H2 Projects at ZAL

Sebastian Altmann, ZAL

ZAL GmbH Overview

Background

- Founded in 2009 on the initiative of the Free and Hanseatic City of Hamburg (FHH) based on the leading-edge cluster Hamburg Aviation
- Successful Public-Private-Partnership
- Status as an independent small and medium sized enterprise

ZAL TechCenter in Numbers

- Area ~ 34,000 m² (366,000 sq ft)
- Workplaces ~ 850 / 35 partners
- Total investment ~ 145m €

Business Areas

- Research & Technology: Expertise in 8 Technology Fields
- Research Infrastructures: Project Planning, Operational Management & Support
- FoLuHH: Aviation Research Network
- ZAL TechCenter: Rental & Building Operation

Shareholders

20%	Free and Hanseatic City of Hamburg
20%	Airbus
20%	Lufthansa Technik
18%	ZAL Association (SMEs, Supply Chain, Start-ups)
10%	DLR German Aerospace Center
3%	Technical University Hamburg
3%	HAW University for Applied Sciences
3%	Helmut-Schmidt-University
3%	University of Hamburg

ZAL TechCenter Research & Technology under one Roof

ZAL Center of Applied Aeronautical Research

OEMs, Suppliers

AIRBUS
LIEBHERR
DIEHL Aviation
Lufthansa Technik

Technology Partners

Capgemini engineering
DASSAULT SYSTEMES
esploro
RST
FFT
FEV feel evolution
Hamburg Invest
AES
Aviasonic
HYDAC
PRODOSE
HEXCEL
AKKODIS
iDS industrial Design Studio
Boost Aerospace
SFS
SIEMENS

Research Institutes

DLR Deutsches Zentrum für Luft- und Raumfahrt – Institut für Technische Thermodynamik
DLR Institut für Instandhaltung und Modifikation
Fraunhofer IFAM
HAW HAMBURG
DLR Deutsches Zentrum für Luft- und Raumfahrt – Institut für Faserverbund-leichtbau und Adaptronik
DLR Institut für Systemarchitekturen in der Luftfahrt
TUHH Technische Universität Hamburg-Harburg
Helmut Schmidt Universität

Innovation Partners

ZAL GmbH
jetlite
SUSTAINABLE AERO LAB
SYNERGETICON

ZAL TechCenter Event Formats

ZAL Center of Applied Aeronautical Research

Technical Events

ZAL Innovation Days
An annual conference/event to promote innovative ideas, concepts and projects

ZAL Discourse
Expert lectures, panel discussions and networking

X meets Aviation
Finding synergies within Cross-industry in a World Café format

Partners: Marketing, Gaming, Logistics, Start-ups

Radar Group
Scenario development on future topics in the context of open foresight

ZAL Science Slam
Humorous way to present scientific content

General Networking

ZAL Lunch Connection
Lunch, getting to know, networking

ZAL After Work
Casual get-together after work

ZAL Makerspace

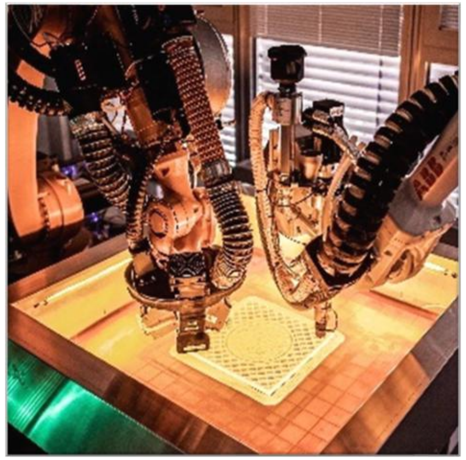
Themed Networking

R&T Hub
Strategic exchange of top management at the aviation location Hamburg

Management Breakfast
Exchange at management level

ZAL as a Service Our Core Competencies Collaboration

ZAL Center of Applied Aeronautical Research



Additive Manufacturing

Data & Processes

Innovation Consulting

Drones & UAV

Intelligent Digital Cabin

Acoustics & Vibration

Robotics & Automation

Fuel Cell & Hydrogen

Reasons for Fuel Cells & Hydrogen

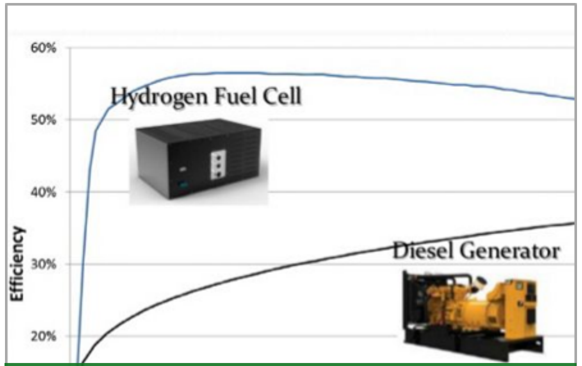
ZAL Center of Applied Aeronautical Research

Goal

Reduce GHG Emission

Goal

Reduce Noise

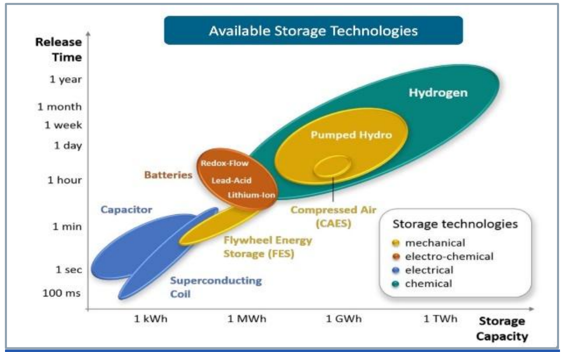


Goal

High Efficiency

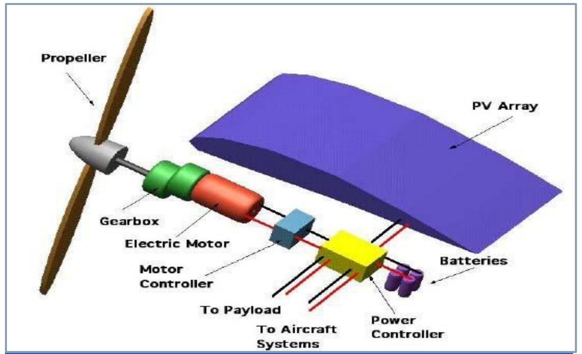
Goal

Urban Air Mobility



Challenge

Energy Storage



Challenge

Propulsion Systems

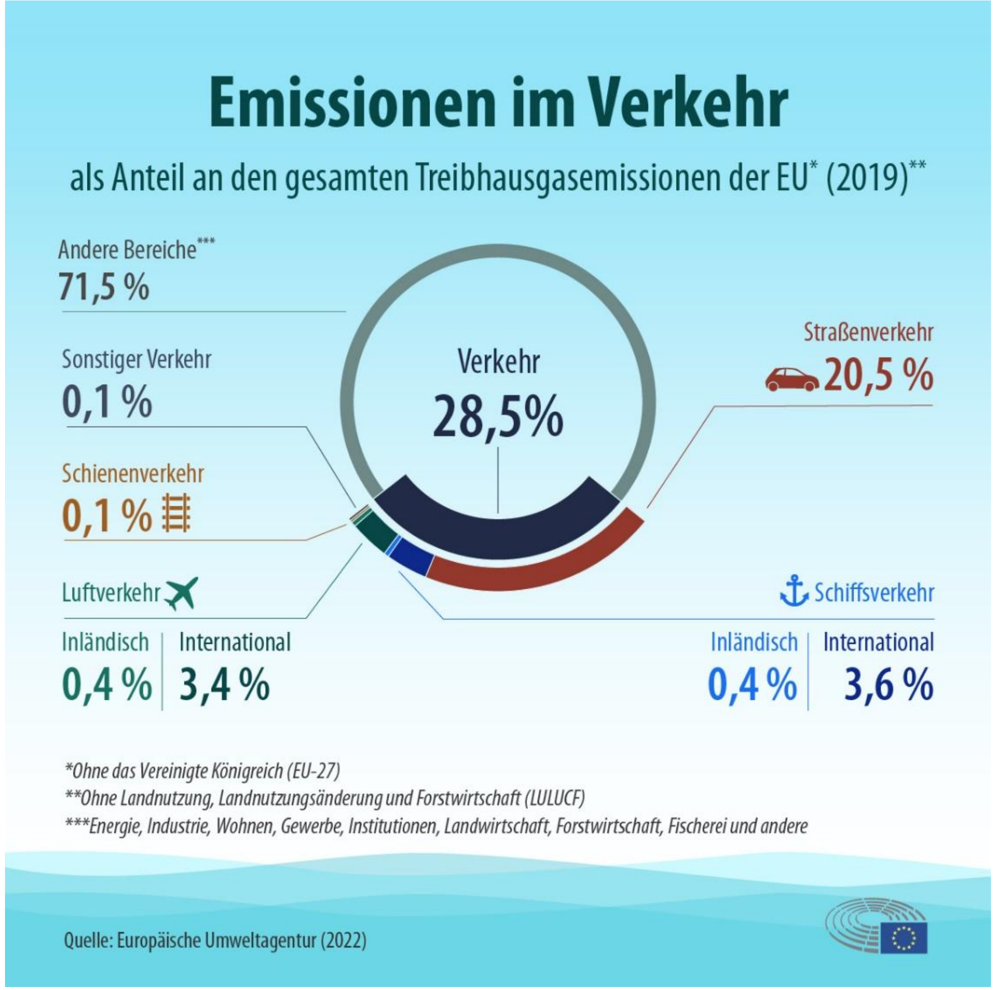
Challenge

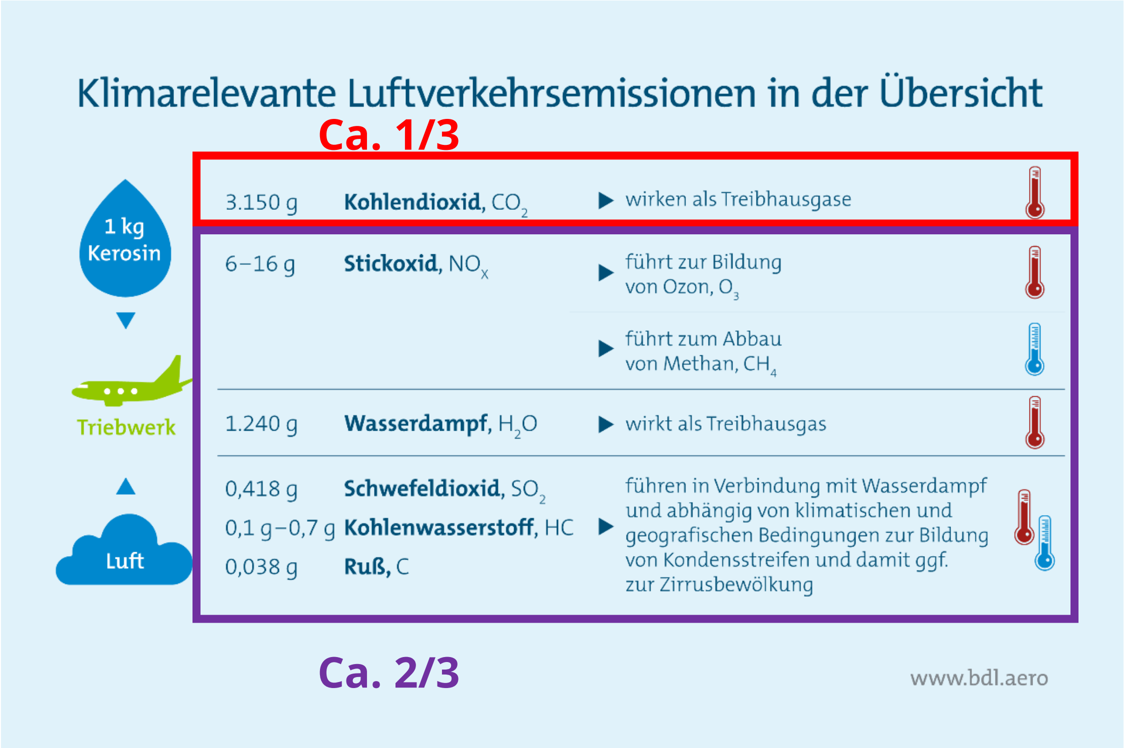
Safety

Challenge

Operation

Aktuelle Situation





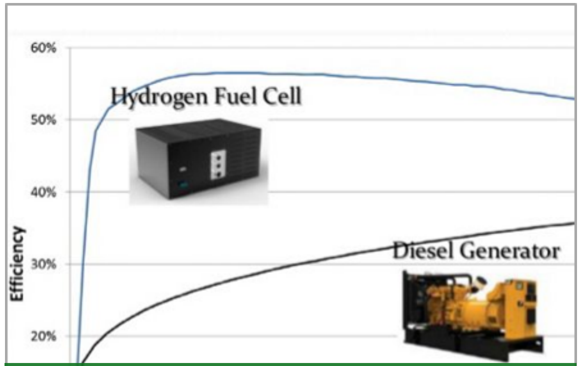
Reasons for Fuel Cells & Hydrogen

Goal

Reduce GHG Emission

Goal

Reduce Noise

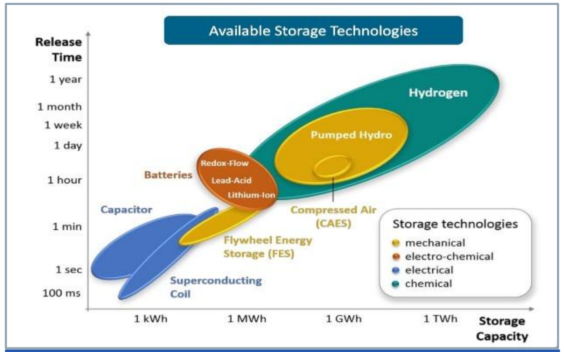


Goal

High Efficiency

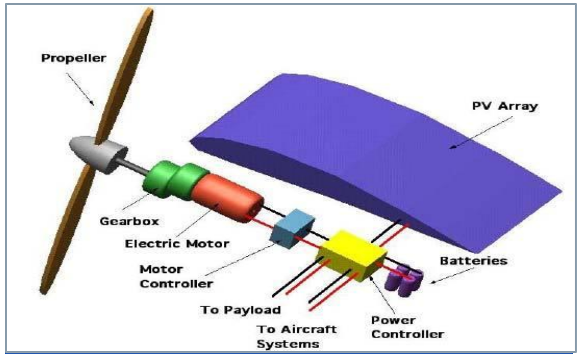
Goal

Urban Air Mobility



Challenge

Energy Storage



Challenge

Propulsion Systems

Challenge

Safety

Challenge

Operation

ZAL Fuel Cell Lab

Applied research on hydrogen has been a pillar of the entity’s setup since its foundation in 2009.

- Ca 3.7M EUR invested in hydrogen infrastructures since 2015
- Eleven laboratories for fuel cell research in the building
- Environmentally friendly energy backfeed into the Hamburg grid
- 20 meter high hydrogen tank with 100 m³ storage capacity

Hanseatic Hydrogen Center for Aviation and Maritime (H2AM)

H2-Testzentrum Bremerhaven für prototypische Anwendungen

- 3D-Teststand zum Testen von Teilsystemen und Systemen im realen Maßstab und standardisierbaren Seegangsbedingungen

LH2-Testzentrum Bremen für Materialen, Komponenten und Teilsysteme

- LH2-Teststand zum Testen und Validieren von Komponenten und (Teil-) Systemen unter cryogenen Bedingungen (LH2)

ITZ Nord Stade – Leichtbaustrukturen für nachhaltige Speicher- und Antriebssysteme in Luft- und Schifffahrt

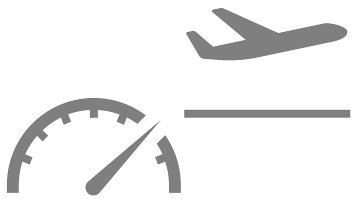
- Entwicklungszentrum für klein- und großvolumige H2-Speicherstrukturen (Ablage, Aushärtung, Montage, Bearbeitung)
- Functional Testing von H2-Leichtbaustrukturen
- Komponentenherstellung
- OpenLab und Protospace
- Business-Support entlang der Wertschöpfungskette

ITZ Nord Hamburg. Entwicklungs- und Testzentrum (Clean Mobility Center)

- Aviation mit Schwerpunkten BZ-Integration, BZ-Einbau, Bodenbetrieb/Betankung und Instandhaltung auf Basis LH2
- Maritim mit Schwerpunkt Systementwicklung und Integration von Brennstoffzellen, Multi Fuel Betankung und Norm- und Regularienentwicklung

ZAL Center of Applied Aeronautical Research

We are planning three activities in the context of research infrastructures:

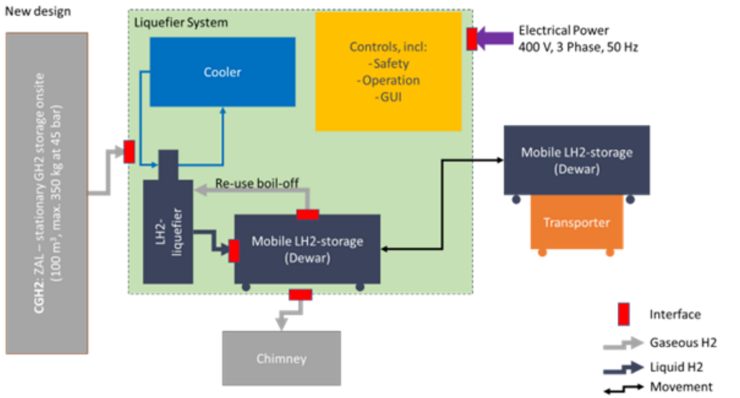


„Altitude Test Bench “

Missionsprofil BeHyPSy

	Flughöhe	Referenzhöhe	Luftdruck	Temperatur	Dauer, ca.	System-Netto-Leistung	BZ-Netto-Leistung
	m	m	mbar	°C	s	kW	kW
Rollen	0	0	1013,25	15	<120	10	10
Startstrecke 15m	15	15	1011,54	14,9	20	70	30
Anfangssteigflug	15...300	150	995,35	14	70	70	30
Steigflug	300...600	450	944,72	12,1	120	50	30
Reiseflug	600	600	944,72	11,1	240+ min	30	30
	1000	1000	898,7	8,5		30	30
	1500	1500	845,5	5,3		30	30
	2000	2000	794,7	2		30	30
	3000	3000	701	-4,5		30	30
Sinkflug	600...300	450	944,72	12,1	155	25	25
Landeanflug	<300	150	995,35	14	<120	10	10
Warteschleife	300	300	977,71	13,1	30 min	30	30

„Cryogenic Test Field “



Building Retrofitting

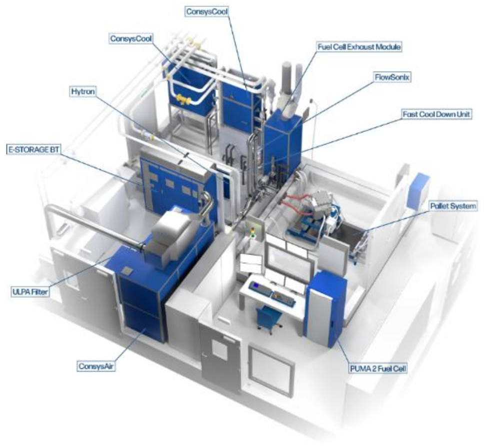
Altitude Test Bench for Fuel Cell Systems

Test Chamber

- Simulating altitudes up to 7600 m / 25.000 ft
- Temperature Range: -40°C to 50°C
- Pressure down to 380 hPa
- Humidity 0 – 100%
- Rate of climb /descent: 2800 / 1700 ft/min
- Ground level access

Fuel Cell System Peripherie

- Supply systems and load for 200 kW fuel cell systems
- High flexibility for system architectures (including air/liquid cooled systems, NT-/HT-PEM, BoP)
- Ready to use operator system including safety
- SUT control by user
- Various interfaces for gases, liquids, data, energy etc.



Actual status: Spec finished, start of tender scheduled for Q1 2026

Test environment for LH2

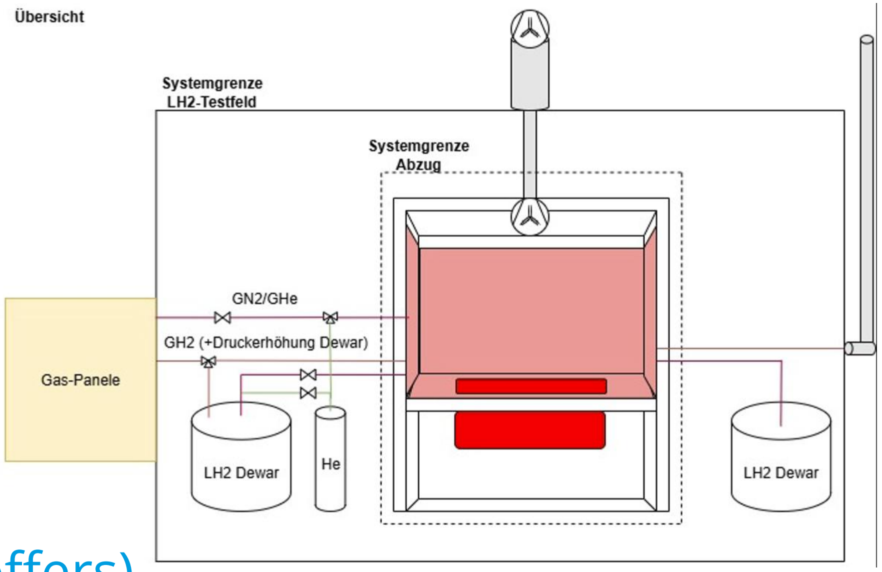
ZAL Center of Applied Aeronautical Research

LH2 liquefier

- Generation of about 5 kg_LH2/day
- Integration into „Gaselager“ inside container
- Works with H2 and energy only
- LIN precooling as option

- Extension to LH2 Transport System planed

Actual status: First part of tender accomplished



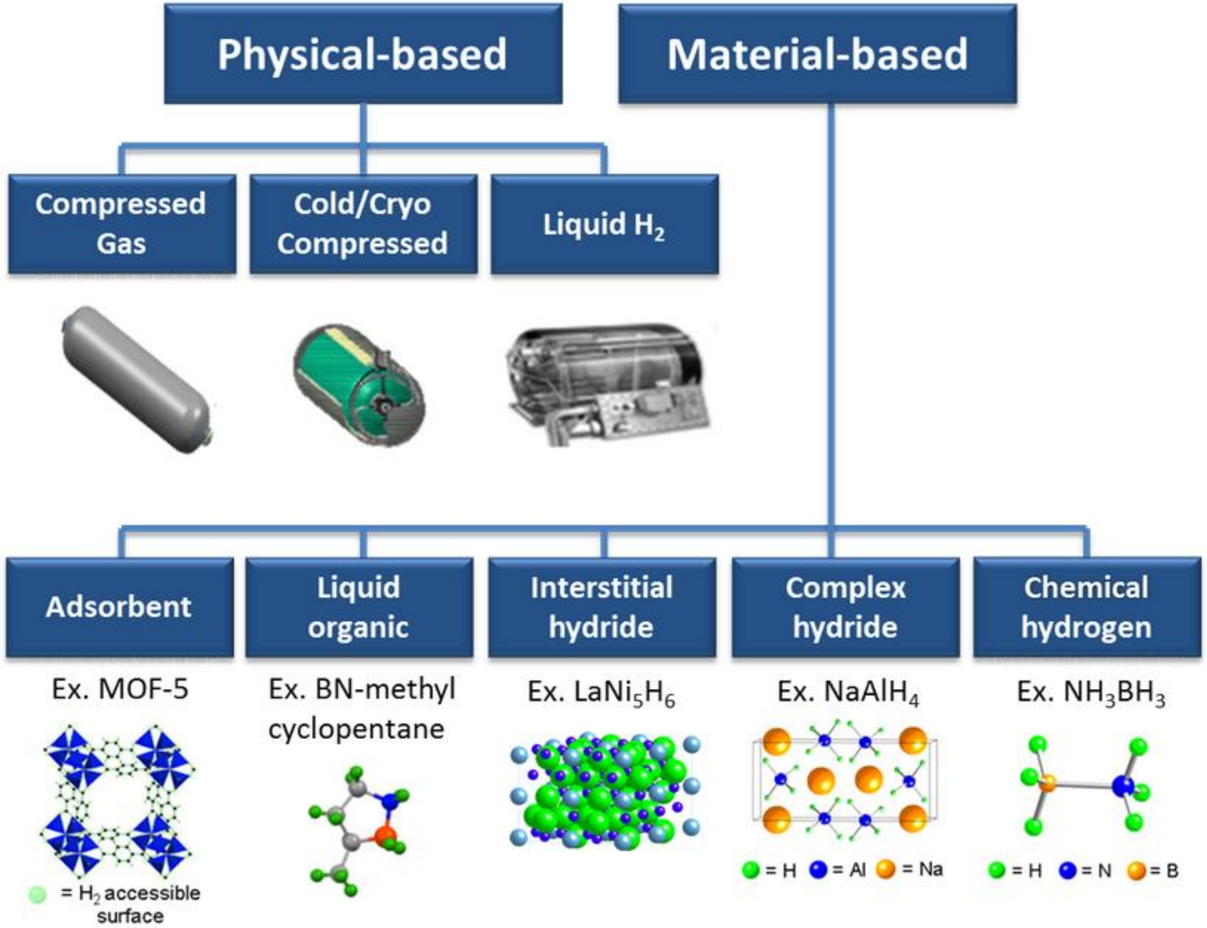
LH2 Test Field

- Ventilated hood for LH2 shall be in E-1-101 installed
- Use of mobile dewars (filled by liquefier) for LH2 delivery
- Test of small components and materials
- Learning/training platform for usage of LH2
- Safety

Actual status: Preparation of procurement (e.g. looking for offers)

Projects BETA – H2 Storages

BETA
Brennstoffzellensystementwicklung für die technische Aviatik



Hydrogen storage is key for mobile application as it has a very big **influence on the total system weight and volume**. Additionally, the handling of H2 can be a safety issue which is for aeronautical use a challenge.

Goal

- Identification of all relevant H2 storage technologies which are available today
- Assessment of different parameters including performance, quality, dynamic, safety, ecology, availability, handling
- Forecast of technological potential in different types of aerial vehicles (UAS to long range A/C)
- Multi-functional approaches to minimize the systemic footprint
- Hardware tests to get data (focus aerospace)
- Modelling & simulation (focus aerospace)

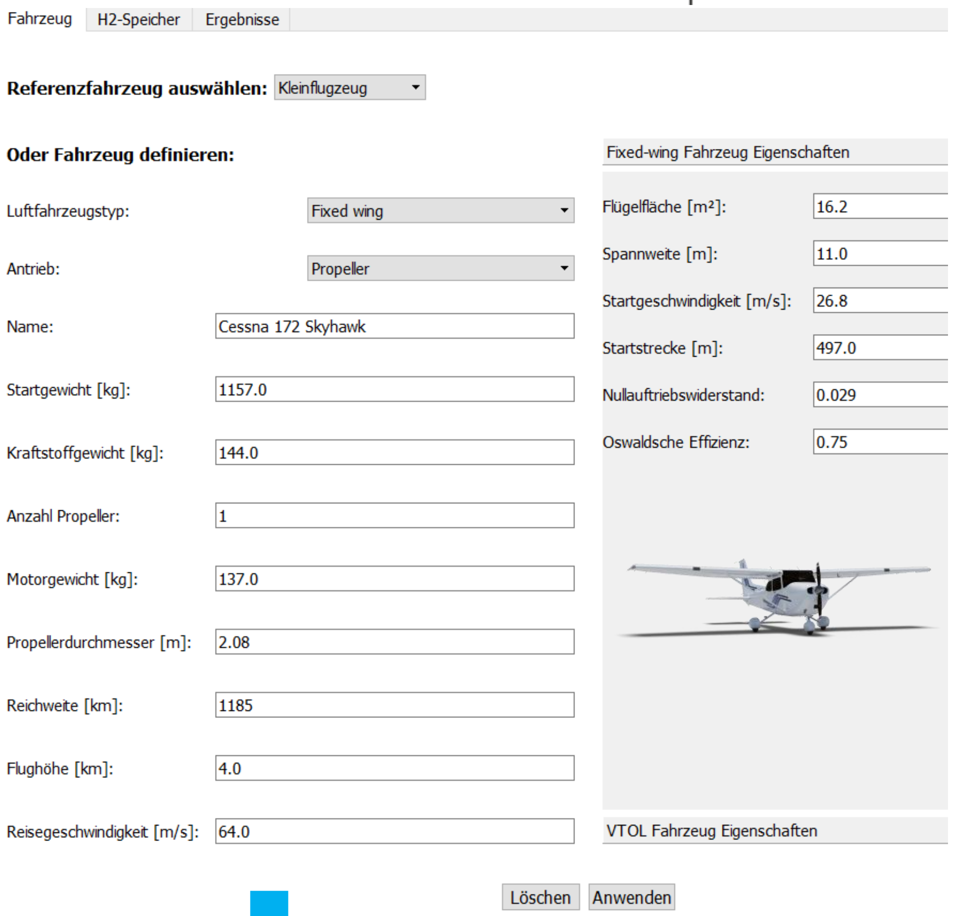
Supported by:
Federal Ministry for Economic Affairs and Energy

Projects BETA – Modelling & Simulation

Integration assessment

- Integration assessment for different vehicle classes: Determination and comparison of the performance of a suitable storage system for each storage technology
- Identification of the most promising technologies for aviationSelection of technically interesting and commercially available
- H2 storage systems with comparable performance for use on a fuel cell test bench

Speichertyp	Masse H2 [kg]	Masse Speichersystem [kg]	Volumen Speichersystem [L]	Kosten [$]	Fahrzeugsmasse [kg]	Massendifferenz [%]
LH2	75,4980805	375,2367284	1412,40791	20082,48941	1277,223421	10,39096119
Ammoniak	83,53162911	842,9100755	1030,223426		1744,896768	50,81216665
Methan	73,00664384	935,0466307	694,6060685	38912,54117	1837,033323	58,77556813
Typ IV (700 bar)	73,00664384	1057,009235	1787,589147	34532,14254	1958,995927	69,31684765
KMH-1	73,00664384	1125,519093	463,0707124	8322,757398	2027,505785	75,23818367
AC	73,00664384	1215,56062	2431,12124	65705,97946	2117,547313	83,02051102
CcH2	73,00664384	1350,622911	1620,747493	28472,5911	2252,609604	94,69400204
Typ III (700 bar)	73,00664384	1405,272393	3038,90155	41321,76041	2307,259086	99,41737991
Typ I (350 bar)	73,00664384	1548,484866	6946,060685	6059,551439	2450,471559	111,7952946
LiBH4-MgH2	90,13165906	1579,675919	1875,865154	180263,3181	2481,662612	114,4911506
Borazan	73,00664384	1620,747493	1774,541051	40153,65411	2522,734186	118,0409841
MOF-5	73,00664384	1870,093261	3473,030343	35773,25548	2772,079954	139,5920444
NaAlH4	85,89016922	2383,452196	7150,356588	31779,36261	3285,438889	183,9618745
IRMOF-8	73,00664384	3038,90155			3940,888242	240,6126398
MgH2	105,8067302	3203,058287			4105,04498	254,8007761
Typ II (350 bar)	73,00664384	3473,030343		6278,57137	4375,017035	278,1345752
NaBH4	73,00664384	5285,046174	4862,24248	12119,10288	6187,032866	434,7478709
FeTi	82,68023085	9177,505624	4235,771827	57876,16159	10079,49232	771,1747897
LaNi5	83,91568258	12149,53143	6985,980574		13051,51813	1028,048239



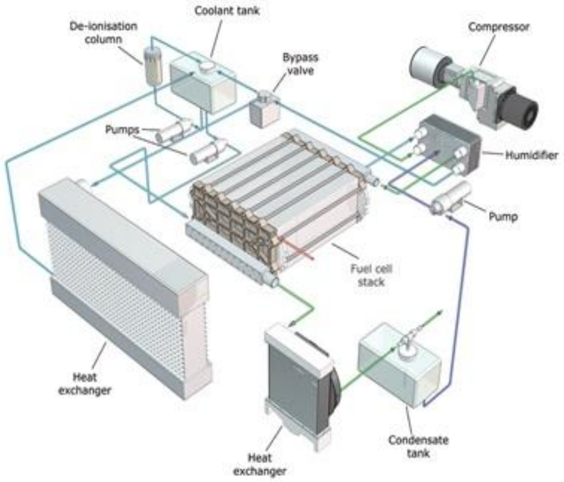
Calculated benefits

Projects BeHyPSy Project

Development, integration and testing of an innovative fuel cell propulsion system

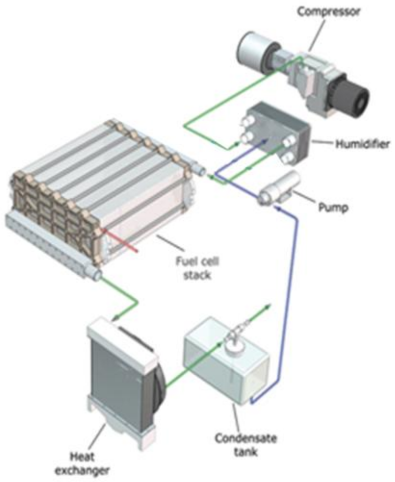
Expected benefits of the design:

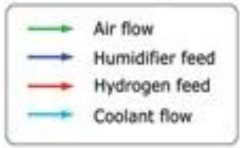
- System architecture does not require a liquid cooling system
  - Reduction of weight and volume
  - Reduced maintenance and increased reliability
- Multi-phase electric motor
  - Increased redundancy and resiliency



without

liquid cooling





Adapted from Intelligent Energy

Breezer Aircraft GmbH & Co. KG

University of Applied Science Hamburg

Helmut-Schmidt-University Hamburg

Rostock-System Technik GmbH

ZAL GmbH

Zentrum für Brennstoffzellentechnik GmbH

Project Hydrogen Aviation Lab

Lufthansa Technik | DLR | Hamburg Airport | ZAL | Hamburg

#MakeChangeFly

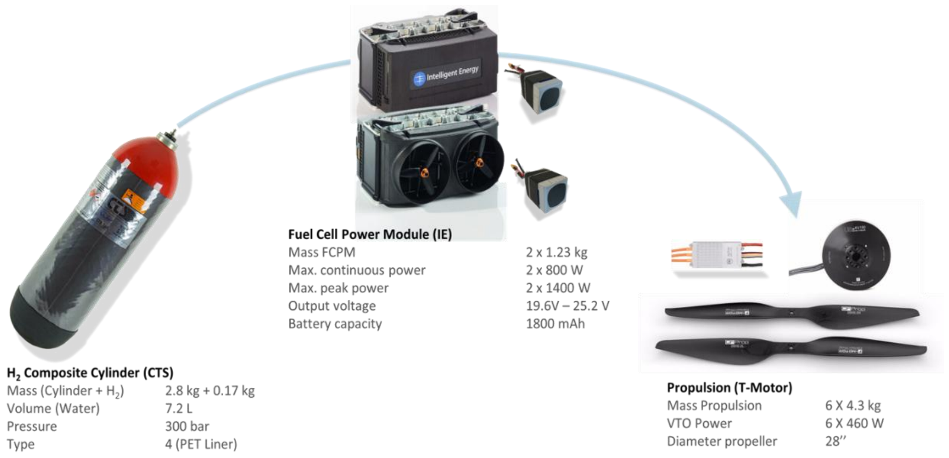
Goals:

- Handle LH_2 at/in the aircraft
- Safety in dealing with LH_2/ gH_2
- Learn effects on operations & MRO
- Test capacities for future projects & developments
- Digital Twin

Projects UAV Development

Overview

- Development, design and build-up of Hexacopter ZALbatros
- Flight tests (incl. permit to flight)
- Test platform related to:
  - Development and test of a LH2-tank
  - Sensor system (incl. payload)
  - Energy management system
  - Flight and FCS controls
- Retrofit of existing UAV (like Wingcopter)
- Scale-up to big UAVs with up to 2.000 kg MTOW



From pGH_2 …

… to LH_2

Products H2PM – Hydrogen UAS

ZAL | Center of Applied Aeronautical Research

150 km
Operational Range[1]

2.5 h
Flight Time[1]

5 kg
Payload[1]

Long-Range, Low-Cost: The Benefit of Hydrogen Drones

Making New Missions Feasible


Energy Inspections


Offshore Operations


Time Critical Logistics


Surveillance

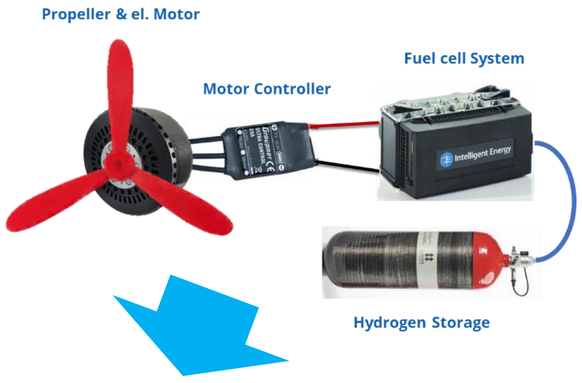
Fynn Schröder
Development Engineer Fuel Cell Lab

+49 (0) 40 248 595-165
fynn.schroeder@zal.aero
www.zal.aero

Projects UAV H2-finity

- Equipping a 25 kg drone with a fuel cell propulsion system optimized for cruising flight
- Demonstration of scalability to approx. 80 – 100 kg
- Use of the REALISE launch system to limit the high energy requirements during take-off and the first climb
- Analysis of the refuelling processes within the REALISE system for the future fully automated refuelling operation

Fuel Cell Propulsion System

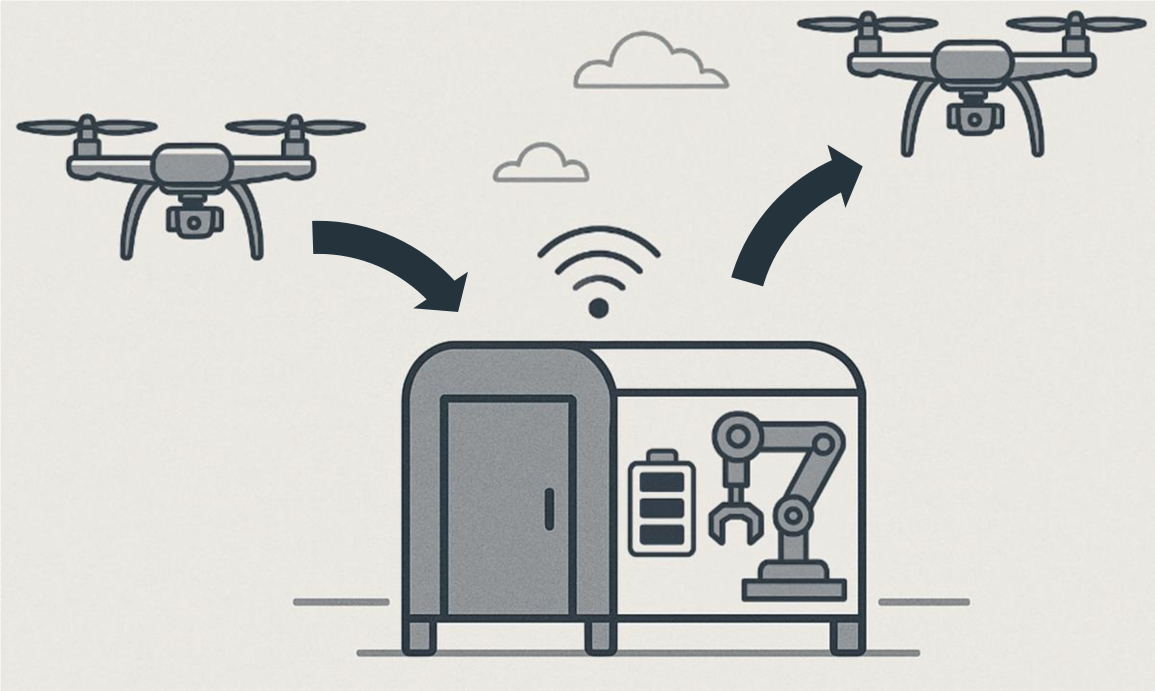


Behörde für Wirtschaft und Innovation

TECCON heart of engineering | mb+Partner Luftfahrt Technologie | THELSYS | ZAL GmbH

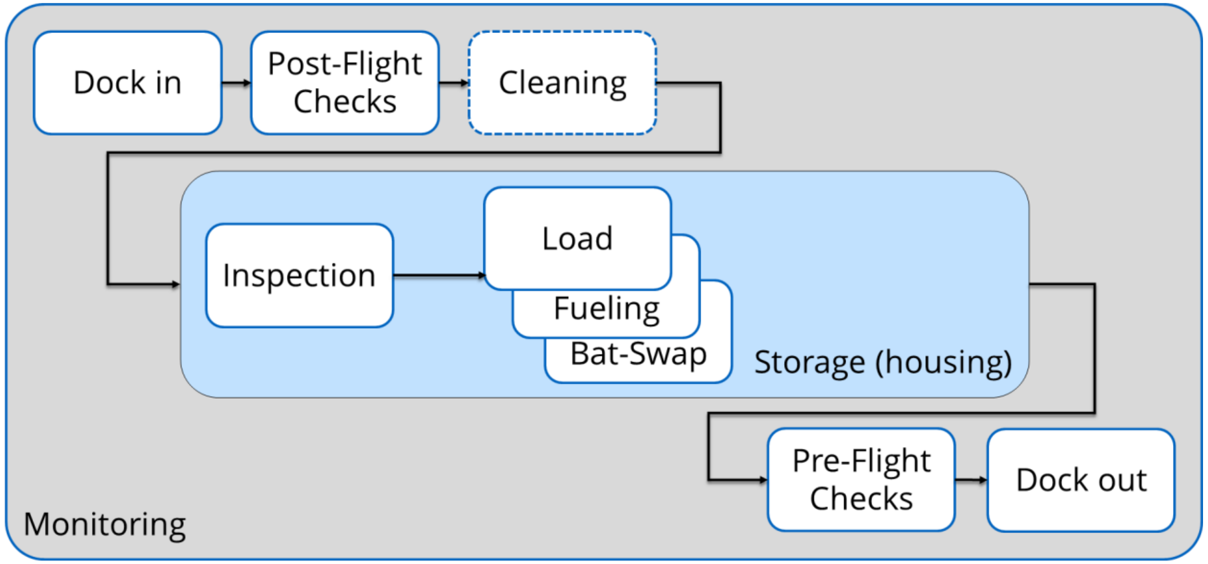
Projects Refueling UAVs

Multi-Fuel Station for UAVs



Manual refueling or reloading of the energy storages are limiting the operation of UAVs in terms of operational range as well as in time. Using an **automated platform** dealing with all processes around the **ground operation** (like loading/refueling, inspection, exchange of payload) can increase the attractivty of UAVs.

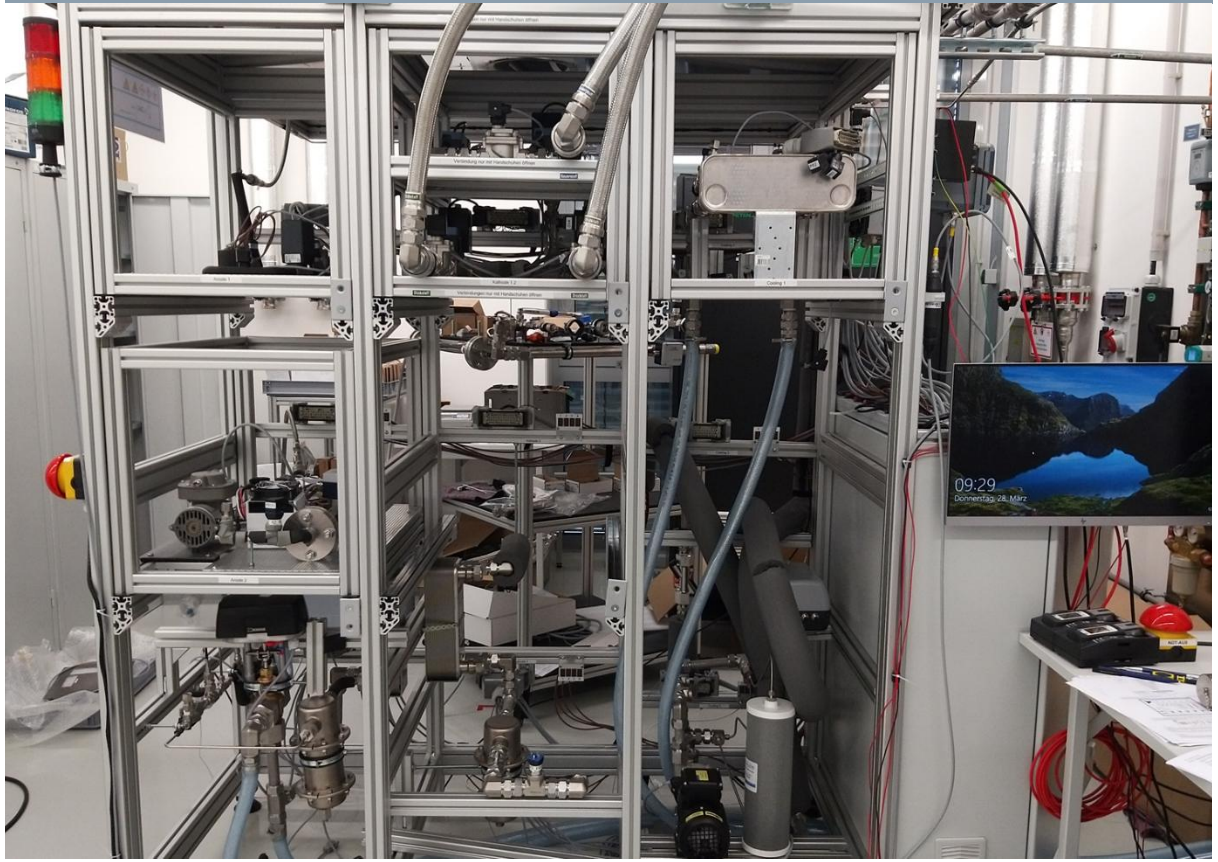
Goal



Projects FC Test Bench

BILBO
Customized Fuel Cell System Test System

based on the Research Project BILBO



Hydrogen Fuel Cell Systems are based on the complex interaction of **several system components** and the **control software**. **Modular** component **test rigs** are used for component **optimization and characterization** under repeatable laboratory environment.

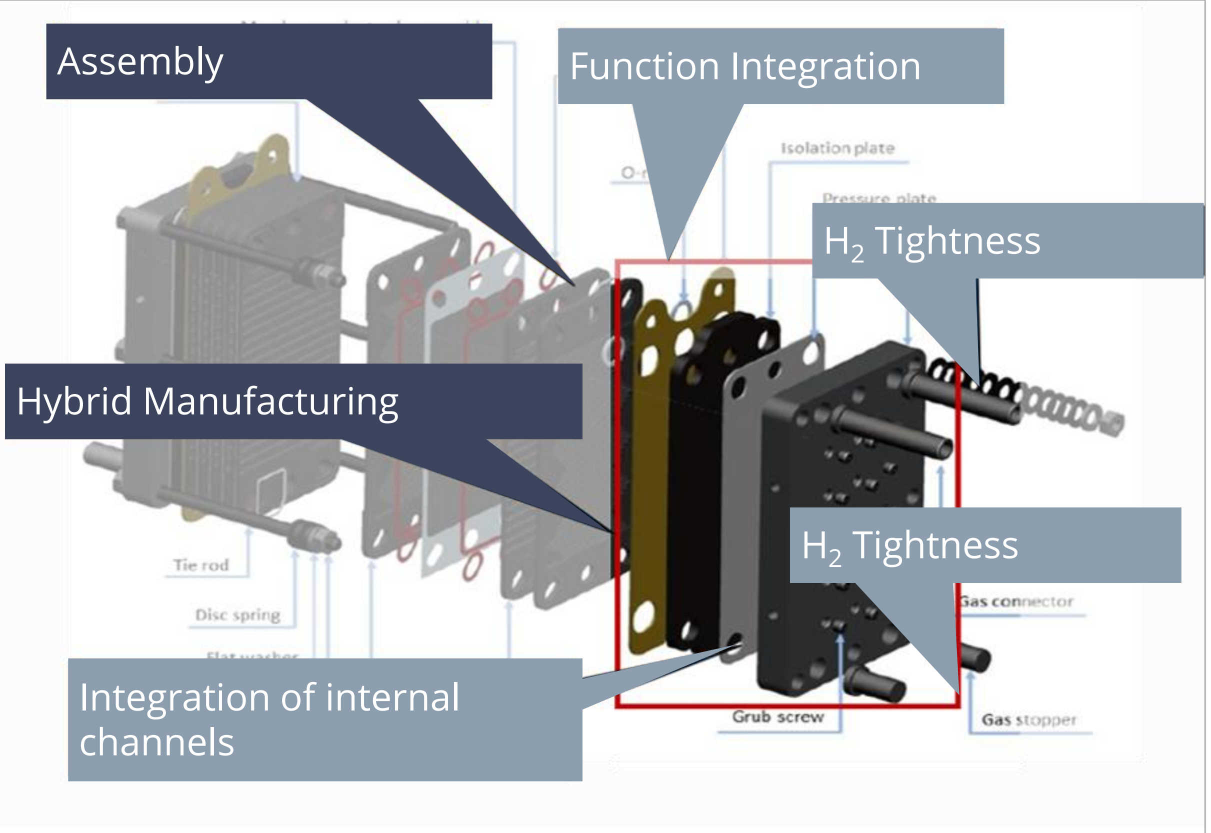
Technical Specification

- Modular test bench for characterizing the components of fuel cell systems at the system level
- Components are tested and evaluated against reference
- Replacement of individual assemblies simple and standardized (modular boxes)
  - Operation with hydrogen, compressed air, pure oxygen and gas mixture
  - Power: 20 kWel (duration) / 30 kWel (peak) / Laboratory or self-supply
  - System pressure up to 4 bara
  - 2-circuit cooling system
  - Control via WAGO with LabView ™

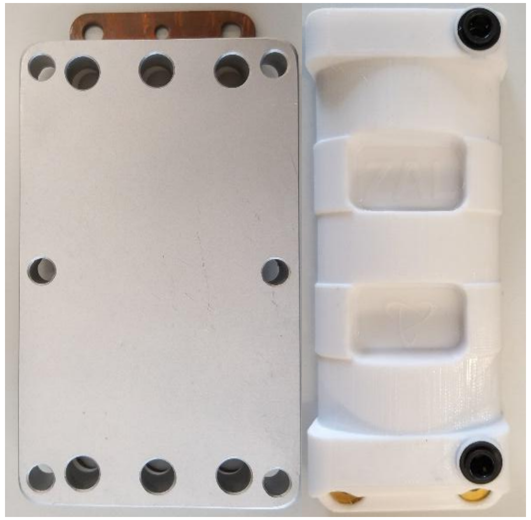
Supported by:
Federal Ministry for Economic Affairs and Energy

Projects Fuel Cell & Additive Manufacturing

Additive Manufacturing Lightweight Fuel Cell



Fuel Cells are complex systems with plenty of single parts. The production of an assembly in one process combined with **lightweight design and optimized functions** allows to improve the fuel itself and the manufacturing process.



Goal

- Topology optimized design with significant weight reduction
- Optimized gas flow
- Manufacturing of assembly

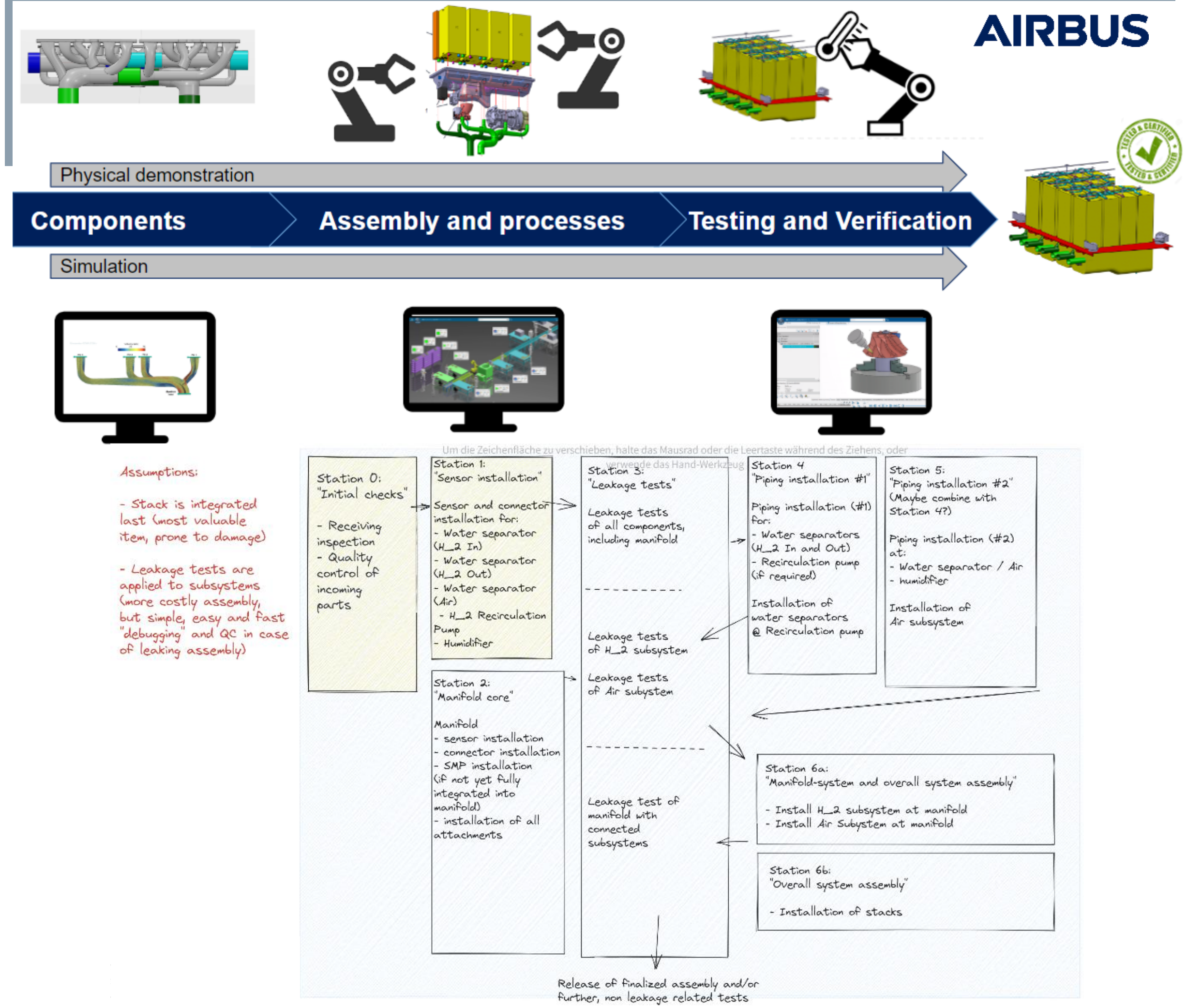
Our Service

- Construction and Topology Optimization
- Process Planning
- Hybrid Manufacturing
- Testing of connections and productivity

Zentrales Innovationsprogramm Mittelstand

Projects Fuel Cell & Robotics

Industrial concept for manufacturing of FCS



Development of an **industrial concept for manufacturing and assembly process** for components and modules of the **fuel cell System**.

Goal

- Data driven development and manufacturing of a Fuel Cell System
- Improvement of performance and efficiency of the manufacturing process
- Improving reproducibility
- Preparation of components for automated assembly
- Improvement of manufacturing quality
- Reduction of manufacturing cost
- Reduction of manual work

ZAL Center of Applied Aeronautical Research

Sebastian Altmann

Hein-Saß-Weg 22
21129 Hamburg, Germany

+49 40 248 595 105
Sebastian.altmann@zal.aero

Quellen

Folie	Quelle
3	https://www.erneuerbare-energien-hamburg.de/de/blog/details/hanseatic-hydrogen-center-for-aviation-and-maritime-h2am.html
5	https://www.cockpit.aero/rubriken/detailseite/news/brennstoffzellen-fuer-kleinflugzeuge https://www.airbus.com/en/innovation/energy-transition/hydrogen DLR
8	Lufthansa Technik https://energypost.eu/dont-commit-to-hydrogen-pipelines-yet-trucks-can-do-the-same-job-more-flexibly/ https://www.cryotherm.de/produkte/lagerung/produktinformation/hydros