To the Media

Ulm, April 2, 2026

Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)

Location: Helmholtzstraße 8
89081 Ulm

Hydrogen power for the maritime energy transition: ZSW presents concept for the world's largest PEM fuel cell stack

Powering ships over long distances efficiently and without emissions is a key step toward the decarbonization of shipping. ZSW has developed a large-format PEM fuel cell stack specifically designed for maritime and stationary, hydrogen-powered applications. With an active cell area of 1,300 square centimeters, the stack delivers up to 500 kilowatts of total output. Initial performance and sensitivity tests were conducted at ZSW's in-house fuel cell test center in Ulm. The results confirmed the stack's previously simulated performance data, underscoring the demonstrator's technological maturity.

ZSW will present this new development along with further innovations in hydrogen, fuel cells, and electrolysis from April 20 to 24, 2026, at booth E07 in hall 11 at the Hannover Messe.

Developing fuel cells for maritime applications

Marine propulsion systems, however, require power levels in the multi-megawatt range. Current stack designs developed for passenger cars and trucks typically deliver less than 200 kilowatts. Many such stacks would have to be combined to power a ship, requiring complex interconnections and driving up costs. The large-format, high-performance stack design developed by ZSW scales to up to 500 kilowatts. It reduces space requirements and costs while simplifying the integration and maintenance of fuel cell propulsion systems in ships.

"With this large-format stack design, we demonstrate that emission-free shipping – ultimately powered by green hydrogen – is both technically feasible and economically viable. The tests confirm the performance of our stack, which sets new standards for the fuel cell industry," says Prof. Dr. Markus Hölzle, ZSW Executive Board member and head of the Electrochemical Energy Technologies division in Ulm.

The bipolar plate at the core of the stack: why design matters

The development process began with the design of the bipolar plate. It provides electrical conductivity within the stack and distributes the reaction gases – hydrogen and oxygen from the air – uniformly across the fuel cell's active area. It also plays a key role in cooling the stack.

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This cooling function is critical. Larger active areas generate more waste heat that has to be dissipated as uniformly as possible. The researchers therefore used CFD simulations to iteratively optimize the flow field design of the graphite bipolar plate. After multiple optimization cycles, bipolar plates with an active area of more than 1,300 square centimeters were obtained.

To ensure reliable sealing and stable electrical contact between the bipolar plate and the gas diffusion layer, the stacked plates are clamped with a force of around 150 kilonewtons (approximately 10 bar). The clamping system developed for this purpose – comprising disc springs, threaded rods, and end plates – was designed by ZSW researchers using FEM simulations and subsequently manufactured by specialized companies on behalf of ZSW.

Demonstrator performs well on the test bench

Seals were applied directly to the bipolar plates using a precision jet dispenser and then thermally cured in the production area of HyFaB, ZSW’s research facility for hydrogen fuel cells in Ulm. The institute’s research team also made the seven-layer membrane electrode assemblies required for the fuel cell stack in-house.

Building on these developments, ZSW assembled and validated an initial short stack with 15 cells at its in-house HyFaB test center. The stack delivered around 25 kilowatts of power and generated an electric current of over 3,000 amperes under these conditions. When scaled to a full stack with 300 cells, this corresponds to 500 kilowatts. The test results confirmed stable operation of the fuel cell stack at this high power level without local overheating.

The maritime fuel cell stack will also be presented by ZSW researcher Frank Häußler at the Hannover Messe as part of the Hydrogen + Fuel Cells Europe Masterclass: www.hannovermesse.de/veranstaltung/hydrogen-fuel-cells-europe-masterclass/mc/71538.

Optimized area and stack height for maximum power

Fuel cells consist of individual cells stacked on top of one another, each comprising a membrane electrode assembly and a bipolar plate. When high power output is required, the active area – that is, the size of these components – is increased first, as a larger area results in higher current flow through the fuel cell. However, there are limits to how far the area can be increased. In a second step, multiple layers are stacked, increasing the voltage of the fuel cell stack. Power is the product of current and voltage, so it increases with both the area and the stack height.

Bipolar plates for automotive applications are typically made of stainless steel, a lightweight material that can be manufactured in very thin gauges. Large-area fuel cells like those used in shipping require graphite bipolar plates, as they remain dimensionally stable and flat even at larger scales – a property difficult to achieve with stainless steel beyond a certain size.

Many years' experience and leading-edge infrastructure

With more than 30 years' experience in fuel cell research and development, ZSW in Ulm has produced over 1,600 stacks with power outputs ranging from 50 watts to 150 kilowatts. At the HyFaB fuel cell research facility, ZSW operates one of Europe’s largest test centers with 50 test benches for power testing up to 250 kilowatts. The facility also hosts HyLaB, one of only three independent laboratories worldwide dedicated to hydrogen analysis.

ZSW provides an open, scalable stack design for research and development called the Generic Stack. Developed in-house, it supports both stationary and mobile applications and covers power outputs of up to 150 kilowatts. The platform serves as a standard for collaborative research projects with industry partners.

The institute collaborates closely with partners in industry and academia to maintain a technological edge and accelerate the transfer of research results into industrial applications. Among these partners are Fraunhofer ISE in Freiburg and the VDMA, both involved in HyFaB.

PEM fuel cells: clean, efficient, and versatile

PEM (proton exchange membrane) fuel cells convert hydrogen and oxygen directly into electrical energy, producing only water during operation. Their high power density, fast response, and modular design make them ideal for mobile applications in trucks, buses, passenger cars, and ships, as well as for stationary power generation. With its large-format 1,300-square-centimeter stack concept, ZSW has delivered powerful technological impetus to drive the deployment of PEM fuel cells in applications such as climate-neutral shipping. The stack concept is also suitable for stationary applications, such as converting hydrogen back into electricity.

About the ZSW

The Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) is one of the leading institutes for applied research in the major topics of the energy transition: Photovoltaics, wind energy, batteries, fuel cells, electrolysis, eFuels, circular economy, policy advice and the use of AI for process

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and system optimisation. Together with industry, we pave the way for new technologies to enter the market. More than 300 colleagues and around 100 scientific and student assistants work at the ZSW locations in Stuttgart and Ulm. The ZSW operates a test field for wind energy and another test field for PV systems. The ZSW is a member of the Baden-Württemberg Innovation Alliance (innBW), an alliance of ten business-related research institutions.

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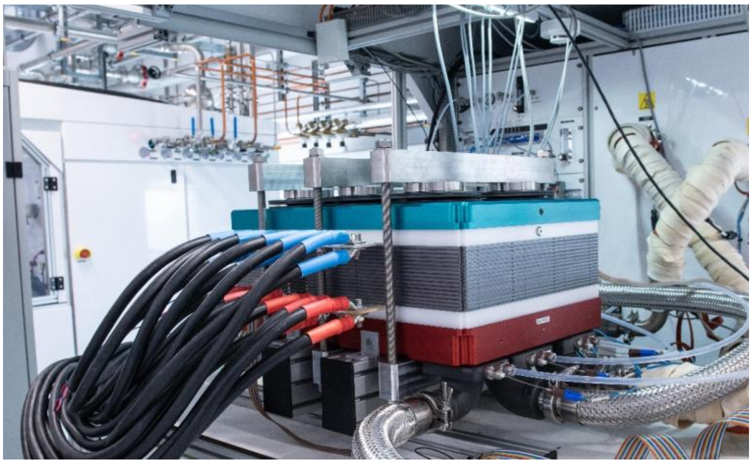

ZSW presents a concept for the world’s largest PEM fuel cell stack with an active area of 1,300 square centimeters: shown is 15-cell demonstrator on the test bench at HyFaB. Image: ZSW / Elvira Eberhardt.

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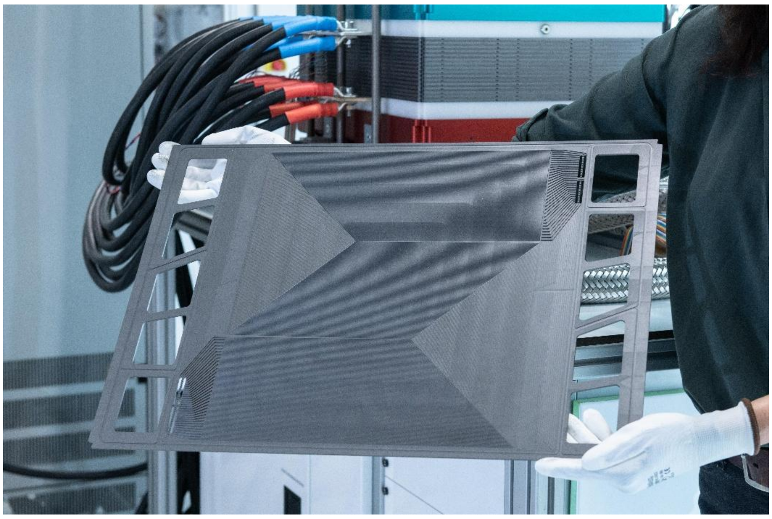
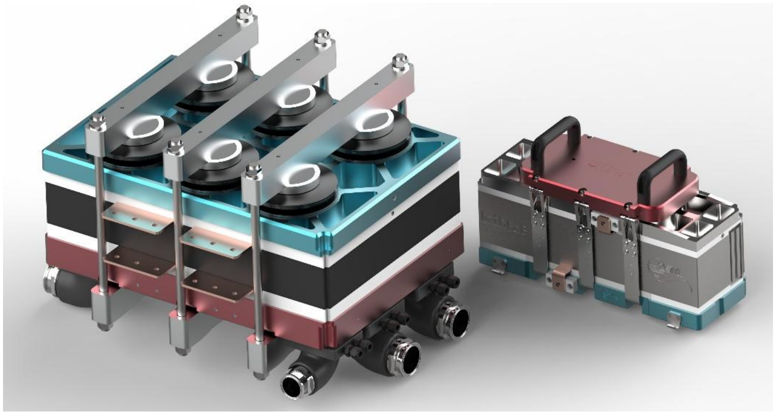


ZSW presents a concept for the world's largest PEM fuel cell stack with an active area of 1,300 square centimeters: shown is the 1,300 square centimeter graphite bipolar plate. Photo: ZSW / Elvira Eberhardt.



ZSW presents a concept for the world's largest PEM fuel cell stack with an active area of 1,300 square centimeters: shown is the 1,300 square centimeter stack as a short stack with 15 cells, compared in size to the generic stack with 100 cells. CAD design: ZSW