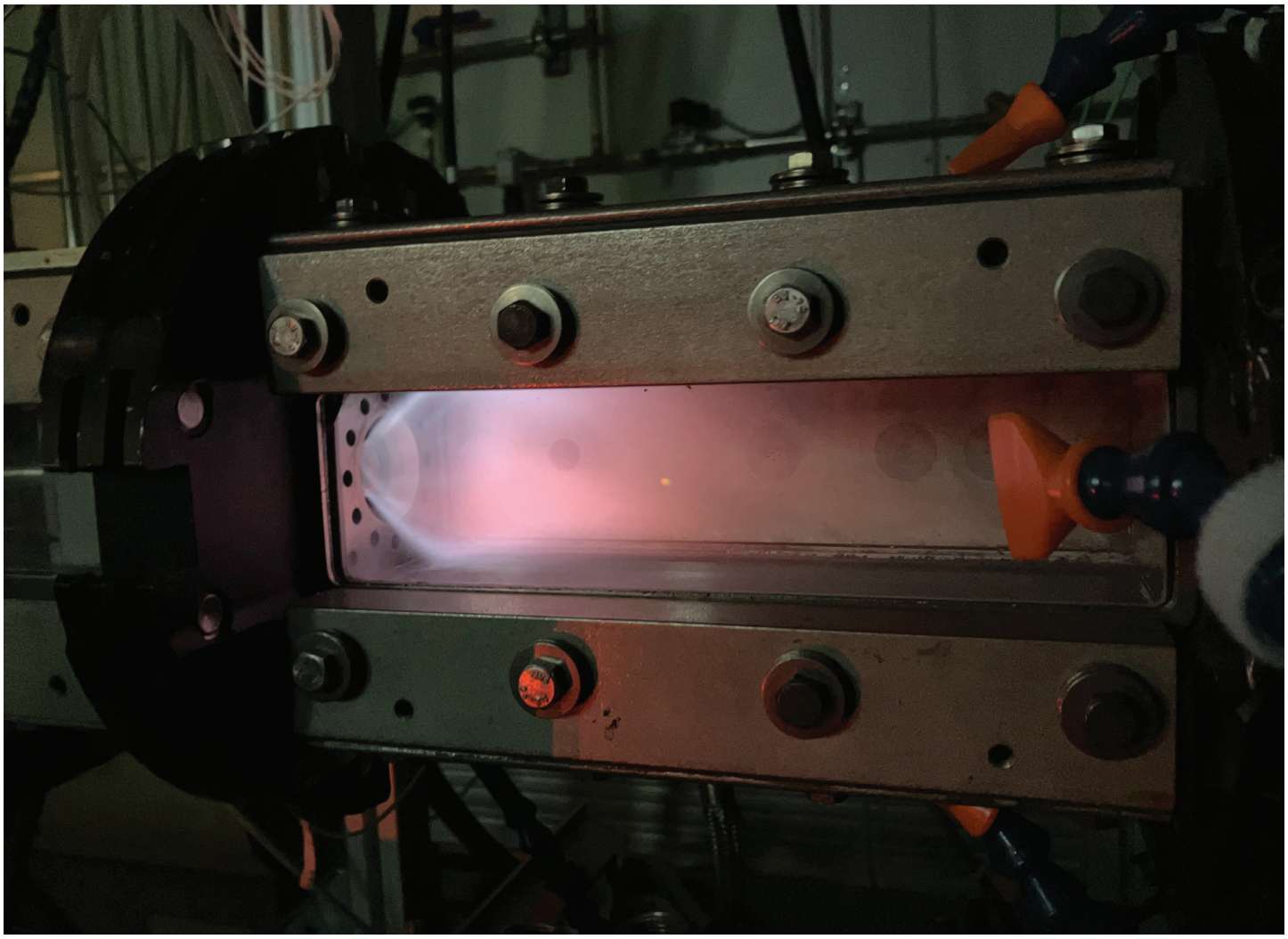
COMBUSTION REINVENTED

Combustion processes are often associated with pollutant emissions and also with harmful greenhouse CO_2 emissions. However, clean and climate-neutral combustion processes can also be developed. Researchers are currently working feverishly on forward-looking solutions. This was demonstrated at this year›s conference on Swiss combustion research in Zurich at the beginning of February.



Hydrogen flames (photo) may cause thermo-acoustic instabilities that can lead to unwanted vibrations of the engines. To enable the use of hydrogen in aircraft engines, ETH Zurich is developing methods to predict and control the instabilities. Photo: ETHZ

Technical article on the findings of the ‹Conference on Combustion Research in Switzerland 2024› held on 1 February 2024 at ETH Zurich, which was supported by the Swiss Federal Office of Energy. The article was published in the specialist magazine Aqua&Gas (issue March 2024).

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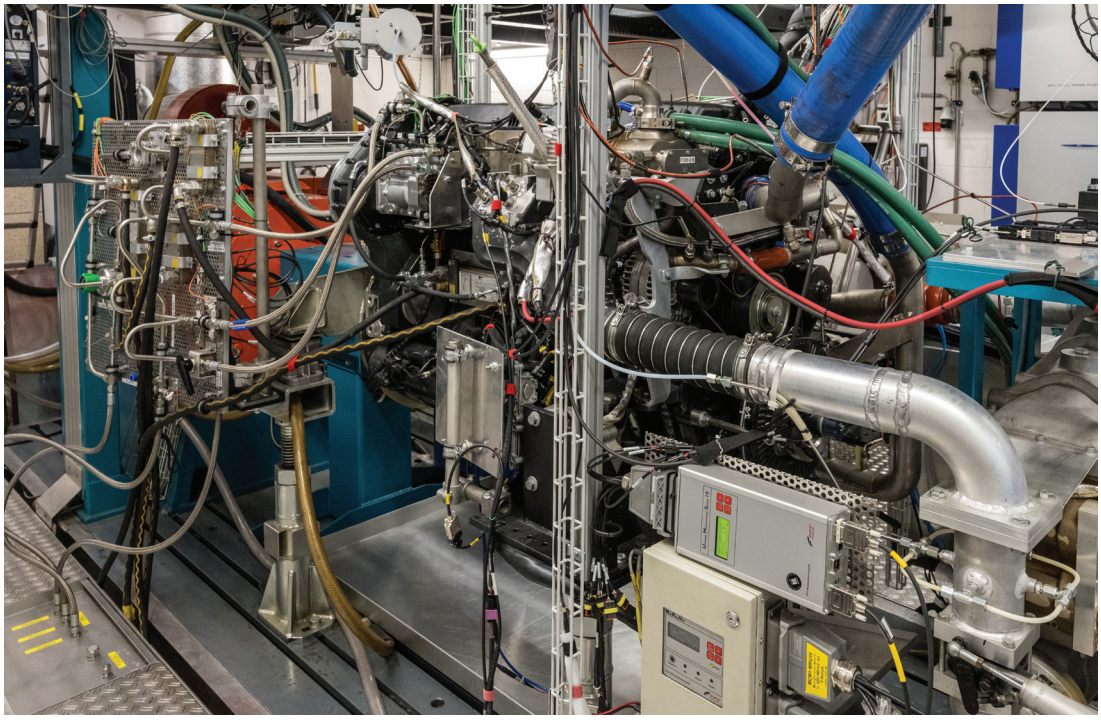
Because of its greenhouse gas emissions, one industry that has been the focus of the climate debate is aviation. As a solution, many are discussing the replacement of the fossil fuel kerosene with hydrogen, for example. The European Union is supporting the idea with the €80 million project HYDEA project. The research consortium has an ambitious time frame: It aims to comprehensively demonstrate the feasibility of hydrogen propulsion in an aircraft engine by 2026, including ground testing. To this end, the gas turbines that have been powering aircraft thus far are to be fueled with hydrogen instead of kerosene. The idea is that the hydrogen would be produced using decarbonized electricity by means of electrolysis. This would mean that aircraft would be able to operate without fossil fuels in the future.

Hydrogen in gas-fired power plants

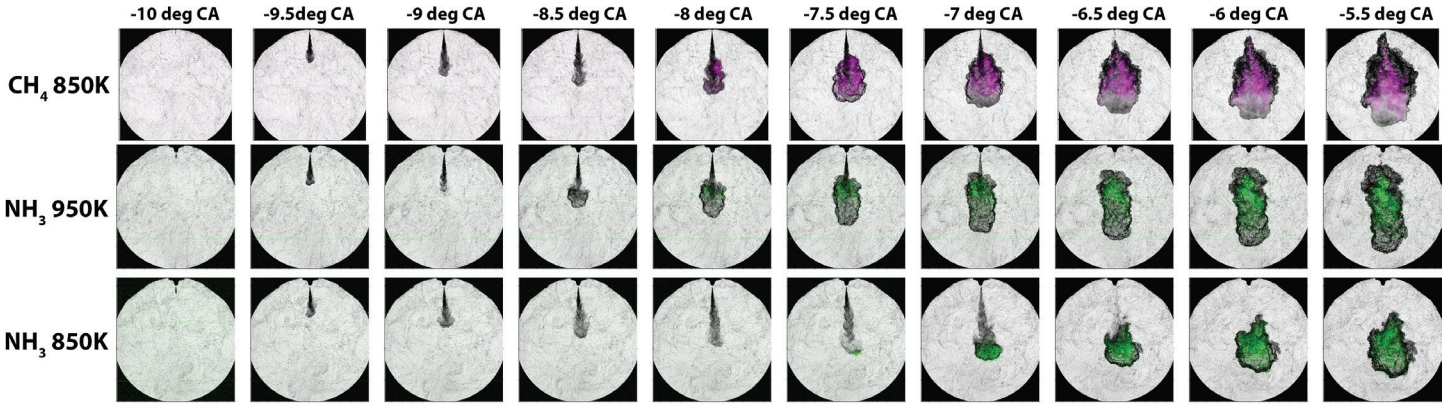
The HYDEA project includes researchers from Switzerland. At the Swiss Federal Institute of Technology (ETH) Zurich, Professor Nicolas Noiray in the department of Mechanical and Process Engineering is leading two projects in relation to H_2 fueled aircraft engines. One aims to ensure that highly reactive hydrogen (H_2) burns in a controlled manner and without causing instabilities. The second project aims to minimize nitrogen oxide (NO_x) emissions during the combustion process.

Hydrogen as an energy source and its contribution to a sustainable energy supply was the main focus of this year›s conference on Swiss combustion research. The event takes place every two years at ETH Zurich, with support from the SFOE. "Renewable" hydrogen is not only intended to make aviation climate-friendly, it could also be used in electricity production and in industrial processes in the future. To this end, Switzerland is working on a national hydrogen strategy, which the Federal Council intends to finalize before the end of this year.

To secure its energy supply and be able to balance the intermittency of wind and solar sources, Germany is also discussing constructing gas-fired power plants that can be operated with hydrogen. A power plant park with a capacity on the order of several nuclear power plants is being discussed. Even if nothing has been decided, such power plants might be an important step towards decarbonization by maintaining the grid stability and satisfying the electricity demand. The power plant industry is doing everything it can to meet political expectations by developing "hydrogen-enabled" gas-fired power plants. "Currently, our single-stage gas turbines can use natural gas that consists of 40% hydrogen, our two-stage GT36 can even operate on up to 70% hydrogen," said Andrea Ciani, hydrogen expert at the Italian power plant group Ansaldo Energia in Baden. «In a research project funded by Switzerland and the EU, we are working toward being able to operate a prototype of the two-stage, sequential GT36 combustion engine with pure hydrogen by 2026," he adds.



At this Empa test bench, researchers are investigating emissions from the combustion of DME, among other things. The test bench is made from a converted truck diesel engine with an output of 338 kW. Photo: Empa



Data on combustion of methane (top) and ammonia (middle and bottom), collected on the optical Flex-OeCoS test bench at the FHNW in Windisch. The sequences of images show that ammonia ignites more slowly than methane. Photo: FHNW

In the coming years and decades, hydrogen is expected to gradually replace the natural gas methane as fuel. Therefore, manufacturers will need to develop gas turbines that can run on 0 to 100% hydrogen. "In order to make our gas turbines fit for hydrogen, cooperation with academic combustion researchers is very important," said Layal Hakim, combustion expert at GE Vernova, the independent energy division of the U.S. company General Electric. Combustion research is trying to answer a range of questions relating to the stability of combustion, or the avoidance of flashbacks of extremely reactive hydrogen. What is needed are experimental data and models that adequately describe the combustion processes.

"Most underestimated" energy source DME

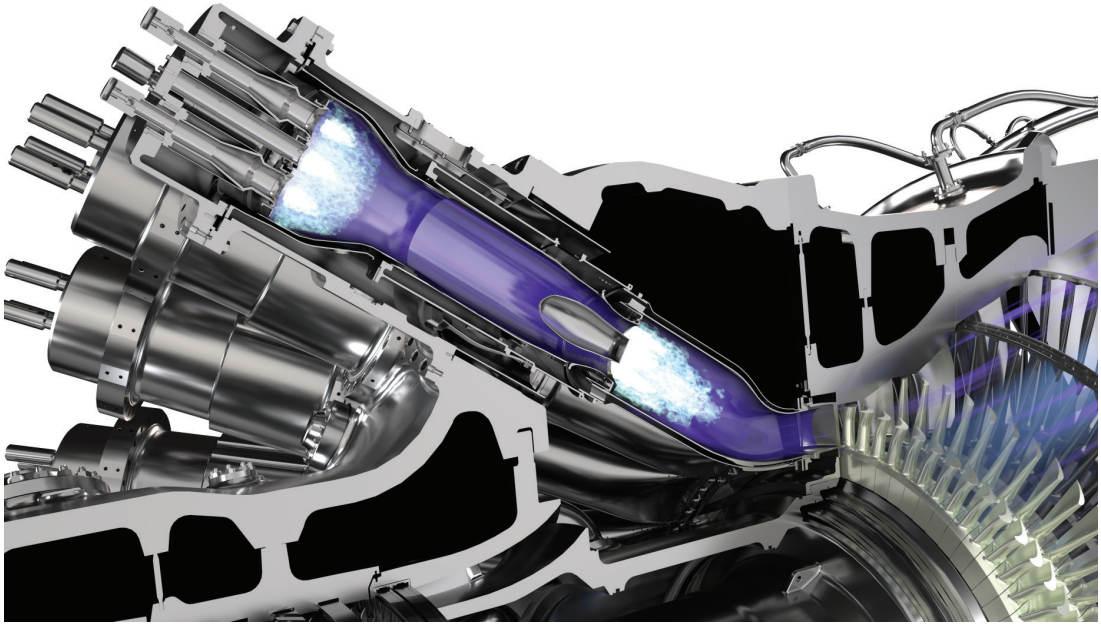
Hydrogen has been on everyone's lips – but it is by no means the only source of a sustainable fuel supply. Methane, methanol, ammonia and dimethyl ether, or DME, also have potential in this regard. Patrik Soltic and his team at the Swiss Federal Laboratories for Materials Science, or Empa, together with their industrial partner FPT Motorenforschung AG, are researching an efficient and very low-emission engine that runs on DME (C_2H_6O). For Soltic, DME is "possibly the most underestimated energy source politically and economically." Although little known, it has numerous advantages. Unlike hydrogen, it does not need to be frozen to be stored and transported, and it has a higher energy density. According to Soltic, DME can be produced in windy or sunny locations, transported to Switzerland and used (directly or reconverted into hydrogen) for energy.

Another possible future fuel is ammonia (NH_3). In Switzerland, NH_3 is being researched at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in Windisch, among other places. Like DME, ammonia is relatively easy to transport, it can be produced from renewable sources and contains no carbon. FHNW Professor Kai Herrmann reported on experiments on the Flex-OeCoS optical test bench. The goal of his research, among other things, is to accelerate the ignition and reactivity of the comparatively inert substance by adding small amounts of hydrogen (which can be obtained directly from NH_3 via a reformer). Another research goal is to reduce climate-damaging nitrous oxide emissions during the combustion process.

Developers are pressed for time

The fight against climate change is urgent. The world needs solutions as soon as possible. In Zurich, German Weisser, representing the marine engine developer WinGD in Winterthur, made it clear that engines must be developed under great time pressure. "Due to new regulatory requirements and demand from our customers, we are under great pressure to develop marine engines that can be operated with sustainable fuels such as methanol or ammonia in the shortest possible time," Weisser said.

As great as the political pressure may be, research takes time. Complex questions about combustion processes must be answered, as the Zurich conference showed. Empa doctoral student Michelangelo Balmelli reported on his research on combustion processes for efficient hydrogen engines. He vividly demonstrated that a hydrogen jet can be ignited at the periphery and then burned in a diffusion-controlled manner, similar to a diesel fueled jet engine. A second demonstration was provided by Professor Oliver Kröcher at the Paul Scherrer



The Ansaldo Energia Group plans to use a gas turbine with a sequential two-stage combustion chamber to burn fuels with a high hydrogen content. This type of combustion chamber makes it possible to tune the operating parameters of the combustion chamber to hydrogen without affecting the efficiency or performance of the gas turbine. Illustration: Ansaldo Energia

Institute (PSI) in Villigen. He is working on the basics for the future development of an exhaust gas purification system for ammonia engines. He uses the zeolite group of substances to remove climate-damaging nitrous oxide (N_2O) and nitrogen oxides (NO_x) from combustion gas.

In addition to electrification, sustainable fuels are important

Research into sustainable fuels is yielding many approaches that could contribute to the decarbonization of transport via air, water and land. "In addition to the electrification of transport, sustainable combustibles and fuels are likely to be of great importance in the future, even if the areas of application are not yet foreseeable in detail," says Stephan Renz, head of the SFOE research program Combustion Based Energy Systems.

↗ For further **information** on SFOE-funded research projects, please contact St. Renz (info@renzconsulting.ch), external head of the SFOE research program Combustion Based Energy Systems.

↗ Further **articles** on research, pilot, demonstration and flagship projects in the field of combustion can be found at www.bfe.admin.ch/ec-verbrennung.

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Version: March 2024