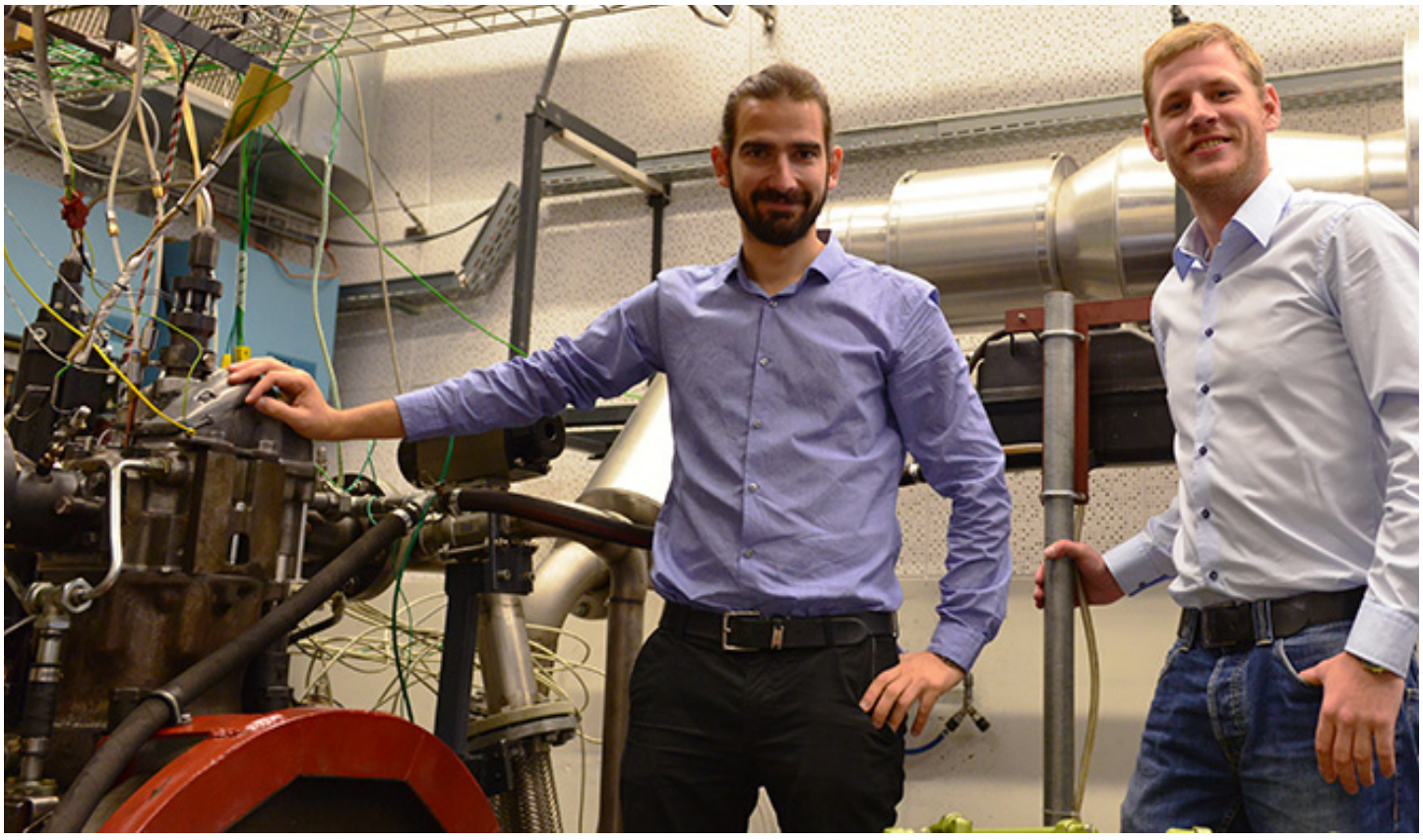
THE DOUBLE BENEFIT OF BIOFUELS

People who fuel up with diesel or gasoline sometimes don't even know that it contains biofuel. This is because small portions of biofuel do not have to be declared. Biogenic fuels account for almost 7% (diesel) and nearly 3% (gasoline) of the fuel sold in Switzerland. In the coming years, they could make a growing contribution to reducing greenhouse gas emissions in the mobility sector. This is thanks to their biogenic origin, but also to efficiency improvements in adapted engines. This is shown in a new study by a team of researchers from the Swiss Federal Institute of Technology Zurich (ETHZ) and the Swiss Federal Laboratories for Materials Testing and Research (Empa).



Dr. Christophe Barro (right) together with Dr. Panagiotis Kyrtatos. The two former ETH researchers founded the spin-off Vir2sense, which specializes in modeling the consumption and pollutant emissions of large engines. Photo: ETHZ

A technical report about the results of a research project in the field of mobility, which was financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Strassenverkehr Schweiz (issue November 2021).

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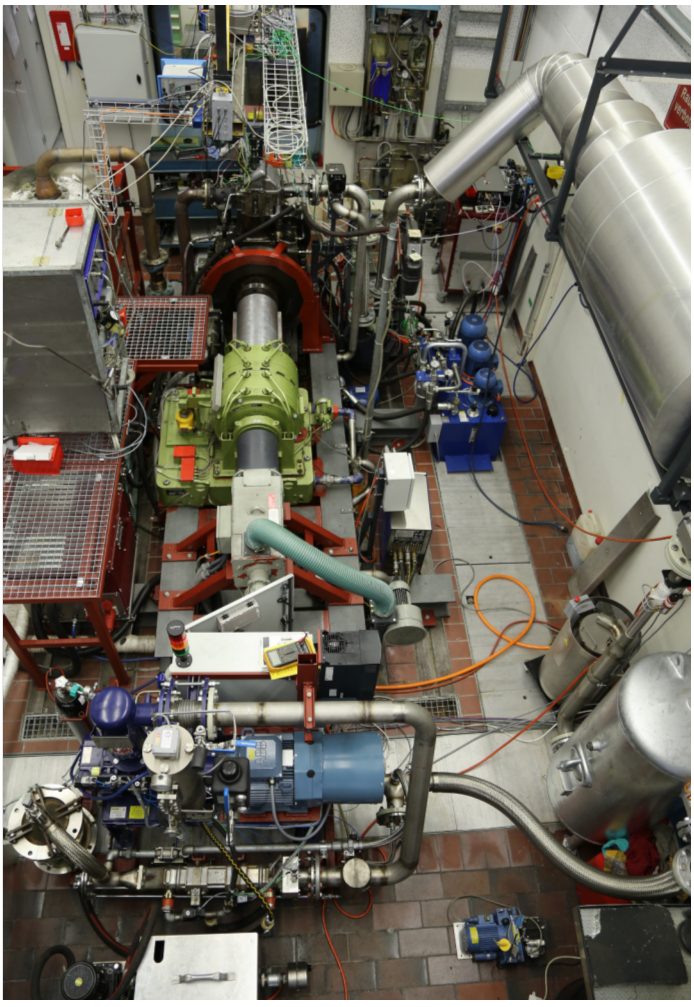
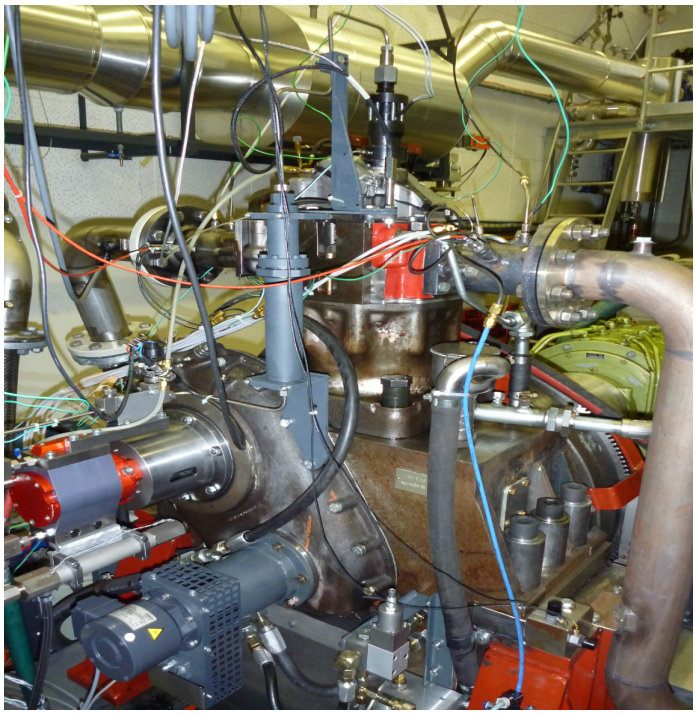
The Federal Council's net zero target for greenhouse gas reduction by 2050 can only be achieved if the mobility sector makes a significant contribution to decarbonization. This means that the fossil fuels gasoline and diesel must be replaced by other fuels and energy systems. These include fuels of biogenic origin. It is no coincidence that these fuels are the subject of current Swiss combustion research, which is focused on sustainable technologies—of which the research of former ETH researcher Dr. Christophe Barro is an example.

The trained mechanical engineer founded the start-up Vir2sense (Baar/ZG) with a colleague from ETH Zurich. The young company is dedicated to modeling the fuel consumption and pollutant emissions of large engines. Because unlike in passenger cars, for which electric drives are a serious alternative, fossil engines are still in demand in shipping or construction machinery and also in mobile power generators for open-air concerts or emergency power supply, for example. "The technology of the combustion engine will continue to accompany us for the foreseeable future, and we must find the best possible solutions here, both, on an economic as well as on a commercial basis", says Christophe Barro.



View of the (now dismantled) engine test bench in the machine hall at ETH Zurich. Here, researchers investigated the efficiency of biofuels for the ReVerDi research project. Photo: ETHZ

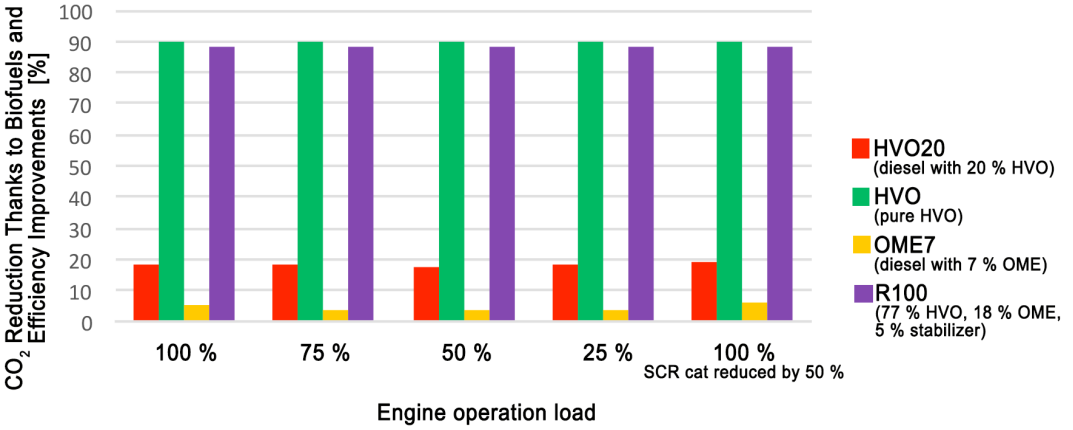


The basis of the ETHZ test bench is a single-cylinder diesel engine with a displacement volume of 4 liters, such as is used in ferries. Photo: ETHZ

Biofuels such as HVO and OME

A research project supported by the SFOE, which Barro completed at ETH in spring 2021, points in this direction: A team of researchers from ETH and Empa investigated the use of biofuels. These fuels are produced from biomass - in Switzerland, primarily biogenic waste and production residues, but also oil, sugar and starch plants worldwide. The combustion of these fuels only produces as many greenhouse gases as were absorbed by the plants during the growth of the biomass. In Switzerland, biofuels are blended with diesel and gasoline, used in gas-powered cars (biomethane) and used by farmers in tractors (mainly rapeseed oil). According to the Biofuels Switzerland Association, biogenic fuels accounted for 6.7% of nationwide diesel consumption in 2019, and 2.6% of gasoline consumption.

Biofuels today and in the future should be used with the best possible efficiency. To this end, researchers from ETH Zurich



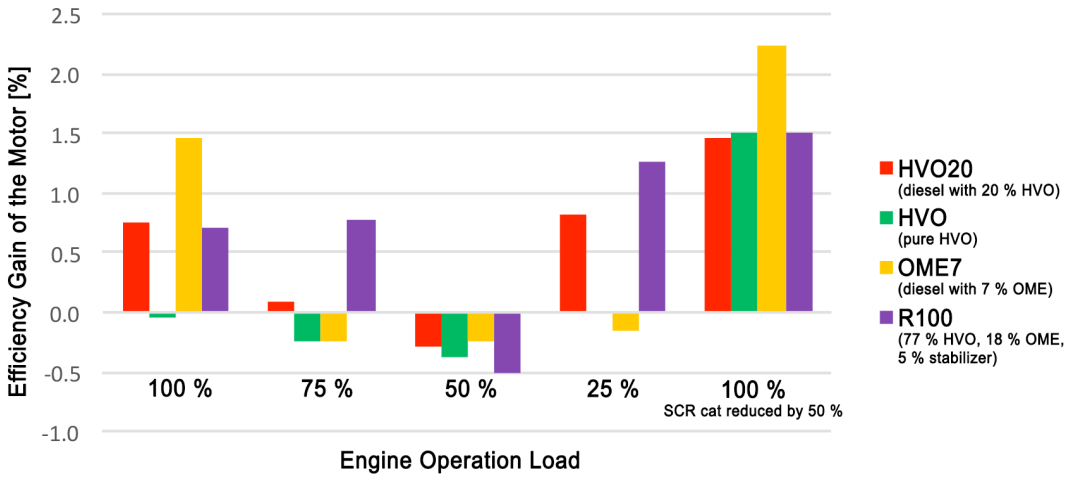
Fuels such as HVO and R100, which are virtually entirely of biogenic origin, can produce around 90% fewer CO_2 emissions than diesel, depending on their origin. In HVO20 and OME7 fuel blends, CO_2 emissions are reduced similarly depending on the proportion of biofuel they contain. Graphic: Final report ReVerDi/edited B. Vogel

and Empa have investigated the CO_2 reduction potential of two biofuels for diesel engines: One consists of hydrotreated plant oil and is known by the abbreviation HVO (for 'Hydrotreated Vegetable Oil'). HVO can be produced from different feedstocks and by different processes. The Zurich research team used HVO from the Finnish company Neste Oil, which produces HVO almost exclusively from vegetable oils and fatty waste materials. The second fuel studied is OME (short for: polyoxymethylene dimethyl ether). If OME is produced from biomass, which is one of several production processes, it is also a biofuel.

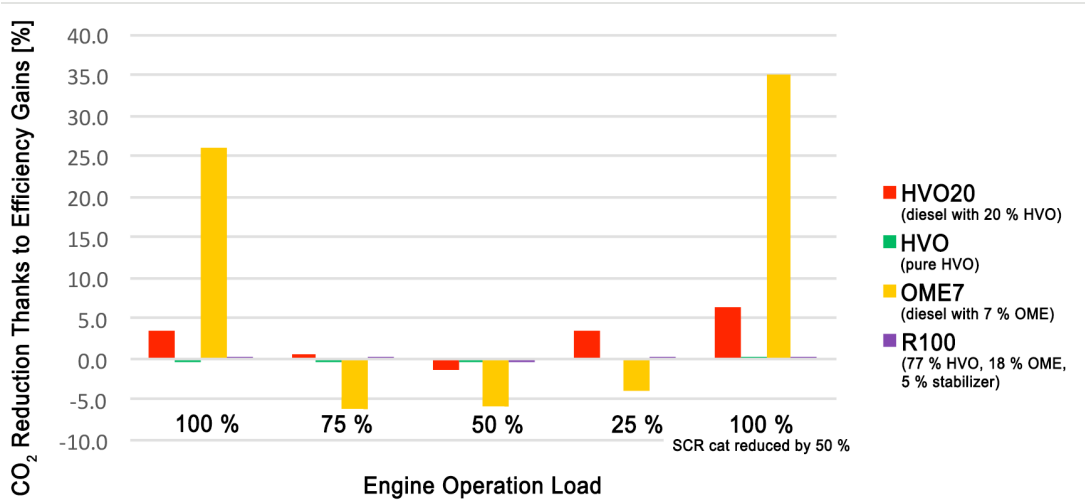
Lower Soot, Higher Power

The research team studied these two biofuels in various fuel blends and showed that biofuels improve the CO_2 balance by around 90 % (see graphic above). That the reduction is not 100% is because greenhouse gas emissions also occur during the production and transport of HVO. According to Christophe Barro, HVO in particular has the potential to contribute to achieving the net zero greenhouse gas emissions target by 2050. The C.A.R.E. diesel available in Switzerland is based on HVO. Barro is more skeptical about OME because this fuel requires a relatively large amount of energy to be produced. The advantage of OME is its high density: OME can be mixed with HVO and a stabilizer to form the biofuel R100. Unlike HVO on its own, this meets the legal density requirements for diesel.

In their project, the researchers from ETHZ and Empa also investigated how maximum drive energy can be extracted from biofuels, i.e. how maximum efficiency gains can be achieved. The background to this research approach is the fact that diesel vehicles powered by biofuels require less energy to regenerate the soot particle filter, since biofuels contain fewer ring-shaped (aromatic) hydrocarbon compounds than diesel fuel and thus are less prone to produce soot. If the engine's software is set correctly, the savings in the particulate filter can be converted into additional drive energy. In the best



Since biofuels are less prone to form soot, they place less strain on the soot particle filter. The energy saved in this way can be converted into efficiency gains of the drive energy. Depending on the fuel or fuel mixture, this amounts to a good two percent. Graphic: Final report ReVerDi/edited B. Vogel



For the pure biofuels (HVO, R100), the additional CO_2 savings are hardly significant due to the efficiency gain. The situation is different for fuel blends containing only a proportion of biofuels (HVO20, OME7). Graphic: Final report ReVerDi/ edited B. Vogel

case, the efficiency gains achieved in this way amount to a good two percent (see Fig. p.4 at the bottom).

Optimum Use of Fuel

Interestingly, this gain in efficiency can be harvested not only when a vehicle is fuelled exclusively with biofuel, but also when the biofuel is included only proportionally in the fuel mixture. The achievable efficiency gain is strongly dependent on the engine configuration (for example, high- or low-pressure exhaust gas recirculation, space velocity in exhaust gas after treatment). Since many relevant effects are non-linear, the benefits of biofuels are noticeable in some cases even in small portions. Christophe Barro describes the practical significance of this finding: "In certain engine configurations, you get a higher overall efficiency gain if you fuel five vehicles with a blend of 80% diesel and 20% HVO than if you fuel one vehicle with 100% HVO and the other four with pure diesel. With the simulation platform we developed, you find out very quickly how to optimally use a particular biofuel."

The efficiency gains from the chemical composition of biofuels enable a CO_2 reduction, because one joule (amount of energy) of fuel results in greater mileage than diesel. However, this CO_2 reduction is rather small when compared to the CO_2 reduction due to the biogenic origin of the fuel (see chart above).

Measurements at the ETHZ Test Bench

The engine experiments and fuel tests were carried out on a test rig at ETH Zurich. This is based on a single-cylinder diesel engine with 4 liters of displacement volume, i.e. a powerful heavy-duty engine type typically used in a ferry with six to 16 cylinders. The measurements were supplemented by simulations of an engine with a displacement volume of 12 liters, such as installed in a truck or construction machine.

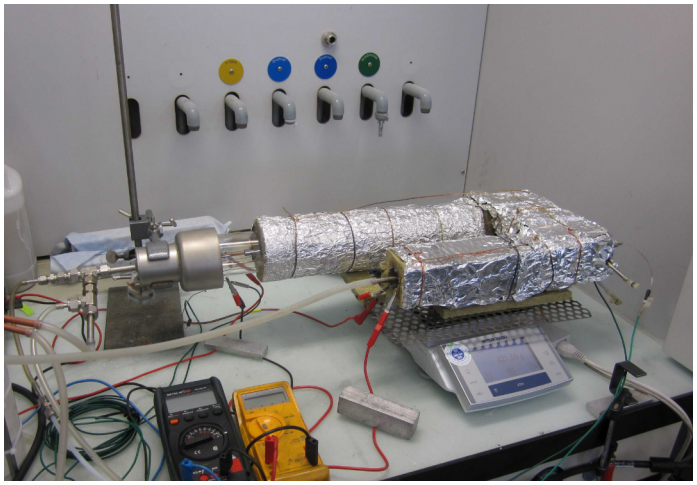
The results of the ReVerDi project are fundamentally important for the decarbonization of the mobility sector, as Dr. Luca Castiglioni, responsible for the SFOE's Mobility Research Program, says: "Biogenic fuels such as OME or HVO can be blended with gasoline and diesel to a much greater percentage than is the case today, and this without sacrificing performance and with a significant reduction in CO_2 emissions. Sin-

FOUR PROJECT PARTNERS

The research work on the ReVerDi project is primarily based on the preliminary work of the NextICE project, in which a team of researchers from ETHZ and Empa also investigated the use of biogenic fuels and fuels produced synthetically with renewable electricity (e-fuels) in combustion engines (see article 'Ein Motor gemacht für erneuerbare Triebstoffe': https://pubdb.bfe.admin.ch/de/publication/download/9725). In the present project, Empa focused its work on the area of exhaust gas after treatment, while the start-up companies Vir2sense and Combustion and Flow Solutions GmbH (Zurich) contributed with the modeling. In the course of ReVerDi, a modular simulation system was developed to enable the optimization of engine and exhaust gas after treatment with different component configuration and different fuels. BV

ce such blends can also be used in conventional car and truck engines, they also allow rapid CO_2 reductions in the current vehicle fleet."

- The **final report** on the SFOE research project 'Platform to reduce fuel consumption and CO_2 emissions of diesel power units using optimized operation and alternative fuels' (ReVerDi) can be found at: www.aramis.admin.ch/Grunddaten/?ProjectID=41489
- For **information** on the project, please contact Dr. Luca Castiglioni (luca.castiglioni[at]bfe.admin.ch), Head of the SFOE Mobility Research Program.
- For more **technical papers** on research, pilot, demonstration and flagship projects in the field of mobility, visit www.bfe.admin.ch/ec-mobilitaet.



Empa researched the aspect of exhaust gas aftertreatment in the ReVerDi project. In the picture: Test set-up to investigate the regeneration of the diesel particulate filter. Photo: Empa

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