Fraunhofer
LBF

Fraunhofer Institute for Structural
Durability and System Reliability LBF

Safe. Sustainable. Efficient.

Materials, Components and Systems for a Reliable Hydrogen Industry

www.lbf.fraunhofer.de/hydrogen

Services for the Hydrogen Industry

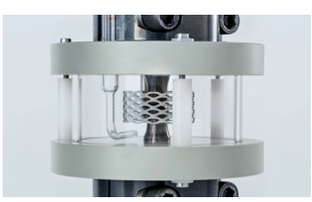
Hydrogen is an energy carrier that has a positive impact on the energy transition and counteracts climate change. With over 85 years of experience in reliability and durability topics, Fraunhofer LBF's interdisciplinary teams of experts are developing new procedures and methods for evaluating and optimizing the reliability of materials, components and systems in the hydrogen industry.

For example, they create new test systems, from conceptualization and design to construction, commissioning and application, in order to efficiently support customers with their issues. The projects cover topics ranging from hydrogen production, storage and transportation to hydrogen use.

Test Benches

Our service portfolio is very diverse. It includes:

The testing of materials used in the hydrogen industry, such as samples made of metal, plastic or composites under realistic conditions. This means, for example, that samples are tested cyclically or statically under pressurized hydrogen at corresponding temperatures. Other media such as methanol or ammonia can also be used.



Testing of materials under variable conditions for the hydrogen industry.

The testing of components such as membranes, pipes or stacks. They can be analyzed in our individually applicable test facilities with regard to their service life and reliability.

Testing and simulation of hydrogen industry systems. Fuel cells, for example, can be examined in our multi-axial vibration table (MAST) under (multi-axial) vibration loads, as they occur when driving a vehicle. Fraunhofer LBF has also developed a method using Acoustic Emission that allows the formation of cracks in a type 4 tank to be measured with spatial resolution, as well as the progress of cracks. The use of this sensor technology also makes it possible to measure whether a tank is still undamaged after a car accident.

Our range of services and the associated customer Benefits are presented here.

Test Bench Development & Realistic Testing of Hydrogen Industry Materials

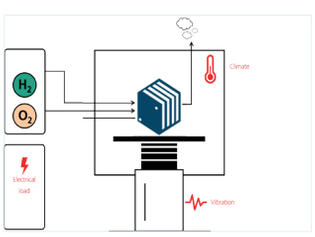
Fatigue tests under pressurized hydrogen and nitrogen for component lifetime analysis

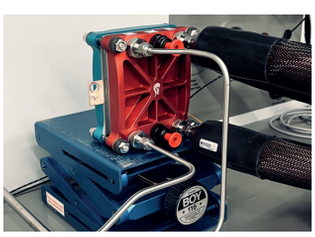
- Pressure range: 7 to 50 bar (for quarter three 2025: up to 100 bar)
- Temperature range: - 40 °C to + 110 °C
- H_2 / N_2 concentration up to 99.9999 %
- O_2 concentration < 4 ppm
- Performance of tensile tests and creep tests
- Rate 0.1 mm/min to minimum 0.018 mm/min
- Servo-hydraulic test system with nominal load of 63 kN
- Compliance with gas purity requirements according to ANSI_CSA_CHMC1-2014
- Fulfilment of the required accuracy in the execution of tests according to ISO 1099 and the code of practice (ISBN-92826-9681; EUR 161382_EN

Test rig for 50 bar H_2 tests.

Contact: Dr. Steffen Schönborn, steffen.schoenborn@lbf.fraunhofer.de, +49 6151 705-448

Multi-Physical Fuel Cell Testing





Vibration testing in operation -> Simulation of the overlapping multiphysical loads

- Enables ‘frontloading’ in the development process
- Flexible and realistic characterisation, performance/long-term tests in all system development stages including BoP (Balance of Plant)

Singel cell

- Dynamic, monoaxial vibration loads
- Dynamic electrical load
- Electrical power $P_{el} \leq 0.1$ kW

Stack, System

- Dynamic, monoaxial vibration loads (55 kN, ≤ 2.5 kHz)
- Climatic ambient conditions (- 60 °C to + 120 °C)
- Dynamic electrical load
- Electrical power Electrical power $P_{el} \leq 10$ kW,
- Electrical power $P_{el} \leq 100$ kW

(*planning status)

System

- Multi-axial vibration loads (≤ 200 Hz, ≤ 1000 kg)
- Climatic ambient conditions (- 40 °C to + 80 °C)
- Fuel cell system conditioning

Contact: Dr. Benedict Götz, benedict.goetz@lbf.fraunhofer.de, +49 6151 705-8524

Materials

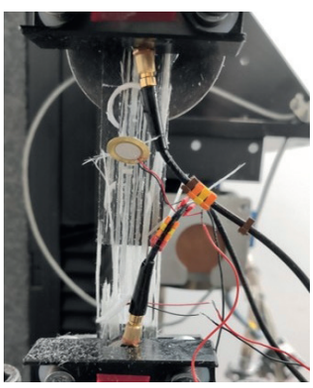
Integration of Sensors in Materials of Hydrogen Industry

Our Service:

- Measurement of mechanical stress of materials based on various sensor technologies
- Data analysis for the derivation of load spectra and test programs as well as the identification of damage and wear mechanisms

Your Benefits:

- Knowledge of the load carrying capacity of the materials for your product or application
- Selective product design through knowledge of the physical-technical relationships (damage mechanisms, material stress)
- Competitive advantage through optimum material utilisation
- Reduction of product costs by identifying and eliminating weak points and recognising potential for optimisation



Test rig for impact testing of materials.

Acoustic Emission (AE) Measurements on Material Samples

Our Service:

- Acoustic emission (AE) measurements on material samples and components under mechanical loads to analyse damage behaviour
- On-time countermeasures through AE measurements. Recording and analysis of damage processes in real time to improve material development and localisation of damage

Your Benefits:

- Identification of damage mechanisms and the location of damage initiation
- On-time damage detection can prevent costly failures and repairs
- Support in the development of more robust and durable materials through detailed investigations and analyses

Contact: Johannes Käsgen, johannes.kaesgen@lbf.fraunhofer.de, +49 6151 705-613

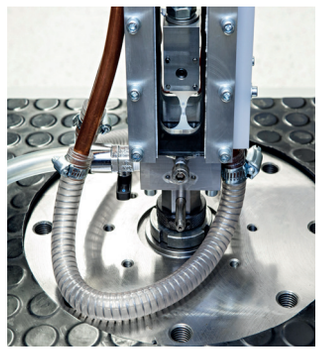
Test Bench Development and Realistic Testing of Materials for the Hydrogen Industry

Our Service:

- Application-oriented evaluation of mechanical behaviour under complex stresses in liquid and gaseous media
  - Metals, polymers and composites
  - Test bench development for static and cyclic ageing experiments under hydrogen atmosphere
  - Static, cyclic and creep
  - Pressurised hydrogen and nitrogen
  - Cooling liquids, acids & alkalis
  - Various load, pressure and temperature ranges
- Physical and chemical characterisation of polymers for hydrogen applications
  - DMTA, FTIR, µFTIR, Raman microscopy and SEM-EDX
  - Analysis methods for ionomer dispersions (DLS, 19F-NMR, viscometry, GPC)

Your Benefits:

- Evaluation of the strength, deformation and fatigue behaviour of materials exposed to hydrogen
- Optimisation of material selection and development for cost-efficient hydrogen systems
- Enhancing the performance of polymers and metals for hydrogen systems
- Improved reliability of (lightweight) structures



Setup for inline testing of materials of the hydrogen industry.

Contact: Dr. Felix Dillenberger, felix.dillenberger@lbf.fraunhofer.de, +49 6151 705-8753

Rapid Test for Metallic Samples in Relation to Hydrogen

Our Service:

- Material analyses under electrolytically generated hydrogen
- Pre-loading of material samples with different hydrogen contents.
- Adjustment of material conditions with very high hydrogen contents (saturated)
- 'Quick test' under hydrogen environment for screening different material alloys
- Examination of very small components

Your Benefits:

- Based on the test results obtained, conclusions can be made regarding the impact of hydrogen on the strength and deformation behaviour as well as the influence on the lifetime and fatigue behaviour

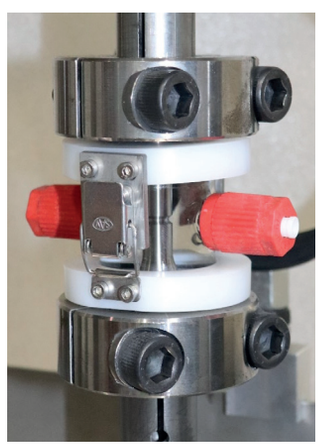
Fatigue Corrosion

Our Service:

- Examination of the corrosion fatigue strength in liquid media, to evaluate the influence of a corrosive environment on the lifetime behaviour
- Use of different media (e. g., methanol, ethanol, biofuels ...)
- Evaluation of the corrosive impact of synthetic fuels (liquid energy sources) on the fatigue strength behaviour

Your Benefits:

- Service in the specific material properties in corrosive environments
- Support in the selection, evaluation and optimisation (e. g., coating) of materials for the design of media-carrying components
- Support in ensuring operational stability and system reliability
- The early detection of materials with potential weak points in terms of media resistance



Test setup with media chamber for liquid media.

Contact: Dr. Steffen Schönborn, steffen.schoenborn@lbf.fraunhofer.de, +49 6151 705-448

Hydrogen Sorption

Sensor of the micro balance for hydrogen absorbtion testing.

Our Service:

- Analysis of the hydrogen absorption by polymers at a pressure of up to 350 bar and a temperature of up to 150 °C
- Illustration of the sorption isotherm for different temperatures
- Examinations of thermoplastics (tank housings), elastomers (sealing materials), hydrates (hydrogen storage tanks)
- Ageing of polymers in a hydrogen atmosphere at pressures up to 300 bar and temperatures up to 300 °C under static or dynamic conditions

Your Benefits:

- Optimised material selection for components used in hydrogen atmospheres at different pressures and temperatures
- Sorption behaviour and material properties for assessing material performance

Material Optimisation and Processing, along with PFAS Substitution, in Specific Hydrogen Applications

Our Service:

- Evaluation and selection of substitution options for PFAS in specific hydrogen applications
- Development and optimisation of polymer materials through optimised formulations and additives (e. g., heat conduction and flame retardancy) for polymers in the hydrogen industry
- Selective modification of sealing materials
- Consultation on material-specific processing and optimization of preparation process for polymers in hydrogen systems

Your Benefits:

- Selective choice of materials
- Optimised product performance and manufacturing processes
- Sustainable, fit-for-the-future products for hydrogen technology
- Conformity with EU regulations

Contact: Harald Oehler, harald.oehler@lbf.fraunhofer.de, +49 6151 705-8669

Test environment for hydrogen absorbtion of materials (weight up to 25 g).

Components

Experimental Examination of Components

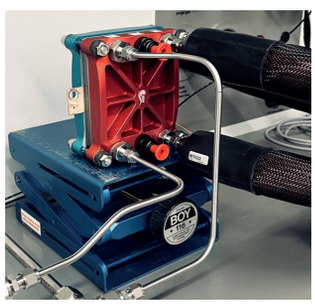
Our Service:

- Experimental investigation of e. g., MEA (Membrane Electrode Assembly) for PEM in single cell tests under vibration loads
- Characterisation and endurance testing of e. g., MEA for PEM in single cell tests

Your Benefits:

- Ensuring the long-term performance and stability of components through comprehensive characterisation and durability testing
- Improving the efficiency and lifetime of components through precise experimental analyses

Contact: Dr. Matthias Enders, matthias.enders@lbf.fraunhofer.de, +49 6151 705-267



Customer specific single cell test capabilities.

Experimental and Numerical Vibration Analysis

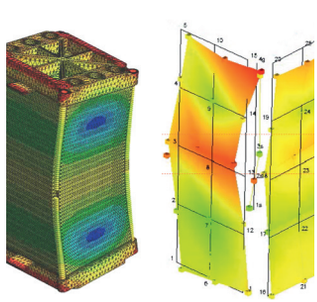
Our Service:

- Determination of preload force of stacks in operation
- Experimental vibration analysis of e. g., fuel cell stacks and cells
- Numerical analysis of vibration behaviour (development of parametric simulation models, comparison of models with experimental measurement data, investigation of model and parameter uncertainties)

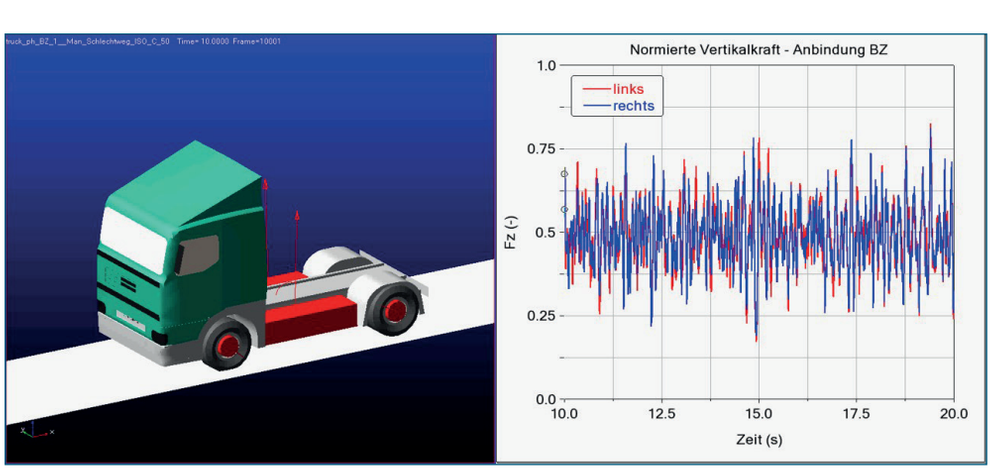
Your Benefits:

- Support in the optimisation of the design and structure of fuel cell stacks and cells
- Insights and technical consultant:
  - Improving the efficiency and reliability of fuel cell stacks and cells
  - Simulation and modelling of the behaviour of components under different conditions

Contact: Georg Stoll, georg.stoll@lbf.fraunhofer.de, +49 6151 705-8528

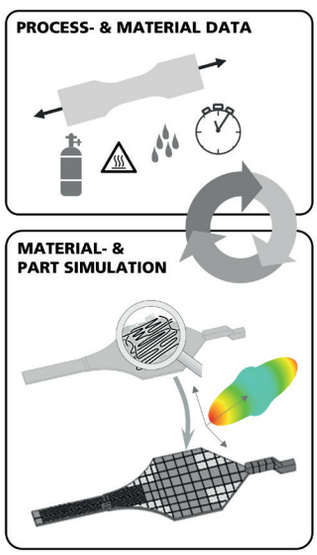


Vibration analysis in simulation and experiment.



With experimental and numerical tools, we help our customers understand the vibration loads that occur during operation, thereby supporting project development and optimization.

Finite Element Structural Simulation of Components



Integrative simulation toolbox for complex mechanical and environmental interactions.

Our Service:

- Development of digital twins for metallic and polymer components
- Numerical modelling and evaluation
- Interactions of media, ageing effects and mechanical loads
- Example of welded joints: lifetime under different loads
- Determination of characteristic values and development of material models
- Development of design methods for safe polymer components
- Integrative simulation toolbox considering processing, complex mechanical stresses, anisotropic material properties and media influences

Your Benefits:

- Ensuring the long-term performance and safety of components through precise design methods.
- Evaluation of the lifetime depending on the external load as well as local stress on the joint
- Increased efficiency in designing through access to specific services

Testing to Ensure the Performance of the Electrolytic Components under Extreme Environmental Conditions

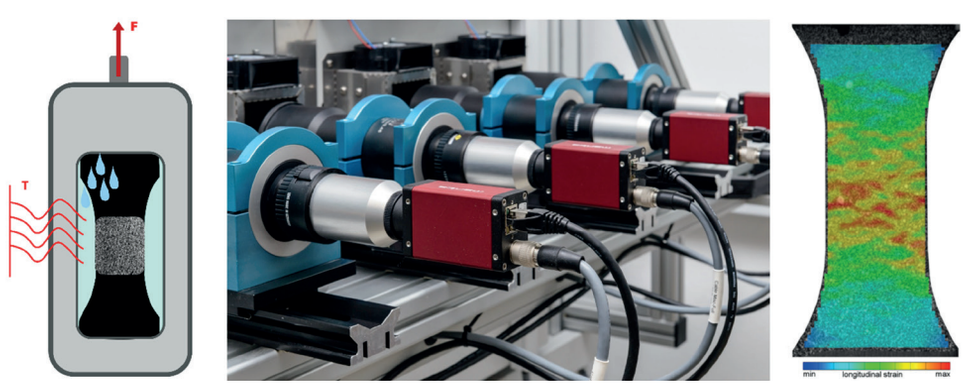
Our Service:

- Analysis of polymer components, e. g. seals or membranes for fuel cells and electrolysers:
  - Static and dynamic
  - Huminity and temperature dependency
  - Coolants, acids and alkalis
  - Various loads, pressure and temperature ranges

Your Benefits:

- Ensuring the long-term performance and lifetime of components used
- Increasing the efficiency, safety and lifetime of components through precise experimental investigations
- Reliable design of components for hydrogen systems

Contact: Dr. Felix Dillenberger, felix.dillenberger@lbf.fraunhofer.de, +49 6151 705-8753



Sketch of media cell (left), creep test stand with cameras for optical strain detection (centre), strain signal evaluated by area (right).

Systems

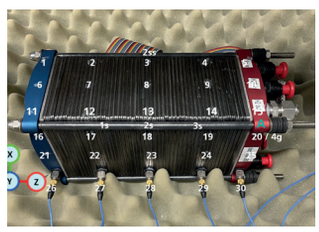
Load Data Acquisition and Measurement Networks

Our Service:

- Sensor instrumentation, data acquisition, implementation and documentation of measurement campaigns (incl. data analysis)

Your Benefits:

- Provide detailed data and analysis to support informed decisions
- Support and/or implementation of sensor instrumentation and data evaluation
- These measurement campaigns can form the basis for realistic analyses of the ageing behaviour of fuel cell systems in the laboratory



Vibration analysis of fuel cell stack.

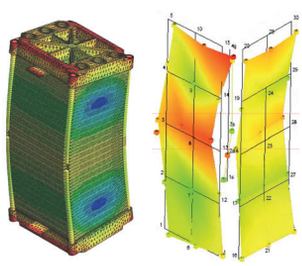
System Identification and Numerical Simulation

Our Service:

- Evaluation of the various effects of vibrations in dependence on the following factors
  - Position in the vehicle
  - Structure and stiffening of the cell stack
  - Connection of BoP (Balance of Plant) components

Your Benefits:

- Analysing and understanding the effects of vibrations at an early stage in the development process
- Support and technical consultant:
  - Experimental system identification
  - Model adjustment and parameter identification
  - Structural dynamic modelling
  - Analysis of components and overall systems



Comparison of experimental and simulated vibration behavior.

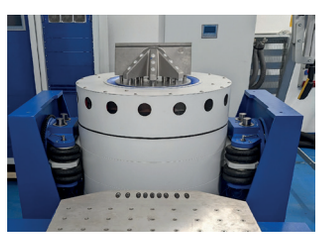
Vibration Tetsing of Fuel Cell, Stack and System

Our Service:

- Vibration tests on fuel cell systems using oscillating systems (with or without H_2)
- Vibration load test on fuel cell systems incl. BoP to evaluate mechanical failure, operating vibration behaviour, and leak resistance

Your Benefits:

- Knowledge for evaluating the mechanical load capacity and operating vibration behaviour of fuel cell systems



Shaker with climate chamber and hydrogen supply.

Contact: Dr. Benedict Götz, benedict.goetz@lbf.fraunhofer.de, +49 6151 705-8524

Tank Systems

Test rig for the characterisation and validation of the AE sensors applied on H_2 tank.

Our Service:

- Analysis of hydrogen pressure tanks (expansion, material stress, pressure tests, impact)
- Reliable assembly in the vehicle for pressure cycles and crashes
- Specific generation and detection of fibre fractures, matrix fractures and delamination in the tank material during lifetime testing and in operation
- Algorithms for evaluating lifetime consumption based on measurement data

Your Benefits:

- Reliable tank installation in the vehicle
- Monitoring the lifetime of pressurised hydrogen tanks
- Mobile or stationary monitoring system for tank systems
- Support in evaluating tank safety after a road accident

Contact: Johannes Käsgen, johannes.kaesgen@lbf.fraunhofer.de, +49 6151 705-613

Probabilistic FMEA (Failure Mode and Effects Analysis)

Our Service:

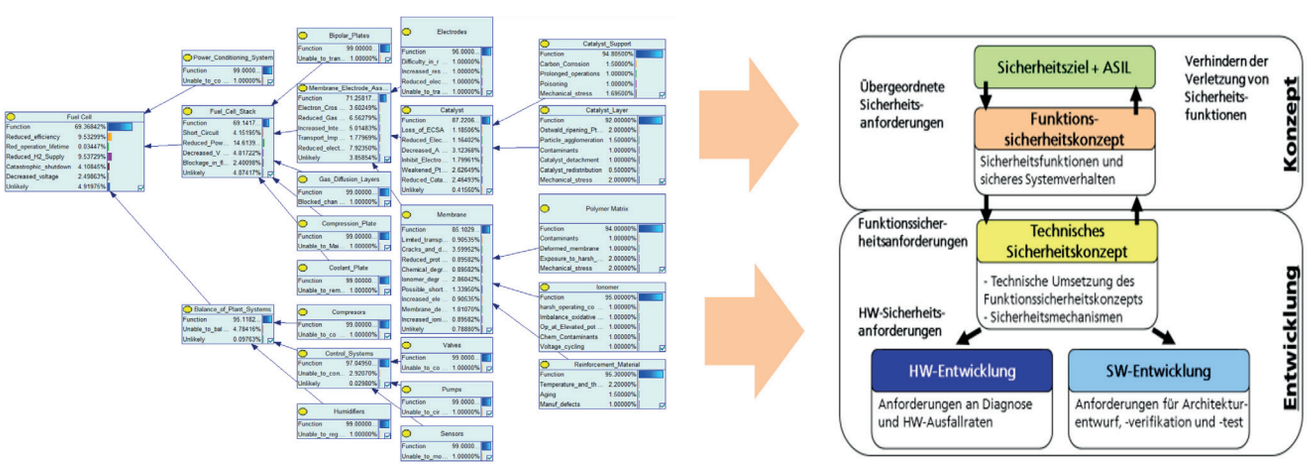
- Performing reliability and safety analyses
- Qualitative methodical failure analyses (e. g. FMEA)
- Probabilistic system evaluation (probabilistic FMEA)

Your Benefits:

- Insights and technical consultant on system reliability and safety
- Determination of failure probabilities at system and subsystem level
- Utilisation of the findings for further considerations, e. g., functional safety

Contact: Dr. Jürgen Nuffer, juergen.nuffer@lbf.fraunhofer.de, +49 6151 705-281

Probabilistic FMEA (left) delivers quantitative failure probabilities as an input for the assessment of functional safety (right).



Training Programes

As part of our hydrogen Service, we offer know-how transfer, market studies and specialised training courses

Our Service:

- Training courses offered for reliability and safety assessment and the sustainability of hydrogen industry systems
- Shaping customised training programes for your specific needs, examples:
  - Reliability and safety assessment and sustainability of systems for hydrogen industry
  - Mechanical behaviour of polymers & composites and elastomers as well as methods for their design and simulation
  - Polymer Service for metal engineers: understanding mechanics and fatigue, implementing material substitution
- Trouble-Shooting: Consultant services in the case of damage: Investigation of cases of damage and derivation of measures
- Additional offers on: ***www.leistungszentrum-wasserstoff-hessen.de/de/Weiterbildungen***

Benefits for you:

- Knowledge gain of own employees
- Improved decision-making for the optimal design of hydrogen systems

Contact: Dr. Felix Dillenberger, felix.dillenberger@lbf.fraunhofer.de, +49 6151 705-8753

Fraunhofer LBF and High Performance Centre GreenMat4H_2

The Fraunhofer LBF, together with the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, forms the Fraunhofer High-Performance Centre GreenMat4H_2, which is directed by Prof. Dr. Tobias Melz, head of the Fraunhofer LBF.

The focus of this High-Performance Centre is to provide the best possible support for the hydrogen industry in the Rhine-Main region and beyond. To accomplish this goal, projects are carried out with industry and other research institutions as well as universities and institutions of higher education.

Public events are organised, such as the Hydrogen Round Table and the Citizens' Dialogue on Hydrogen, in order to create a broad acceptance of hydrogen across and to network companies, associations, research institutes, universities and institutions of higher education. Fraunhofer LBF together with Fraunhofer IWKS organise workshops on hydrogen-related topics, and exhibit their services at official events such as exhibitions and congresses to the hydrogen industry.

You can find more information at: ***www.leistungszentrum-wasserstoff-hessen.de***

Contact

Prof. Dr. Saskia Biehl
Head of Strategic Management
Fraunhofer LBF
Head of Innovation Center GreenMat4H2
Phone: +49 6151 705 282
saskia.biehl@lbf.fraunhofer.de

Fraunhofer Institute for Structural Durability
and System Reliability LBF
Bartningstr. 47
64289 Darmstadt, Germany
www.lbf.fraunhofer.de