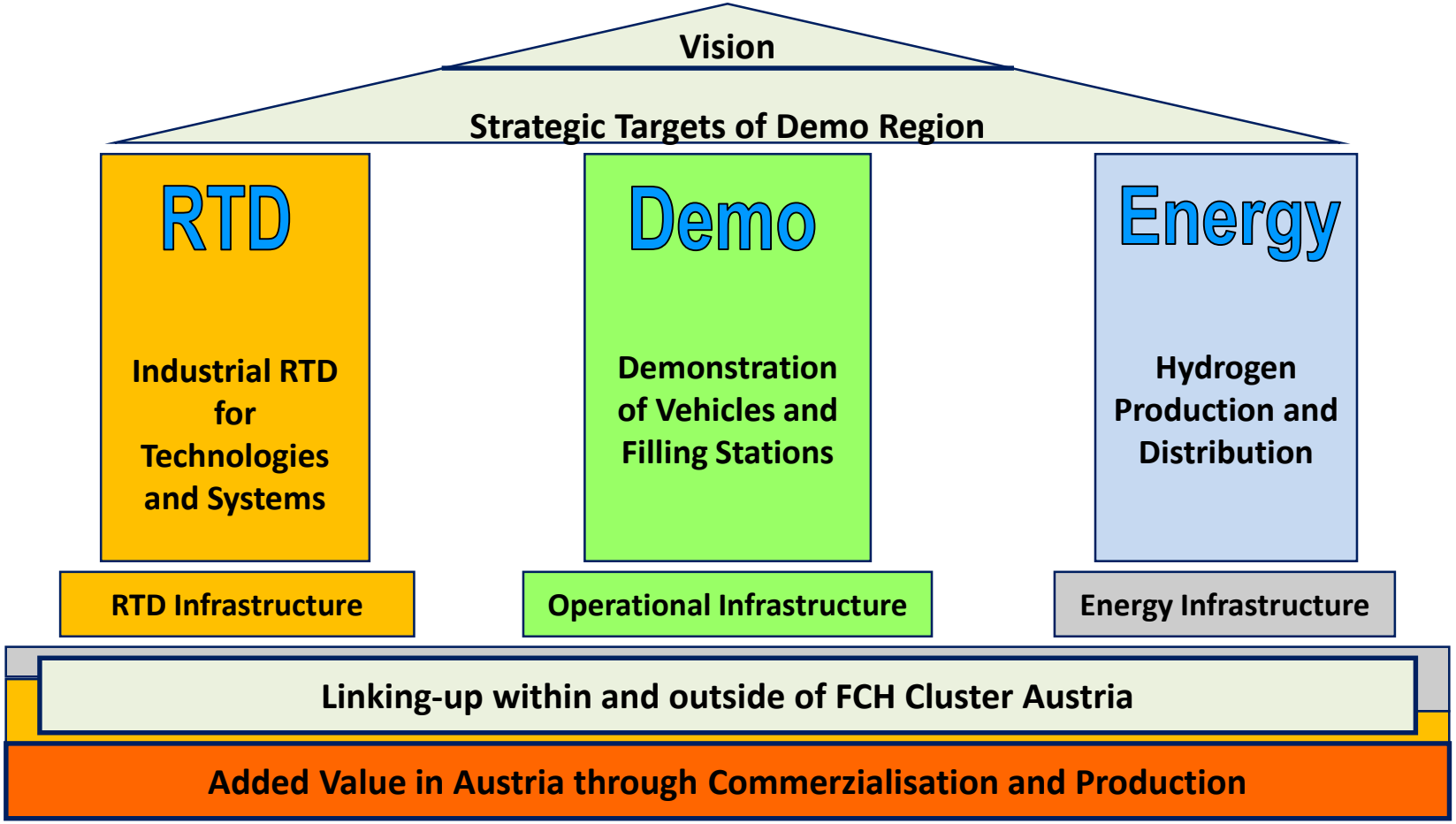
In order to concentrate and to coordinate the Austrian knowledge and competence in the field of Fuel Cells and Hydrogen the FCH- Cluster Austria was initialized in 2013 and is coordinated by the A3PS

Strategic cooperation between industry, public authorities and research institutions

Hydrogen and Fuel Cells as Key Technologies for Austria

FCH- Cluster Austria - Vision

Austria as capable supplier and internationally acknowledged partner for Fuel Cell & Hydrogen Technology with H_2 - Stations and FC Demo-Vehicles



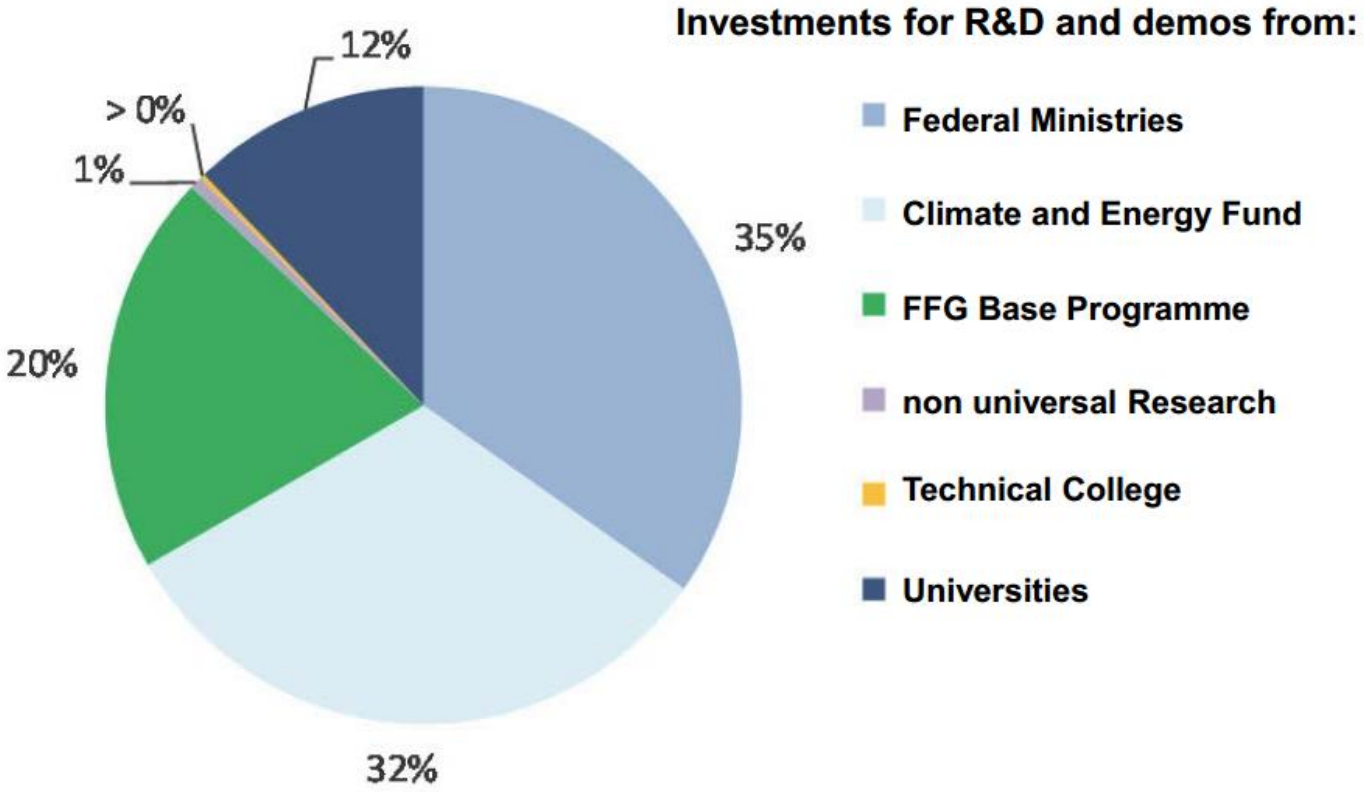
FCH- Cluster Austria: Participants

FCH- Cluster Austria: Research Activities

Examples of Research Topics

- Materials, components and auxiliaries for Fuel Cell Systems
- Functional, harmonized and integrated development of fuel cell and hydrogen technologies
- Safety concepts for hydrogen (storage) systems
- Hydrogen distribution for R&D and demos
- Techniques of measurement and testing for development of fuel cell and hydrogen systems
- Functional integration of fuel cell components
- System integration of fuel cell and hydrogen components
- Vehicle integration

Austrian Players financing FCH- R&D and demos



* FFG (Austrian Research Promotion Agency)

Policy Framework: R&D- Funding Programs

R&D- Funding Program "Mobility of the Future"

- Program running from: 2012 – 2020
- Thematic Field: "Transport Technologies"

- **Research Areas:**
  - Development of alternative drives and fuels for all vehicle classes
  - Liquid and gaseous alternative fuels
  - E/E Architecture
  - Lightweight components and vehicles

Policy Framework: Funding of FCH- projects

R&D-Funding Program "Mobility of the Future"

- Call 2012: Budget 10.3 Mio EUR with 3.6 Mio. EUR focus on FCH
- Call 2013: Budget 6.75 Mio. EUR with 4 Mio. EUR focus on FCH
- Last Call 2014 (Fall 2014 to spring 2015):
  Budget 10.9 Mio. EUR with 6 Mio. EUR / $ 8.2 Mio. only for FCH-projects
  Projects in the following areas are funded:
  - fuel cell components and systems
  - production of hydrogen for mobile applications
  - hydrogen storage technologies in vehicles and at filling stations
  - hydrogen fueling infrastructure for vehicles
  - distribution of hydrogen for mobile applications
  - system and vehicle integration

Overview about recent FCH- projects in Austria

E-LOG BioFleet (2010 - 2014)

- Replacement of industrial trucks battery by a fuel cell range extender (PEM) and a 200 bar hydrogen storage system

- Onsite hydrogen production from biomethane

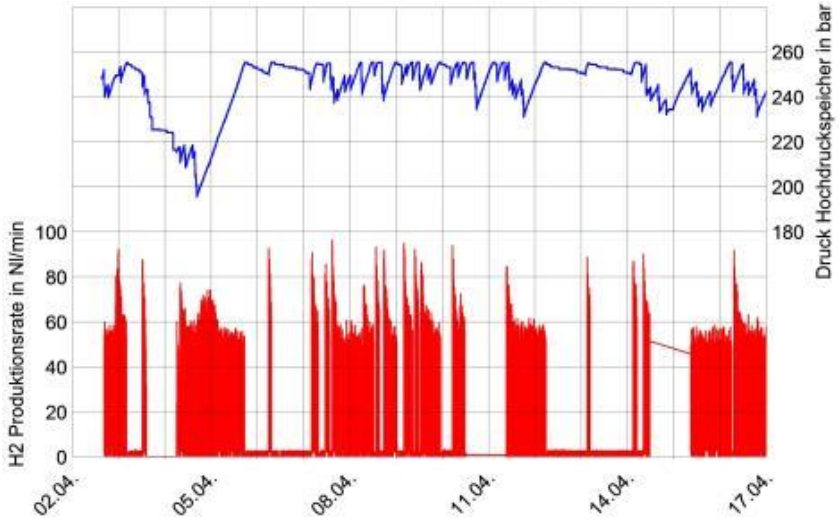
- Europe‘s first hydrogen indoor refilling infrastructure

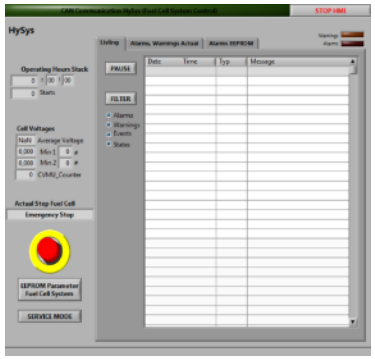
JOANNEUM RESEARCH OMV Fronius Linde Material Handling Linde DB SCHENKER

Project E-LOG BioFleet II (2014 – 2016)

Scientific project contents:

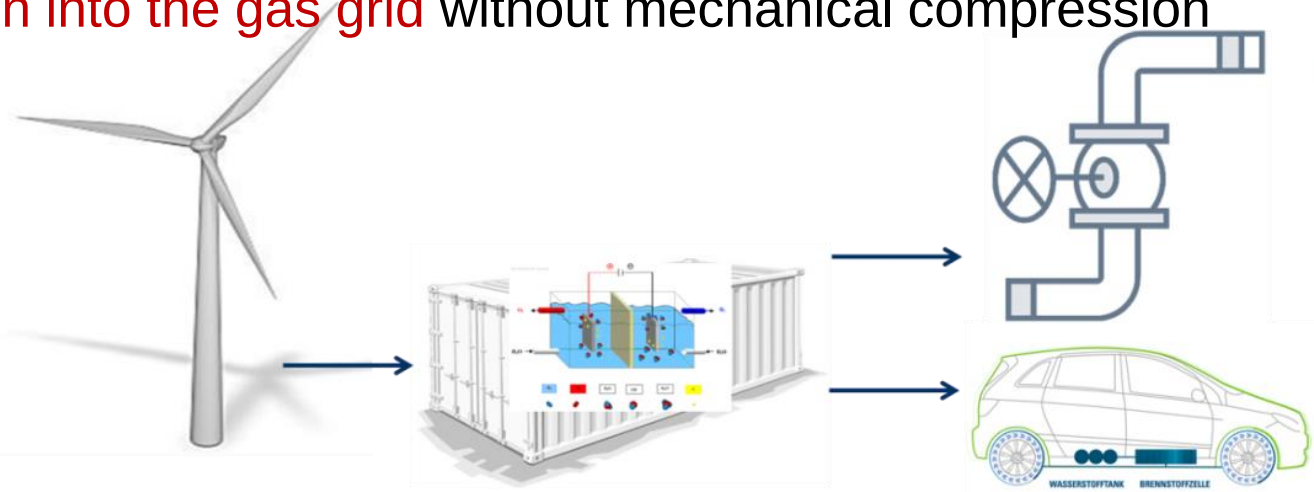
- Monitoring and optimization of the fuel cell battery hybrid system
- Monitoring and optimization of the onsite hydrogen infrastructure
- Maintenance and service requirements under real-life operating conditions and advanced system lifetime
- User research and evaluation of demonstration





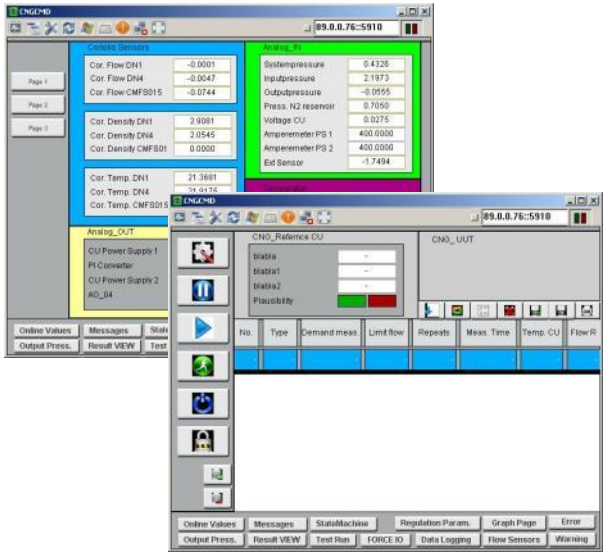
Project w2h - Wind2Hydrogen (2014 – 2016)

- Storage of volatile, renewable electricity by production of hydrogen
- Installation of a 100 kW pilot plant
- Development of innovative high pressure PEM-electrolyser 150 – 300 bar
- Production of hydrogen for sustainable mobility and injection into the gas grid without mechanical compression



Project FCH Media (2014 – 2016)

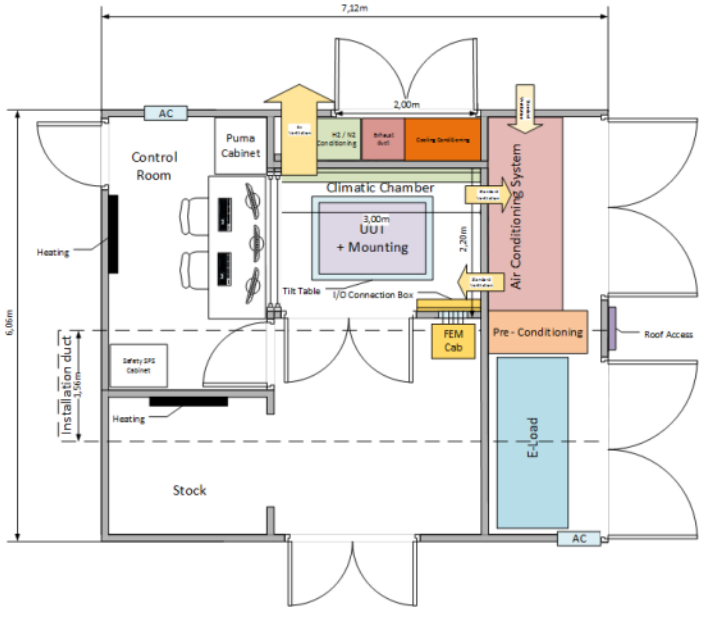
- Research on instrumentation and actuation of fuel cell test benches, focused on high dynamic conditioning of hydrogen and air as well as dynamic flow measurement principles including appropriate calibration techniques.

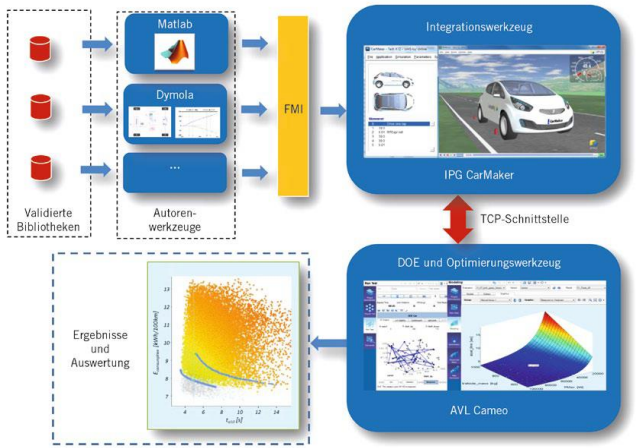


Project HIFAI – RSA (2014 – 2017)

Highly Integrated Fuel Cell Analysis Infrastructure

- System integration test bench for scientific research on PEM fuel cell systems up to 100 kW
- Hardware in the Loop, real time simulation of vehicle, driver, and driving cycle
- Continuous tool chain for optimization of application concepts by combining simulation, optimization and test bed tools

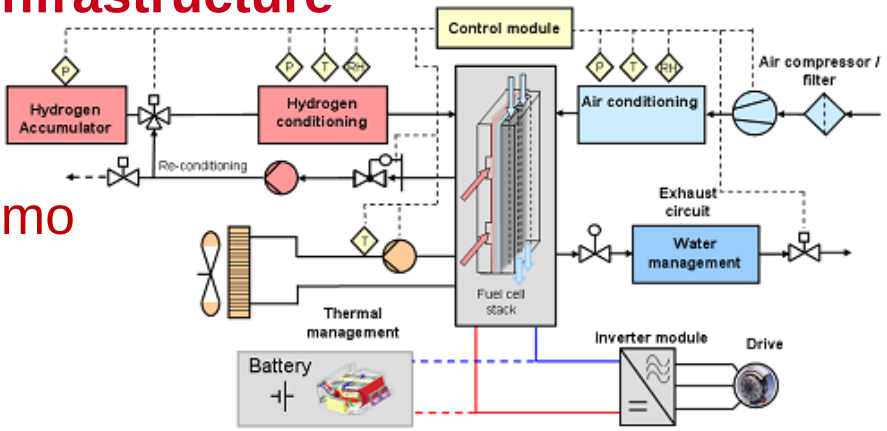


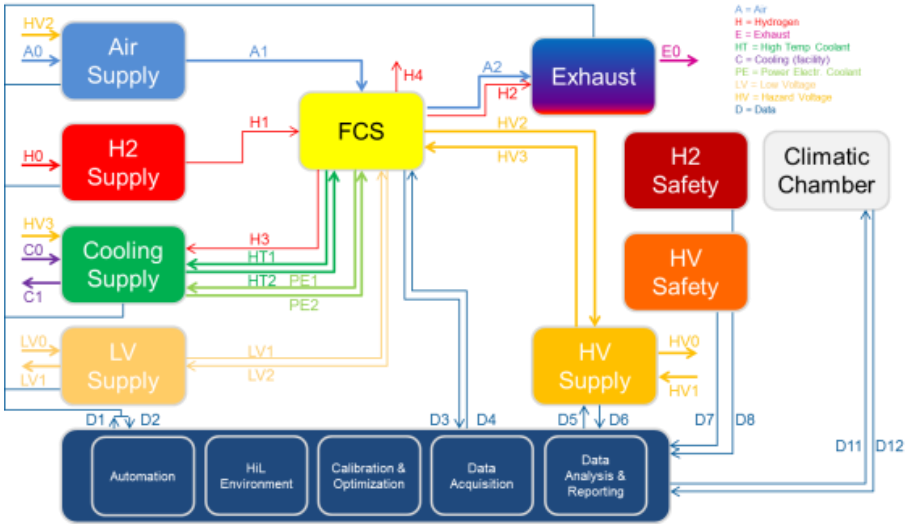


Project HIFAI – RSA (2014 – 2017)

Highly Integrated Fuel Cell Analysis Infrastructure

- Research topics:
  - Optimization of energy and thermo management
  - Accelerated aging tests procedures
  - Improved cold start behavior
  - System configuration and integration for stationary and mobile applications
  - Improved energy efficiency of entire test bed





Strategy: HyCentA

First Austrian research center for hydrogen with test stands and filling facility since 2005

- Testing activities with customer-specific hydrogen test setups with electronic process control
- Thermodynamic analysis of hydrogen processes and systems
- Economical and ecological analysis of hydrogen processes and systems
- Expertise in questions of safety, standards and regulations of hydrogen processes and systems
- Scientific research, lecturing and publications

Project HyCentA 2.0

- **HyCentA 2.0** with Austrian as well as international partners serves as a focus for comprehensive research and development activities for all aspects of hydrogen economy.
- Targetoption 1: COMET K1 Centre for Hydrogen
- Targetoption 2: Christian Doppler Labor „Thermodynamics of Hydrogen“
- Targetoption 3: TU Graz Foundation Institute for „Hydrogen Economy“

From prototype to serial production - Linde starts small-series production for hydrogen fuelling stations

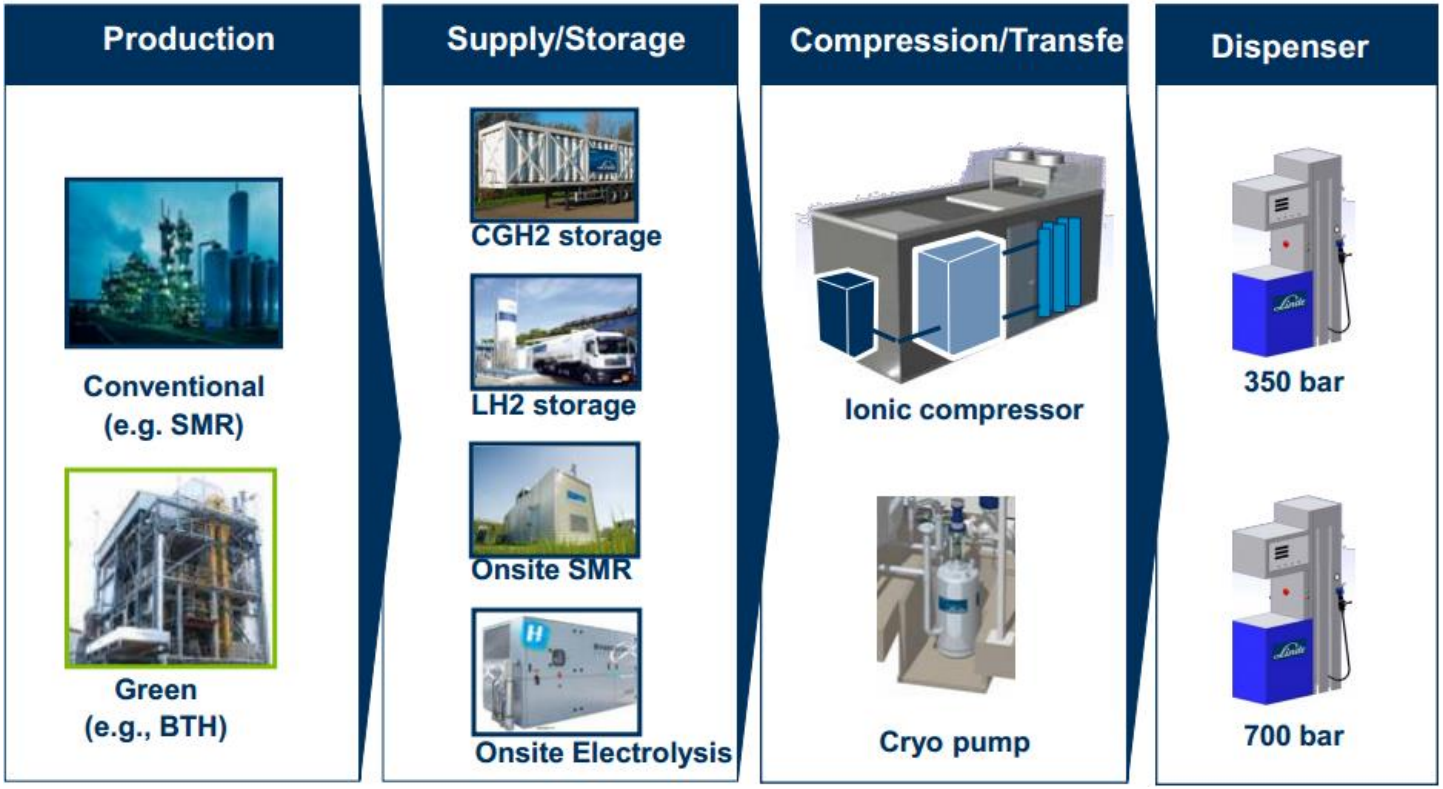
Progress in Hydrogen fuelling station technology development

- World's first small-series production facility for hydrogen-fueling stations in Vienna
- The expansion of production capacity in Vienna to 50 units a year dovetails with the introduction of the first series-produced fuel-cell cars by leading manufacturers between 2014 and 2017
- Standard agreement closed with Iwatani Corporation (Japan) for delivery of 28 units
- Technology leadership through innovative ionic compressor

THE LINDE GROUP

Hydrogen fuelling station – Linde Group

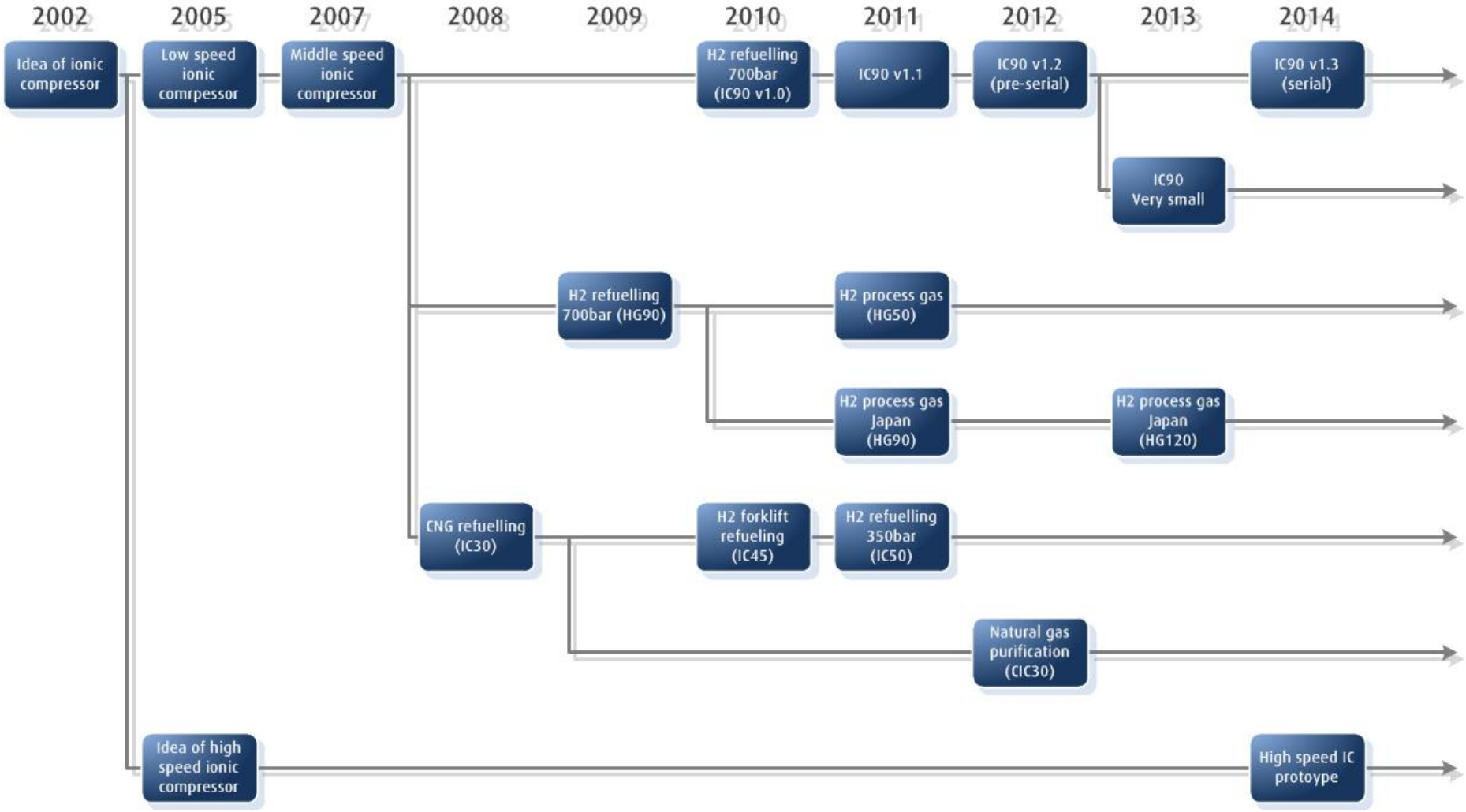
- The Linde Group is the world's largest industrial gas company by market share as well as revenue.
- Linde covers the entire hydrogen value chain



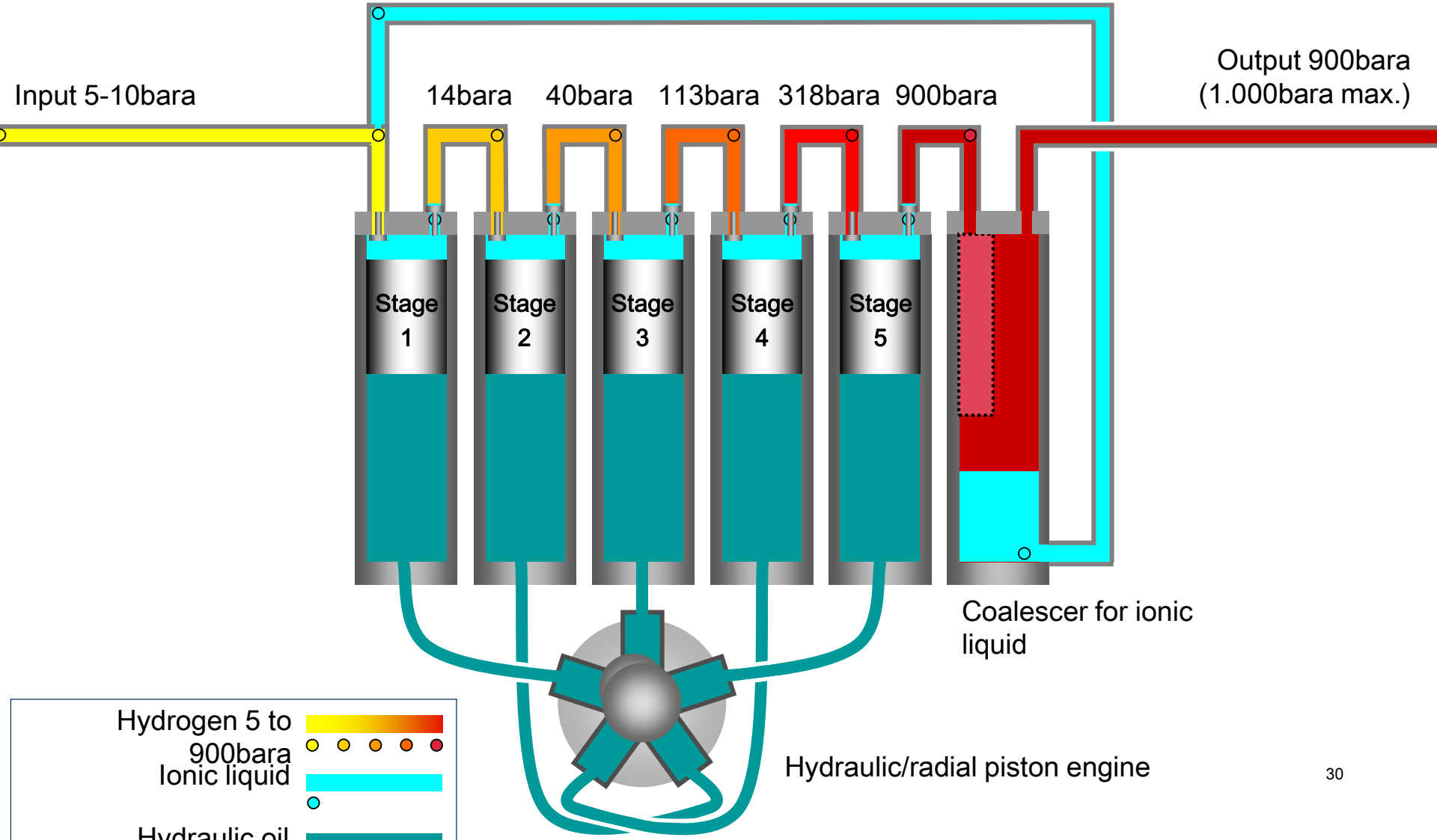
Linde Vienna – Application Technology Center (ATC)

- The Linde Vienna – Application Technology Center (ATC) develops and brings breakthrough innovations to market in a unique collaboration with internal and external customers.
- The ATC is renowned as a world leading competence center for advanced hydrogen & CNG fuelling and for its thermodynamic- and compression solutions
- Since 2012 the ATC has had a department that deals with production transfer into serial and the related small serial production
- ATC projects: >120 H_2 compressors and over 380 compressors for other gases like CNG, Ar or N2 worldwide
- ATC was extensively modernized and expanded specifically for the small-series production facility

Hydrogen fuelling station – technology development

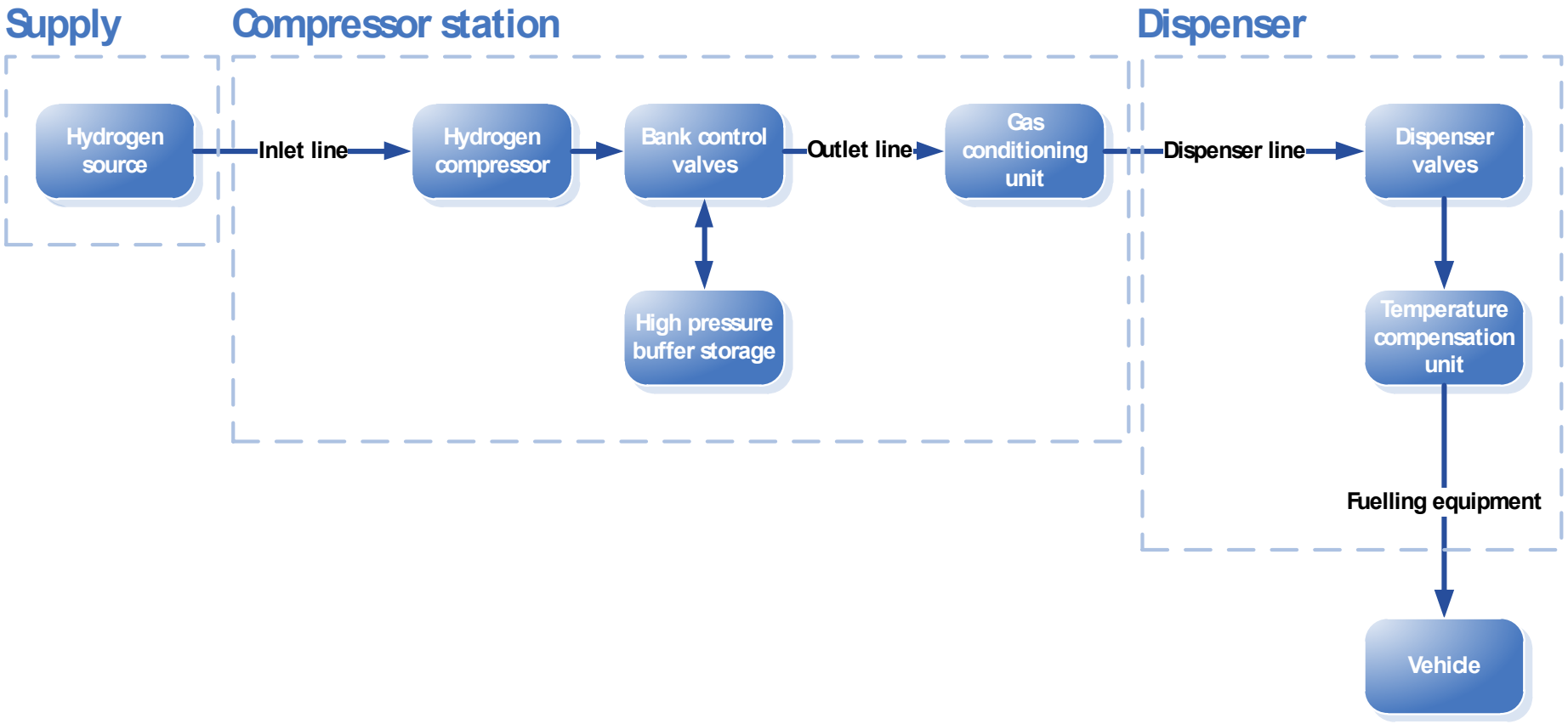


Ionic compressor 90MPa - IC90 (functionality)

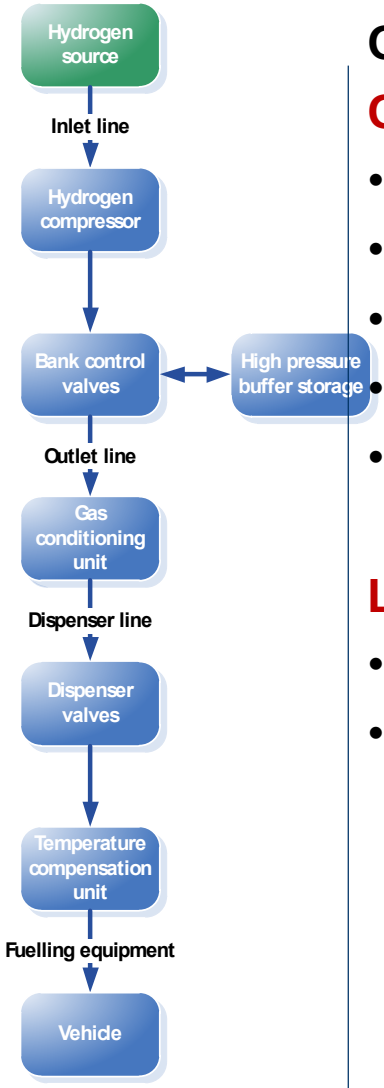


Hydrogen refuelling system – Linde Group

Layout – 700bar hydrogen filling with compressor overview



Basic layout - Hydrogen source



Options:

Gaseous supply

- Onsite 45bar standard tank
- Onsite 200bar/200kg tubes (Fig. 1)
- GH2 trailer supply (Fig. 2)
- Onsite steam reformer
- Onsite electrolyser

Liquid supply

- Liquid tank
- LH2 trailer supply

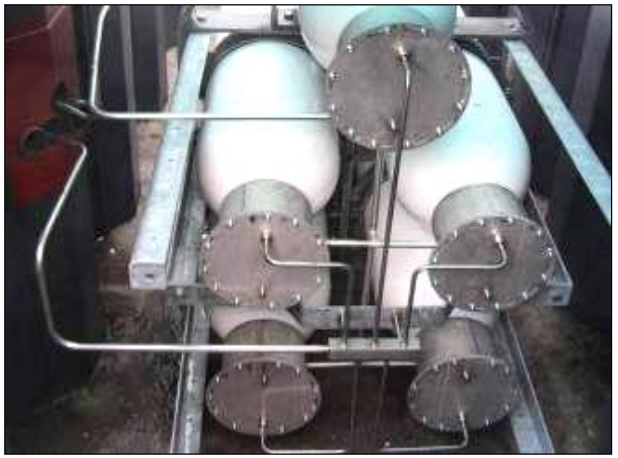
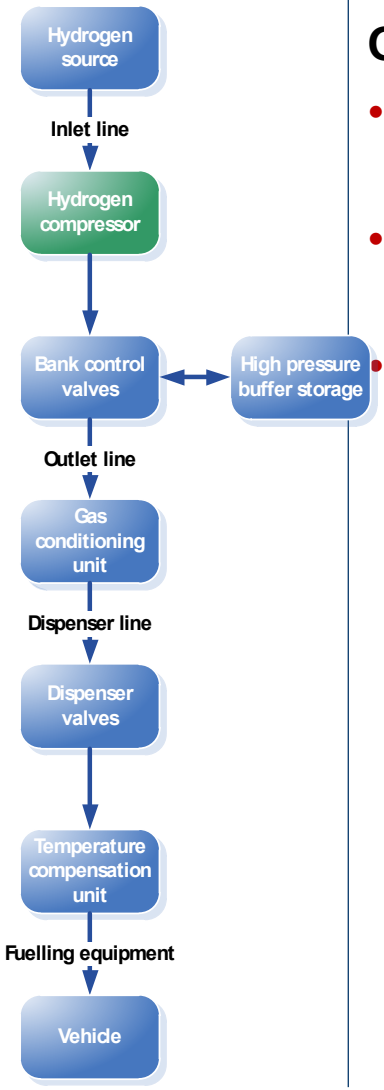


Fig. 1: 200bar tubes with caps for underground installation

Fig. 2: 200bar trailer (Type T 7228 – 38m³)

Basic layout - Hydrogen compressor



Options:

- **Very small:** Downsized IC90 (Fig. 1)
- **Small:** 1 standard IC90 in one standard container (Fig. 2)
- **Medium:** 2 standard IC90s in one standard container (Fig. 3)

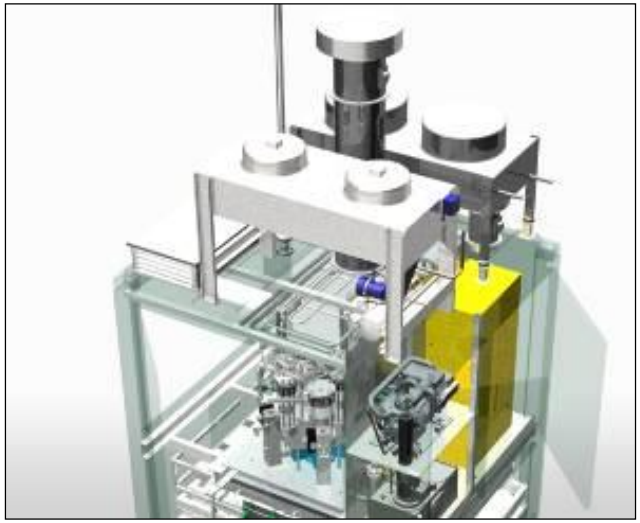


Fig. 1: IC90 very small

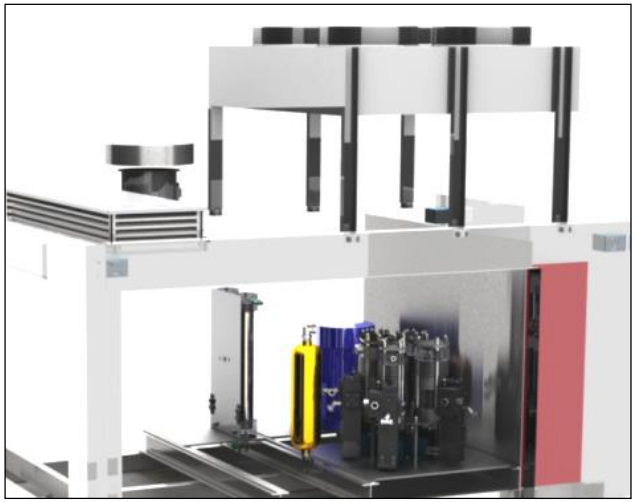


Fig. 2: IC90 small

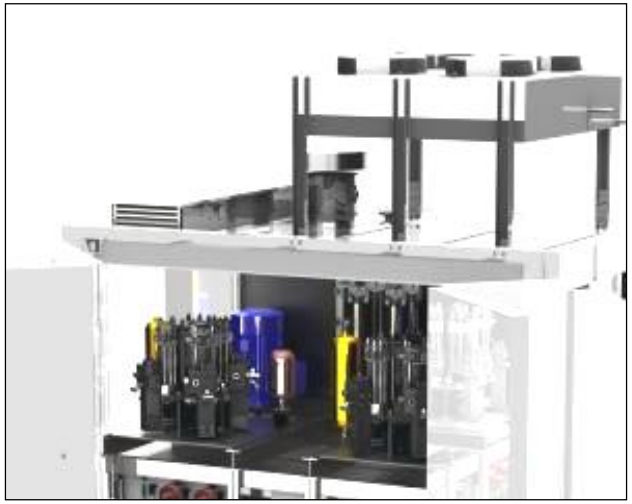
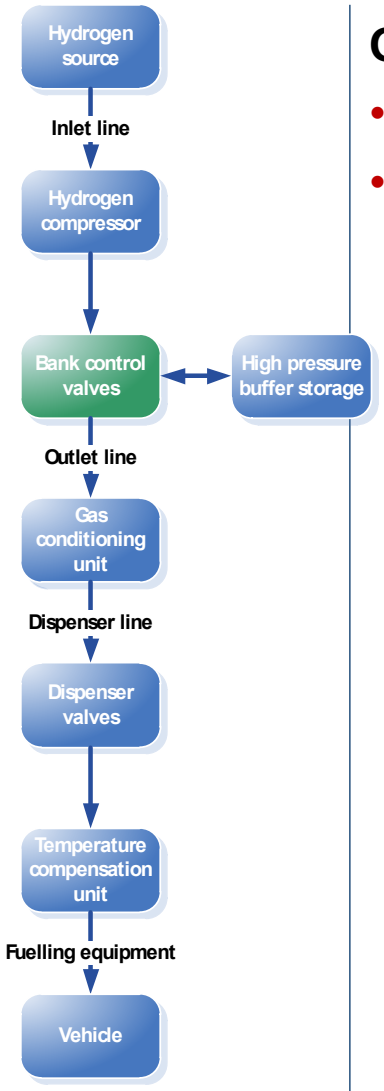


Fig. 3: IC90 medium

Basic layout - Bank control valves



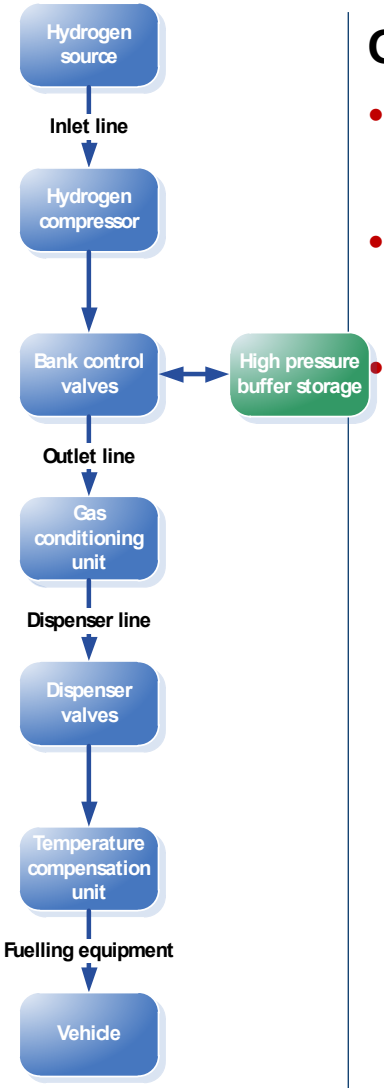
Options:

- Modular 3 Bank block for one dispenser line (Fig. 1)
- Modular 3 Bank block for two dispenser lines (Fig. 2)

Fig. 1: 3 Bank block for one dispenser line

Fig. 2: Bank block for two dispenser lines

Basic layout - High pressure storage



Options:

- **Modules of 5 or 8 cylinders** for 1000bar (Fig. 1)
- **Up to 26 cylinders** in one standard IC90 container (Fig. 2)
- **External bundle container**

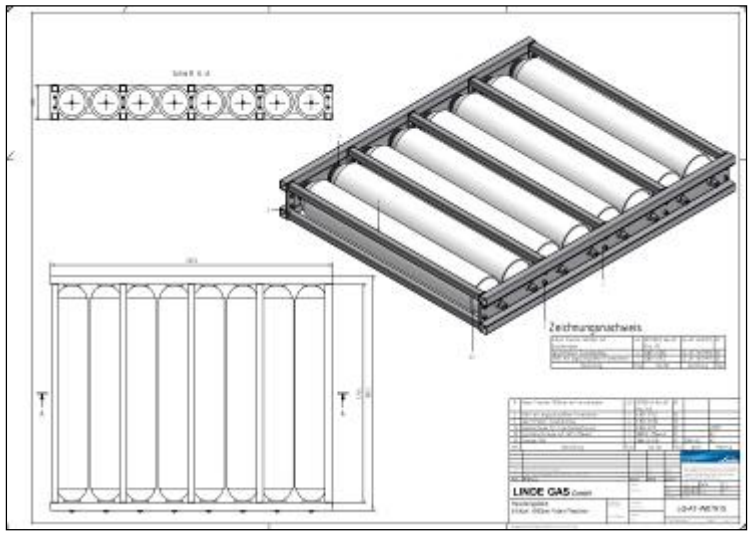
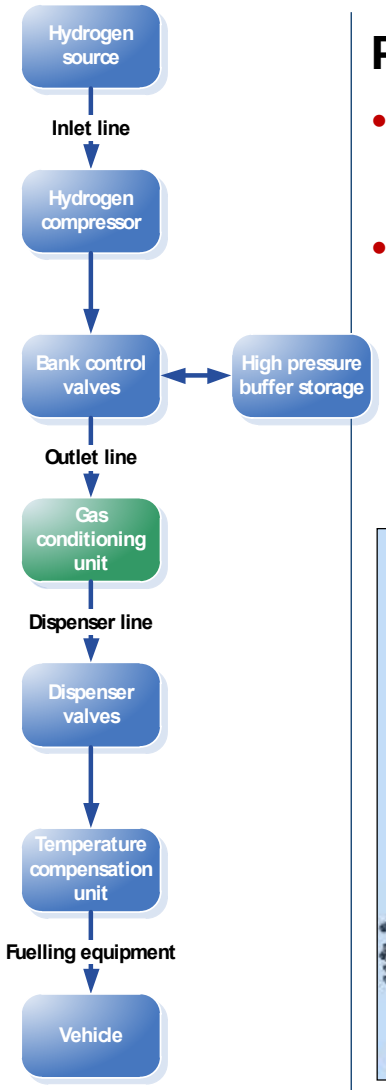


Fig. 1: Bundle for 8 bottles

Fig. 2: Installed bottles – EU standard station

Basic layout - Gas conditioning unit (Cold Fill)



Patented layout:

- **Standard cooling unit** with option for temperature compensation unit (Fig. 2)
- **Maintenance free solid cold** accumulator (Aluminium) with several heat exchanger lines (Fig. 1)

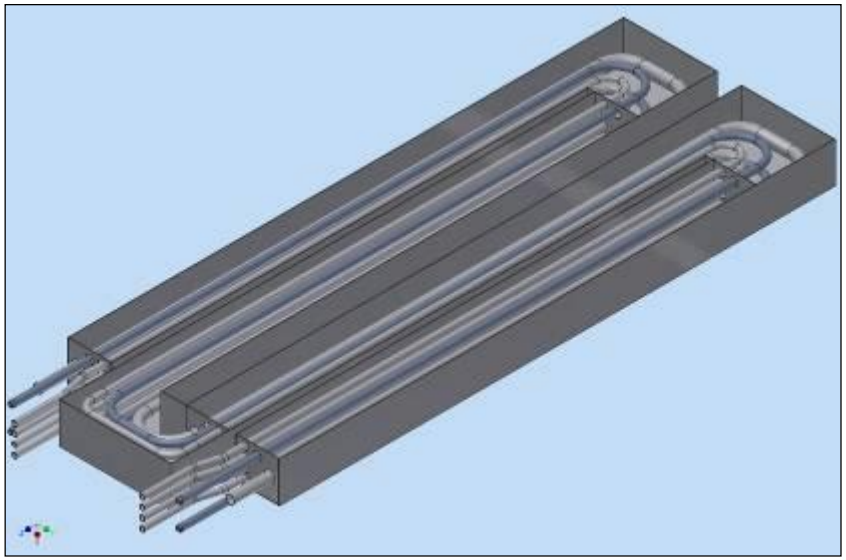
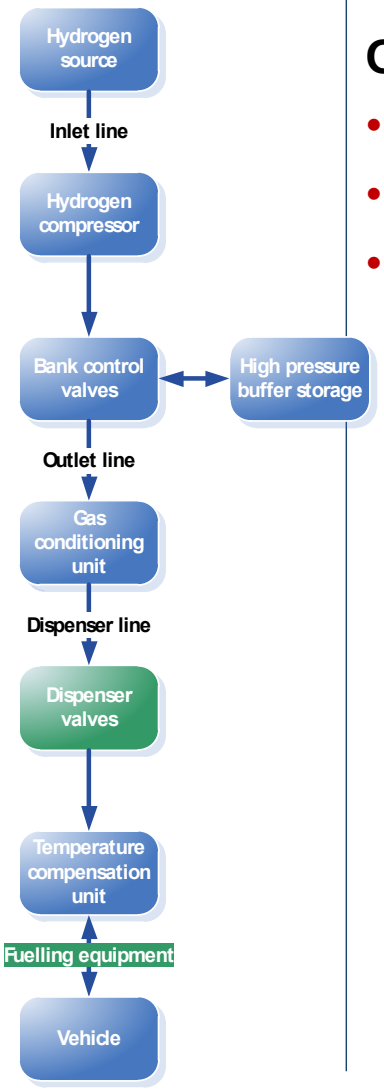


Fig. 1: Solid coldfill heat exchanger module (w.o. Aluminium)

Fig. 2: Standard cooling unit

Basic layout - Dispenser



Options:

- **Dispenser: 1 hose** – 700bar (Fig. 1)
- **Dispenser: 2 hoses** – 700bar (Fig. 2)
- **Dispenser: 1 hose – 700bar; 1 hose – 350bar**

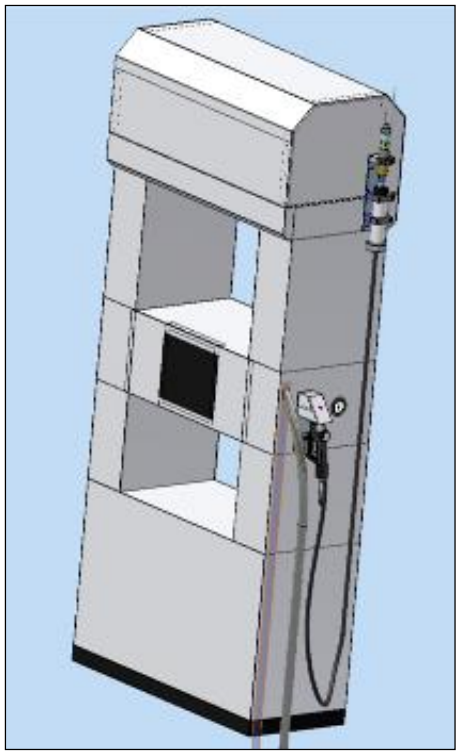


Fig. 1: Dispenser 1 hose-700bar

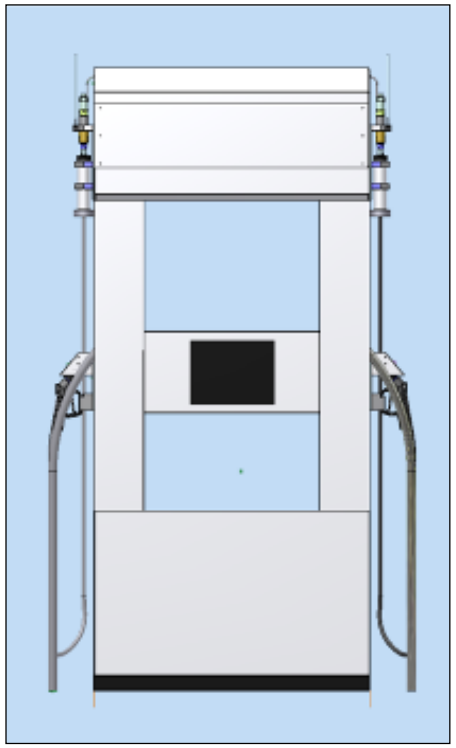
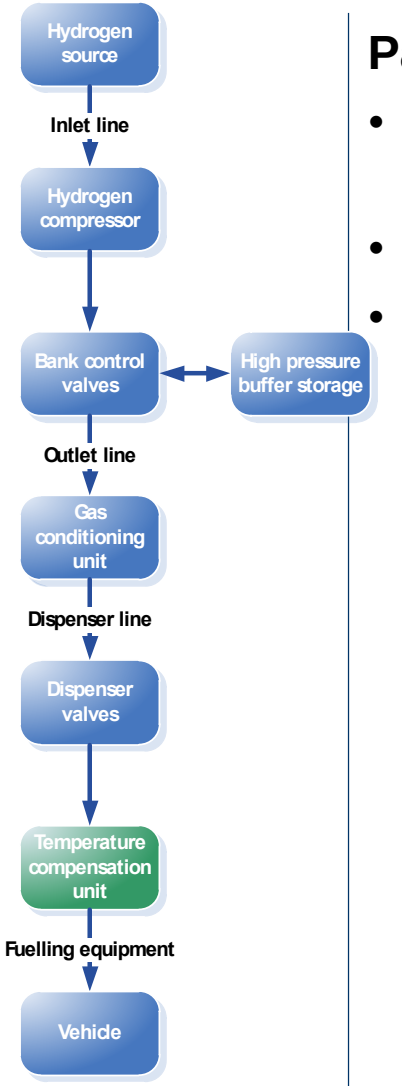


Fig. 2: Dispenser 2 hoses-700bar

Basic layout - Temperature compensation unit (TCU)



Patented layout:

- Used to compensate the warm dispenser line up to 50m (with standard TCU)
- Supplied by standard cooling unit in container (minimal losses)
- Maintenance free solid cold accumulator (Aluminium) for 1 dispenser line (Fig. 1)

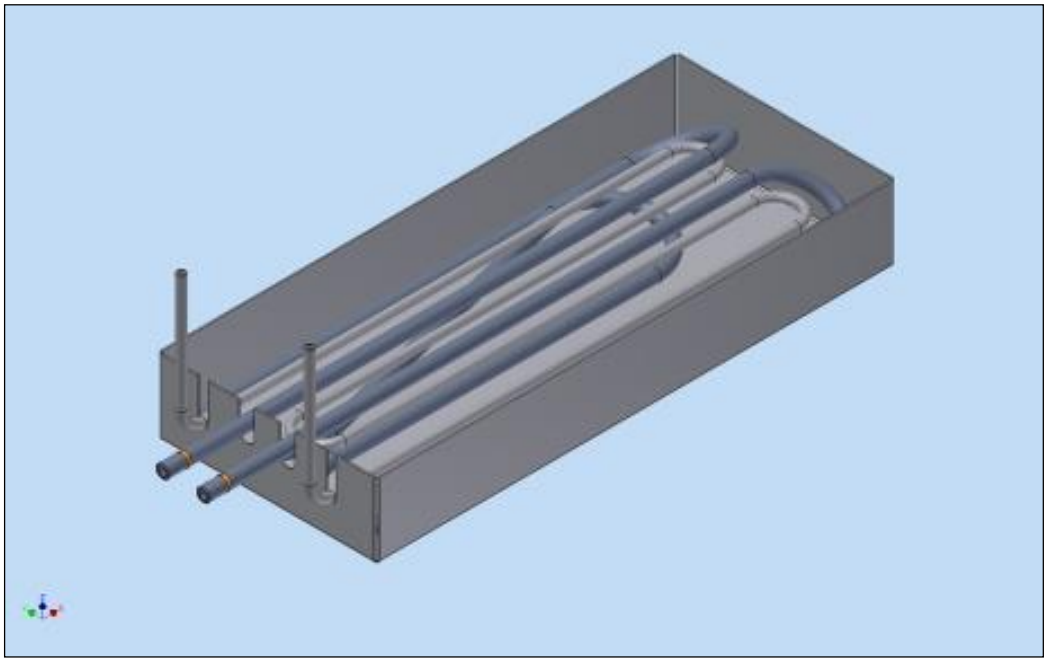


Fig. 1: 3D model - standard TCU (without Aluminium)

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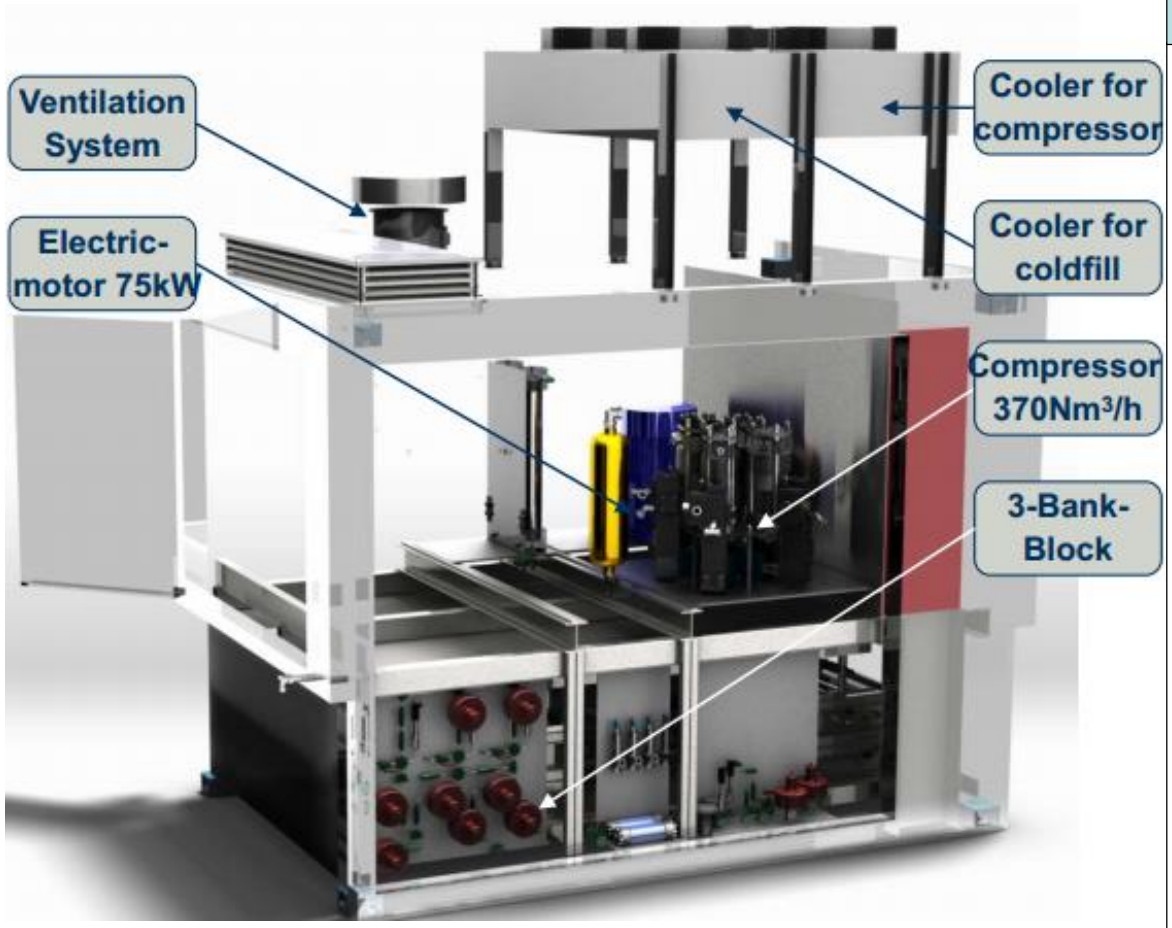
Linde small serial production of hydrogen fuelling stations (overview)

Hydrogen fuelling station for serial production

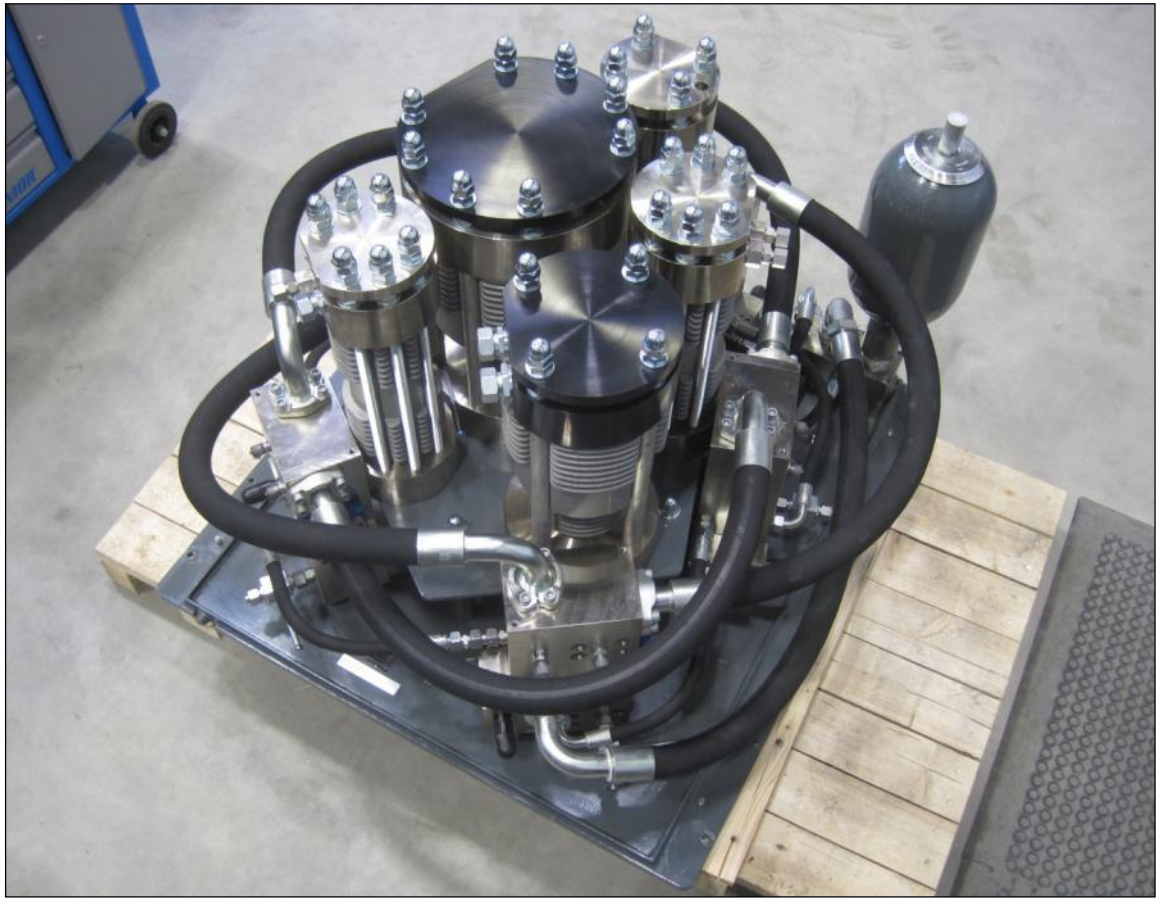


Example: New design of IC90 (US+EU Version)

Layout & performance

- Small footprint: **2,7m x 4,3m**
- Connected load: 105kW
- Compressor type: **Ionic compressor for H2 – IC90**
- Noise emission: <75dB(A)
- Supply: **gaseous or liquid**
- Option for capacity upgrade (**33,6kg/h => 67,2kg/h**)
- Fuelling protocol: **SAE J2601-A70**
- Same container for **US** and **EU** model

Ionic compressor 90Mpa - “IC90”



Ionic compressor 90MPa – IC90

Performance

- Ionic compressor for H2
- **5-stage** compression
- Stage compression ratio: **1:2,8**
- Max. delivery rate: **370Nm3/h ~ 33,6kg/h**
- Min. input: **5bara**
- Max. output: **1.000bar**
- Power consumption at 5bara inlet pressure: **75kW**
- Stroke frequency: **5,8Hz**
- **Specific energy consumption: 2,7kWh/kg H2** (= energy saving of around 40%)[1]

•1 compared to conventional dry running piston compressor for 90MPa

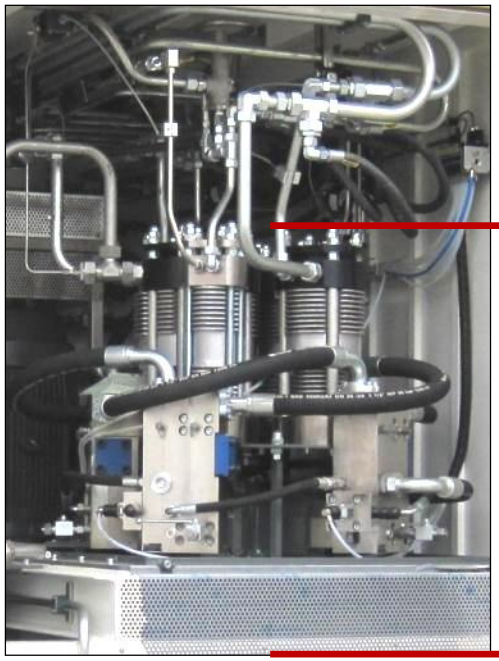
Benchmark - Hydrogen compressor of competitor and Linde IC90

Hydrogen compressor of competitor

- Manufacturer: ---
- Technology: 4-stage piston compressor
- Delivery rate: **100 Nm³/h**
- Max. outlet: **440bar**
- Inlet range: **4 – 7bar**

•VS.

Linde ionic compressor – IC90



- Manufacturer: Linde Gas – Austria
- Technology: 5-stage ionic compressor
- Delivery rate: **370 Nm³/h**
- Max. outlet: **900bar**
- Inlet range: **3,3 – 200bar**

Small serial production of hydrogen fuelling stations

Work shop and assembly area


Ware house


EU station at test facility

Overview and Outlook

Actual[1]:

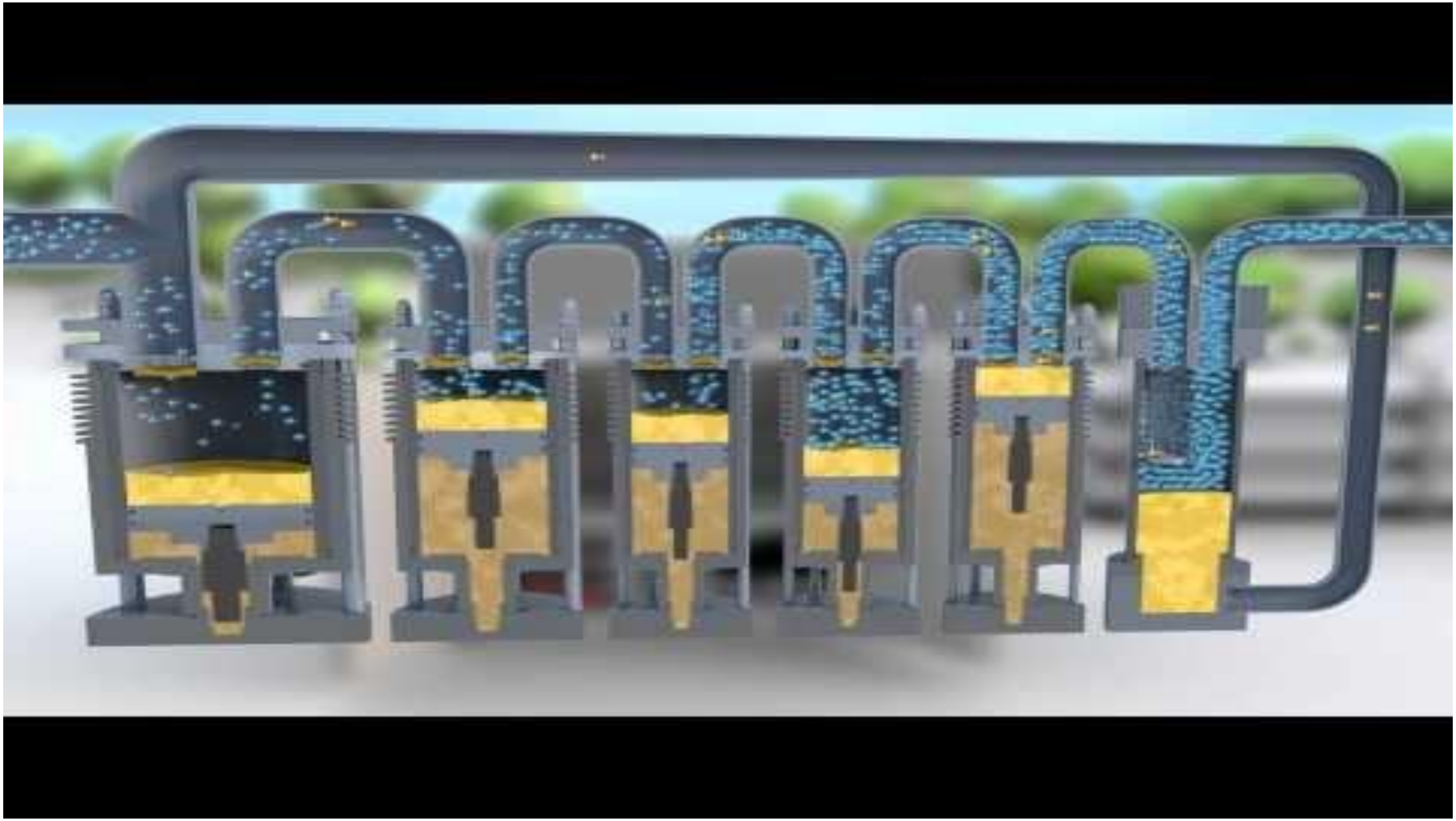
- Capacity: 50 stations/a
- Avg. lead time: 8 months
- Testing capacity: 2 boxes on test stand for testing activities

Outlook[1]:

- Capacity: 100 stations/a (second shift)
- Avg. lead time: 5 months
- Testing capacity: 4 boxes on test stand

•1 based on EU stations with similar scope of supply

Demonstration video



Conclusion

- Trend towards Eco-mobility in Austria
- OEMs have announced the launch of FCV in Austria for end of 2015
- Roadmap for infrastructure (today: 1 HRS): 2015 (3 HRS); 2020 (15 HRS); 2030 (100 HRS)

- FCH- Cluster Austria in order to concentrate and to coordinate the Austrian knowledge and competence in the field of FCH
- Special expertise exists in: hydrogen tank systems (cryogenic and high pressure) & SOFC-components and systems

- R&D-Funding Program “Mobility of the Future” with a specific focus on FCH-projects: 2014/2015 (€ 6 Mio. / $ 8.2 Mio.) - First Call focusing only on FCH

Thank you for your attention!

Questions?

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