Under **high pressure**

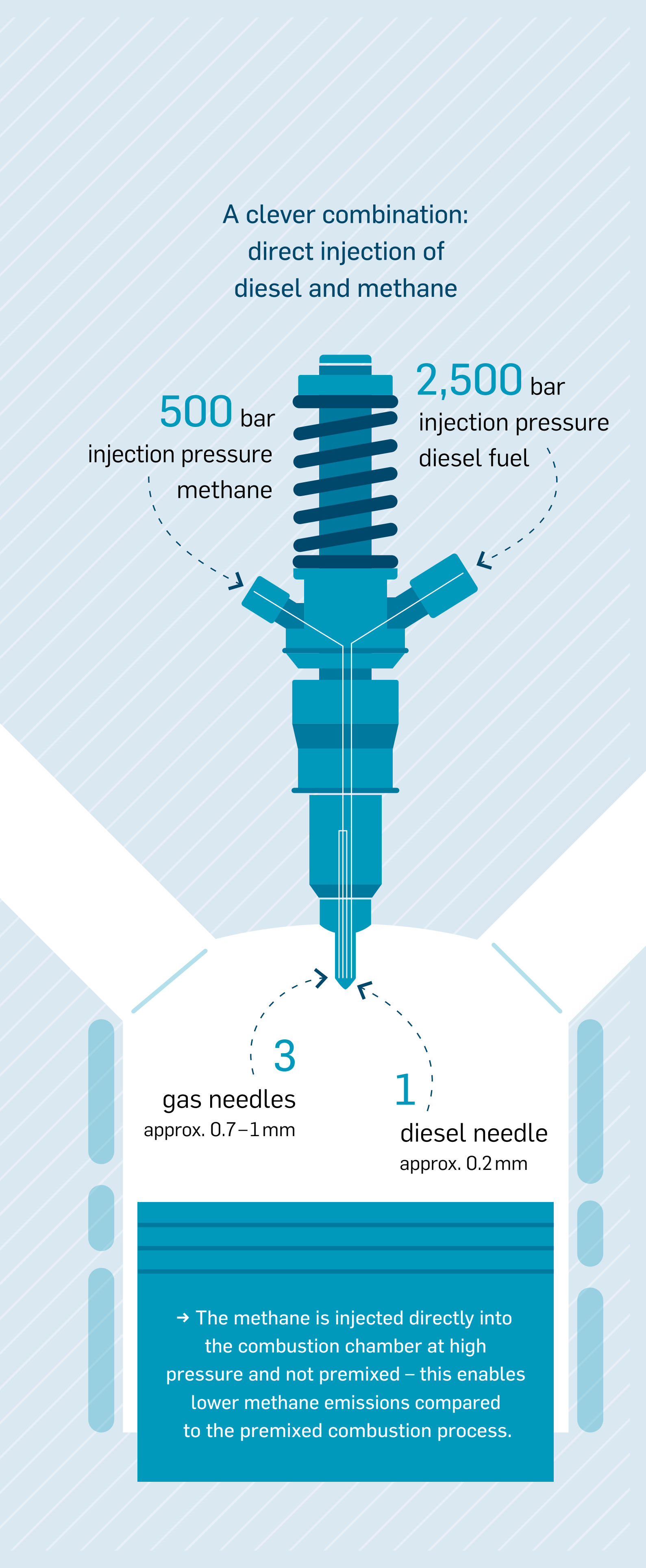
Gas engines can play a significant role in achieving the climate goals – if methane slip can be successfully avoided. In an FVV project, researchers from Zurich and Munich investigated a new gas-diesel combustion process with this aim in mind.

Gas-diesel combustion process // In the field of engine development, there is seldom the opportunity to save large amounts of CO_2 with a single process. Gas engines have the potential to do just this: if an injection and combustion process similar to that of a diesel engine can be realised, a gas engine would emit around a third less CO_2 per kilowatt hour of mechanical energy in total. In addition, performance could be increased, as the process similar to diesel is not naturally limited by uncontrolled auto-ignition. However, the conditional tense is no accident: due to the complexity of the process, it is not easy to bring high-pressure gas injection for gas engines to commercial maturity.

While gas engines in cars are conventionally realised on the basis of spark-ignition engines, a process similar to diesel is suitable for large and stationary engines – which enables a degree of efficiency of almost 50 %. A further advantage of the diesel-like process is that, in contrast to the process used in spark-ignition engines, hardly any unburned methane is produced. It is essential to prevent this material escaping into the atmosphere, as methane is a greenhouse gas 30 times as potent as CO_2.

However, there is still a lack of basic understanding of the injection, ignition and combustion procedure. In the recently completed FVV project on a gas-diesel combustion process, researchers from ETH Zurich and Universität der Bundeswehr München (UniBw Munich) jointly developed simulation methods and validated them in experiments.

»Our task was to use experimental and numerical techniques to find out exactly what happens in the combustion chamber, how the gas jet spreads out, mixes with air and ignites, and whether methane condenses at the nozzle exit,« explains Prof. Dr. Konstantinos Boulouchos, Head of the Aerothermochemistry and Combustion Systems Laboratory at ETH Zurich. In collabora-



tion with UniBw Munich, the aim was to validate the developed flow simulation tools in order to predict how a high-pressure injection procedure for gas engines can be realised.

At the Institute of Energy Technology at ETH Zurich, a number of test devices allow engine-like conditions to be created. In a heated constant volume chamber, temperatures and pressure can be approximately simulated in the manner in which they would occur in a diesel engine. The project partner Woodward L'Orange from Stuttgart provided prototype injectors. These are significantly different to those used in a diesel engine: nozzle design for gas engines is generally much simpler, as there are no cavitation phenomena. »But because the methane is ignited by a further diesel injector that is integrated with the gas nozzles in a housing during the gas-diesel combustion process, the injector as a whole is relatively complex,« reports Dr. Michael Willmann, Senior Manager New Technologies at Woodward L'Orange and Chair of the FVV research project. The simulation results gained during the project are being incorporated in design models, enabling future injectors working according to this functional principle to be designed even more effectively and allowing us to better understand combustion results.

The researchers in Zurich and Munich experimented with different injection pressures and durations, as well as various compression ratios. »The special thing about the chamber is that we have an optical port with which we can observe the dispersion of the gas in the combustion chamber, among other things,« comments Professor Boulouchos. To this end, the researchers used various procedures. The schlieren technique makes it possible to see how far the gas jet goes and how the gas spreads out in the combustion chamber. This qualitative method is based on the density gradient of the working medium – because the gas has a different density to air, the dispersion of the gas jet is visible.

The experts need a laser-based measuring procedure to quantitatively detect the concentration of methane within the gas jet. Stimulated by the laser, the methane fluoresces and the signal is picked up by a camera with a high spatial and temporal resolution. In addition, using the Mie scattering method, in which the scattered light of droplets is detected, the researchers investigated whether methane condenses. Comprehensive simulations on this had already been conducted at UniBW Munich. Here it became apparent that methane can condense to a liquid state under certain conditions, such as low pressure and temperature. »But would it also happen in an engine?« asks Professor Boulouchos, who immediately adds that droplets were no longer formed in the constant volume chamber under realistic conditions. »That answered the question for us: no condensation can be expected in engine applications,« states Boulouchos.

→ CO_2 is saved simply by switching from liquid fuel to methane.

–25 %
CO_2 emissions

→ If the thermodynamic potential of diesel is also used, gas engines achieve far higher degrees of efficiency.

Up to **50 %**
efficiency

Project data

→ »Gas-Diesel Combustion [1236]: Improvement of understanding of penetration and ignition behaviour of high-pressure gas jets in Gas-Diesel combustion systems«

→ **PROJECT FUNDING**
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→ **PLANNING GROUP**
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→ **PROJECT COORDINATOR**
Dr. Michael Willmann, Woodward L'Orange

→ **RTD PERFORMERS**
Institute of Energy Technology (IET), Aerothermochemistry and Combustion Systems Laboratory (LAV), ETH Zurich // Institute for Thermodynamics, Universität der Bundeswehr München (UniBw M)

Photo: B. Schneider, LAV | ETH Zurich

The experts at UniBw Munich simulated the process in the nozzle up to the area close to the nozzle in the combustion chamber. Supersonic flows occur here when the gas is injected at up to 500 bar and the counterpressure in the cylinder is only 100 bar. In addition, methane does not behave as an ideal gas under these conditions – but rather as a real gas, which necessitates new simulation models. ETH Zurich was responsible for both the experiment and the modelling of the ignition. Methane is difficult to ignite and requires an additional ignition source. However, the classic spark plug is not an ideal solution, as the spark cannot be maintained for long enough at the extremely high gas speeds. »The question for a future research project is therefore how gas can best be ignited,« concludes Boulouchos. //