Our research unlocks the full potential of hydrogen and its derivatives, empowering our customers to launch competitive products faster and with lower risk.«

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Further information

Cover image: AEM electrolysis test bench with a 4 cm² electrolysis cell developed by Fraunhofer ISE for characterizing new non-precious metal catalyst materials under industry-relevant conditions. ©Fraunhofer ISE / Photo Joscha Feuerstein

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Empowering the Hydrogen Economy

Hydrogen Technologies

www.ise.fraunhofer.de/hydrogen-technologies

Hydrogen Technologies

We support our customers from the microscale up to global energy systems: We develop models and analyze materials, components, production processes, and infrastructure systems. In addition, we carry out techno-economic and life cycle assessments.

Membrane Electrolysis

Hydrogen production in water electrolyzers is a clean and efficient process to convert and store large quantities of renewable electricity. Our R&D focuses on membrane water electrolysis and involves fundamental research on single cell components such as the membrane electrode assembly (MEA), the porous transport layers, coatings, and bipolar plates. We are investigating the influence of various stressors on cell and stack performance and aging mechanisms. Furthermore, we are increasingly focusing on low-cost cell concepts and MEA production. In-house developed laboratory cells, stacks and automated test stands form the backbone of our R&D projects. Based on our operational experience with field test facilities, we offer services for condition monitoring and targeted measurement programs under real conditions. In addition, we have developed comprehensive system-level expertise, operating our own hydrogen injection and fueling stations with several fuel cell vehicles and related research on field test systems.

Our services include:

- Scientific investigations of performance and degradation mechanisms of cell and stack components for membrane water electrolysis using state-of-the-art electrochemical characterization and ex-situ analysis
- Research on manufacturing processes for cell and stack components, such as catalyst-coated membranes and protective coatings

Fuel Cells

Membrane fuel cells are recommended for applications such as zero-emission mobility, small traction vehicles, off-road vehicles, stationary combined heat, and power plants, and back-up power. Especially, the electrochemically active components, like the membrane electrode assembly, must operate reliably and efficiently under extreme conditions with high stability. We support and advise customers with our interdisciplinary know-how and comprehensive services, ranging from basic R&D to product commercialization. Our research encompasses the development, simulation, production, and ex-situ analysis as well as in-operando characterization of components, single cells, and stacks.

Our services include:

- In-situ characterization of components, cells and stacks with regard to performance and degradation, using state-of-the-art electrochemical measurement techniques
- Ex-situ analysis of fuel cell components
- Production research along the value chain from catalyst ink formulation to membrane electrode assembly – with processes from lab scale up to roll-to-roll industrial series production characterization at extreme climatic conditions
- Modeling and simulation performed from the microscale up to the system level

Prototype of a concept for PEM electrolysis stacks developed at Fraunhofer ISE, incorporating innovative sealing elements and significantly reducing the number of required components. ©Fraunhofer ISE / Photo Joscha Feuerstein



Laboratory for fuel cell and electrolysis production research. We support our customers to scale up fuel cell and electrolyzer MEA production. © Fraunhofer ISE / Photo Dirk Mahler





Distillation column with a total height of 7.5 meters for developing an industrial scale synthesis of dimethyl ether and other sustainable energy carriers. ©Fraunhofer ISE / Photo Joscha Feuerstein



Infrastructure for hydrogen and its derivates in the port of Rotterdam. ©stock.adobe.com/Nataraj

Sustainable Synthesis Products

Hydrogen und its derivatives, such as methanol, dimethyl ether (DME), Sustainable Aviation Fuel (SAF), and ammonia are essential for a resilient economy and for defossilizing hard-to-abate sectors. To ensure energy security, economy, and ecology, all renewable feedstocks, including biogenic and waste streams, must be considered. These feedstocks require innovative materials and gas pretreatment processes. We shape new supply chains for hydrogen and carbon, considering local resources (biogas, landfill gas, etc.) and designing scalable solutions for the global market. Our process development with industry partners involves experimental tests and simulations along the entire value chain. We develop processes for syngas production (mixtures of carbon oxides and hydrogen) for efficient synthesis processes. This includes gas cleaning technologies, Direct Air Capture (DAC) and reforming processes (hybrid reforming concepts, partially electrified, etc.) as well as reverse water gas shift processes. Additionally, we create intensified synthesis processes (sorption-enhanced, reactive distillation, etc.), such as INDIGO for DME production, a promising hydrogen carrier and platform molecule. Ammonia is a carbon-free hydrogen carrier, and we have developed a dynamic, modular, and quick start capable reforming system based on our CatVap® technology. We offer sophisticated characterization of materials, such as innovative X-ray photoelectron spectroscopy (HT-NAP-XPS).

Our services include:

- Reactor and process development of efficient gas cleaning, syngas production, reforming, synthesis, and separation processes including a powerful simulation platform (Aspen, MATLAB/Simulink, CFD, machine learning-enhanced modelling, etc.)
- Design, test, and characterization of commercially available and tailor-made adsorption materials and catalyst systems
- In-house design, construction, programming, and operation of fully automated, remote-operated mini and pilot plants

Hydrogen System Analysis

Efficient production of hydrogen and its derivates requires integrated planning, design, and operation across the entire value chain. Our holistic system analyses deliver tailored solutions for our partners. We map, analyze, and optimize the upgrading and construction of regional and global infrastructure and the full value chain of supply networks (from feedstock provision through hydrogen and syngas production, conversion, and storage to transport until final offtake) in geo-techno-economic and environmental terms. The cost-efficient, locally optimized hydrogen and Power-to-X hubs that we develop avoid stranded assets and consider transport costs, renewable energy potential as well as infrastructure and offtake requirements. Building on a detailed data base, we calculate electricity costs for promising sites and derive the final costs of producing hydrogen and green molecules. We optimize synthesis and reforming processes and plants, incorporating material/energy integration and costs models. Leveraging advanced techno-economic assessments, we evaluate and optimize electrolysis systems and hydrogen-based infrastructure for performance and cost-effectiveness. Our life cycle assessment methodologies enable the environmental comparison of processes and products in the light of current as well as future economies and production processes.

Our services include:

- Identification of the most promising locations for hydrogen and Power-to-X hubs worldwide
- Geo-techno-economic analysis of regional and global hydrogen production and supply chains
- Optimization of Power-to-X plant configurations and systems
- Development and assessment of advanced operating concepts and business models for electrolyzers
- Process optimization and cost analysis for advanced synthesis and reforming processes
- Prospective LCA to analyze environmental impacts, resource use, and energy requirements under future conditions
- Analysis of the optimal means of transport and distribution of hydrogen and its derivates from the production site to the point of application/usage