Hydrogen Storage Systems

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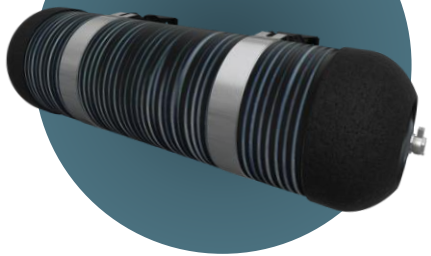
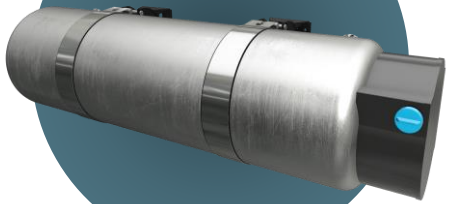
Available Technologies

Compressed



- Passenger Cars
- Heavy duty trucks
- Transportation
- Off highway vehicles
- Aerospace

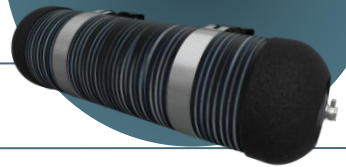
Liquid



- Heavy duty trucks
- Off highway vehicles
- Aerospace

Key Facts

COMPRESSED HYDROGEN STORAGE SYSTEM



Type IV	BASIC DESIGN
-40°C to +85°C	H_2 TEMPERATURE
700 bar (875 bar max.)	H_2 PRESSURE
mechanical stability	MAIN CHALLENGE
tightness	

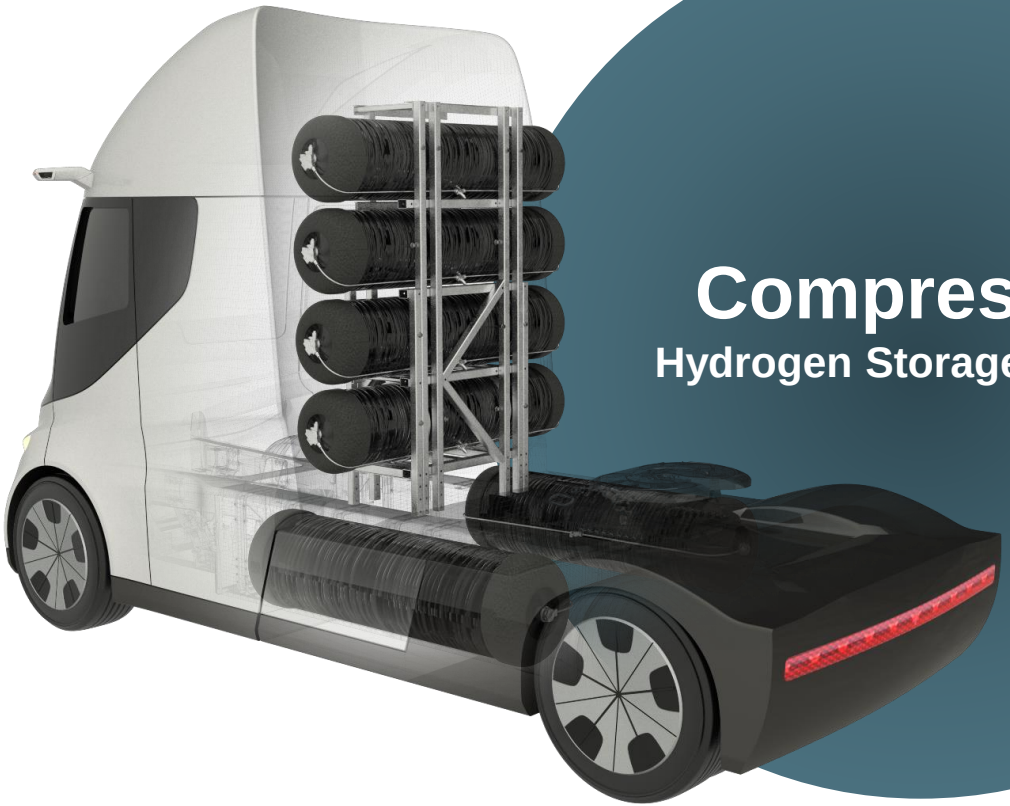
LIQUID HYDROGEN STORAGE SYSTEM

stainless steel
-253°C
7 bar (20 bar max.)
vacuum
insulation

Benefits

COMPRESSED HYDROGEN STORAGE SYSTEM		LIQUID HYDROGEN STORAGE SYSTEM
~2.6 kg / 100L	CAPACITY	~3.6 kg / 100L
no loss	FUEL MASS LOSS	0g up to 160h then 80g/h
~600 km* (FC with 300kW)	RANGE	~900 km* (FC with 300kW)
factor 20 of stainless steel	CO_2 FOOTPRINT	low due to stainless steel
small tanks feasible	DESIGN FLEXIBILITY	large tanks required

*based on legislation for European semi-truck (class 8)

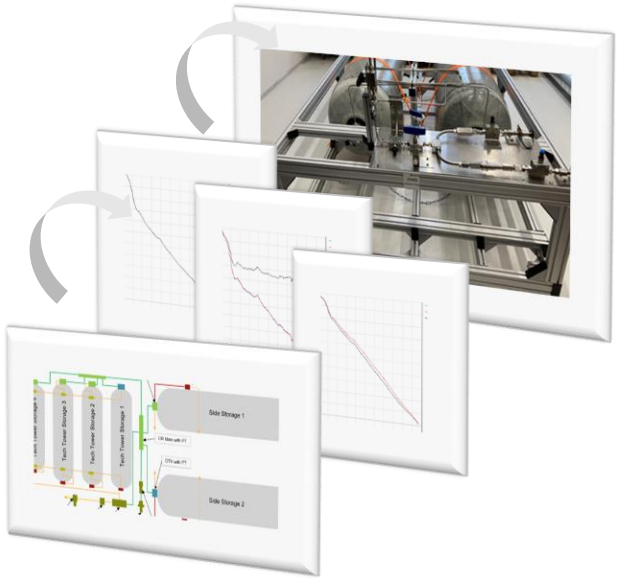


Compressed
Hydrogen Storage System

Challenges

Vessel development

- Virtual development considering boss, liner, composite
- Efficiency decrease of composite at higher thickness
- Sealing concept for low temperature and low pressure



System development

- 1D-Simulation of system performance at high flow refueling
- CFD-Simulation for optimization of valves and pipes
- Validation of simulation with test system (700 bar)

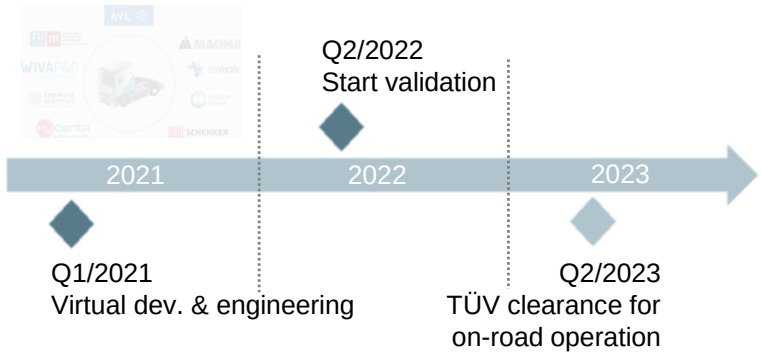
Prototype and Validation

Demonstrator consortium project

- Fuel Cell for Heavy Duty (FC4HD)
- TÜV Certification for on-road operation Q2/2023

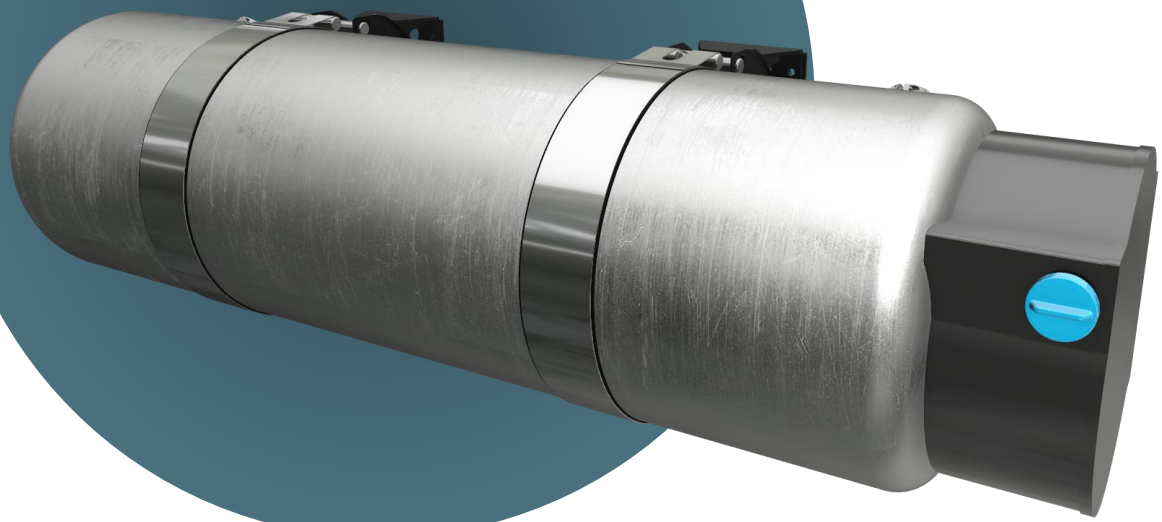
Storage vessels - facts & figures

- Operating pressure: 700 bar
- Dimensions: 613 x 2050 mm
- Weight: 215 kg
- Water volume: 381 L
- Gross capacity: 15.3 kg



Liquid

Hydrogen Storage System



Development focus and Challenges

Development focus

- Improvement of filling capacity
- Improvement of dormancy time > 7 days
- Vacuum generation below 60h
- Improvement of multi-layer-insulation application

Challenges

- Subcooled LHSS for zero loss at refueling
- Suspension and pipe routing for low heat influx
- Cryo-Connection-Line for Dual-Tank refueling
- Boil-Off-Management system

Development focus and Challenges

Development focus

- Improvement of filling capacity
- Improvement of dormancy time > 7 days
- Vacuum generation below 60h
- Improvement of MLI application

Challenges

- Subcooled LHSS for zero loss at refueling
- Suspension and pipe routing for low heat influx
- **Cryo-Connection-Line for Dual-Tank refueling**
- **Boil-Off-Management system**

KEY Technologies

Patent Pending

Cryogenic connection pipe

- Movements of interfaces
- easy mounting/dismounting from tank
- encased for vibration and environment

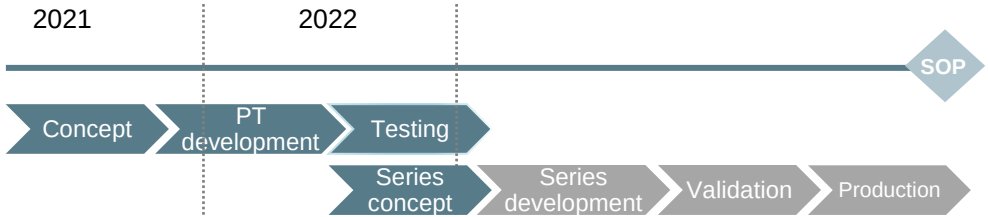
Boil-Off Management System

- fully mechanical system
- negligible H2 emission at -40°C start up
- optimized for dual-tank system

Prototype Development & Testing

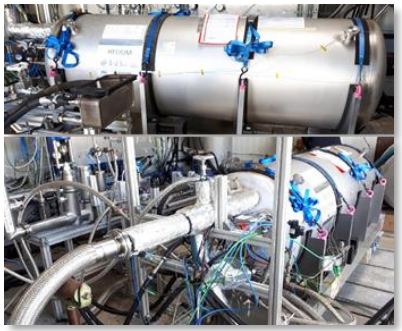
Funded R&D project

- Demonstration of basic vessel functions
  - refuel ✓
  - delivery ✓
  - store & hold ✓
- TÜV Certification for rig testing



Storage vessels - facts & figures

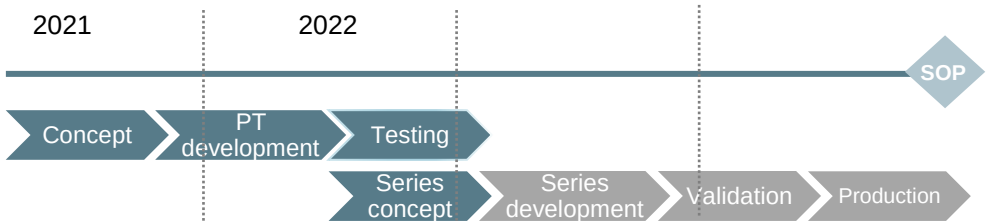
- Dimensions: D: 711mm, L: 2480mm
- Weight: 380kg
- Water volume 620L
- Dormancy time 120h (50% filling level)
- Gross capacity 36kg H_2 (95% and 4bar)



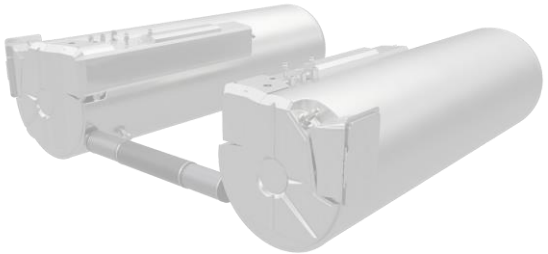
Series Concept

Future customer projects

- Subcooled LHSS for zero loss during refueling
- Cryo-Connection-Line for Dual-Tank refueling
- Boil-Off-Management system
- Suspension and pipe routing for low heat influx



Storage Vessels - Facts & Figures



- Dimensions: D: 711mm, L: 2500mm
- Weight: 480kg
- Water volume: 755L
- Dormancy time: 170h (50% filling level)
- Gross capacity: 45kg H_2 (95% and 4bar) // 90kg per system

Conclusion and Outlook

- **CHSS and LHSS are viable technologies for heavy duty trucks**
- **Deciding factor: availability of infrastructure**
- **Expected SOP of large-scale programs after 2030**