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Drive CLEVER with natural gas and electricity

Empa has played a major part in the development of natural gas cars that are suitable for everyday use. Now comes the next chapter – the CLEVER natural gas hybrid car. The test vehicle has just driven its first few laps with EmpaNews sitting at the helm.

TEXT: Rainer Klose / PICTURES: Empa

From the outside the vehicle looks like a normal 2007 model of the VW Touran. But lurking under the bonnet is a revolution – a drive concept that has never been seen before and is now being researched and developed at Empa. It's a sunny September afternoon, and the CLEVER, the world's first natural gas full hybrid vehicle with manual transmission, is ready for its maiden test drive at the Empa Motorenhaus.

Initially the vehicle is still sits on the roller dynamometer, on which the fine tuning of the drive systems takes place. Before the journey commences, project leader Patrik Soltic explains how the project arose, and what the vehicle can do: Empa has been researching natural gas engines for several years. One of the world's first natural gas turbo cars was created on the Dübendorf premises, where combustion methods were researched that made it possible to start an engine directly by using natural gas – without petrol as a starting aid. The technology, developed at Empa, has now been on the road for quite some time: economical, reliable and powerful natural gas turbo engines are available today from VW, Opel and Fiat.

Saving money

Empa is now taking things further: "A natural gas hybrid powertrain would make a medium class vehicle about 20 percent more expensive – but it would save up to 45 percent CO_2" explains Soltic. "This potential of saving greenhouse gas emissions could be extremely interesting, particularly to fleet operators." Professional car buyers are not just interested in the purchase price of the vehicle, but also in the "Total Cost of Ownership" (TCO) – the overall costs over the entire service life of the vehicle.

Rather than just running through the entire model theoretically, Empa decided to build a real vehicle that could be tested in the field. At the same time, Soltic's team developed new concepts for more efficient natural gas combustion on the engine test benches at Empa. The ETH Zurich also is involved as a partner: the research group managed by Konstantinos Boulouchos researches the basics of combustion processes by simulating the flow and combustion behaviour of fuels in the cylinder on the compute. The research group managed by Lino Guzzella provides the theoretical basics for controlling the hybrid control systems and the dimensioning of the components. Industrial partners Volkswagen and Bosch aditionally provide series production technology in order to ensure that the

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The CLEVER on its first drive on the Empa campus. The exterior of the VW Touran is unchanged.

2
The 4.5 kWh battery is accommodated in the luggage compartment. The module originates from ETH Zürich and has already proven itself in the "Formula Student" race series. Empa developed the power electronics.

3
The heart of the hybrid drive is the electric motor, which sits in front of the rear axle in the underbody.

4
An additional display on the dashboard provides the driver with information and gear changing advice.

CLEVER test car can be put on its wheels. But Empa researcher Soltic likes to emphasise: “The idea of a natural gas hybrid with manual gear changes is not one of the company strategies of our industrial partners”. “However, I am certain that they will be taking a close look at our results”, he says.

A “stripped” VW Touran

The beginnings of the CLEVER project go back to the year 2007. The goal was to combine a hybrid system with a natural gas combustion engine. However, the 2008 car crisis put the stoppers on everything: many suppliers ended up in difficulties, and agreements were broken. This meant that special pistons for the engine could not be delivered. The project ground to a halt. However, the delay also had some advantages: In 2009 some automotive components that had been specially designed for Hybrid vehicles suddenly became available that did not previously exist.

Finally the Touran on which the CLEVER is based could be stripped and reconstructed at Empa. Its conventional 1.6 litre engine ended up on the shelf, and a 1.4 litre natural gas turbo engine was installed under the bonnet. Another series-produced component from VW provides the power-coupling of the electric engine and the petrol engine: the all-wheel-drive gearbox of a VW Tiguan. The drive shaft, which leads from the gearbox towards the rear and normally drives the rear axle, is simply used in the opposite direction: The electric motor drives this shaft and therefore transmits its power to the gearbox and finally to the front wheels.

Battery technology from ETH

Now a suitable battery was needed. Patrik Soltic relied on a development by ETH students, who had created an appropriately powerful basic system for the “Formula Hybrid” student race series. The tried and tested battery-module was equipped with new electronics and now occupies the former luggage compartment of the CLEVER. The battery capacity of 4.5 kWh “is more than adequate for our purposes”, says Soltic. Nor does the power consumption of the 30 kW electric motor cause any problems – the component copes with up to 100 kW during a “Formula Hybrid” race.

Soltic has now detached the CLEVER from the roller dynamometer and pushes it out of the engine building. Now EmpaNews can get behind the steering wheel. Over the first few metres the car feels like any series-produced VW; The interior and the controls of the Touran are unchanged. The six-gear transmission also operates as usual. The first thing that you notice is the monitor in the middle of the dashboard. This is where the CLEVER gives the driver recommendations for gear changes and shows whether the drivetrain would work more energy efficient in the next gear up or down.

Smart driving with the CLEVER

When the car rolls up to the first red light, Soltic gives the first driving advice: “Put it in neutral and roll up to the traffic light just with slight pressure on the accelerator”. This is where the hybrid shows its strengths: Instead of letting the engine run inefficiently in the partial load range, it is shut off by the on-board electronics. The electric motor provides propulsion until the car stops at the traffic light. Once it arrives there the combustion engine stops until the driver presses the clutch and selects first gear again.

It takes a bit of getting used to before you comprehend the philosophy of the car and adapt to the actual driving style. In certain situations it is worth driving the CLEVER using the electric motor only – to do this the gearbox must be in neutral and the thrust of the electric motor is controlled using the accelerator. The electric motor also is active if a gear has been selected. It either provides additional power and saves fuel, or it obtains power from the transmission and charges the battery. The on-board computer selects the operating modes in such a way that the natural gas engine always operates in the most energy-efficient range and the battery has a balanced charge situation. Hence the car is completely autonomous and never needs to be plugged into a socket.

“Of course, we simulated all of this on the computer first. We would not have needed a real car to work out the potential and the operating strategy“, says Soltic. However, during test drives in a real car you can evaluate many fine details such as driveability and acoustics better than in a computer animation. And that would be the true sense of the CLEVER: Thenatural gas hybrid should not just help to do research on new technology, but also show whether normal people without a degree in engineering can cope with it. “Empa is the link between research and practical use”, says Soltic. “The CLEVER is a good example of this. We want to use it to bridge a knowledge gap in the alternative drives area”. //

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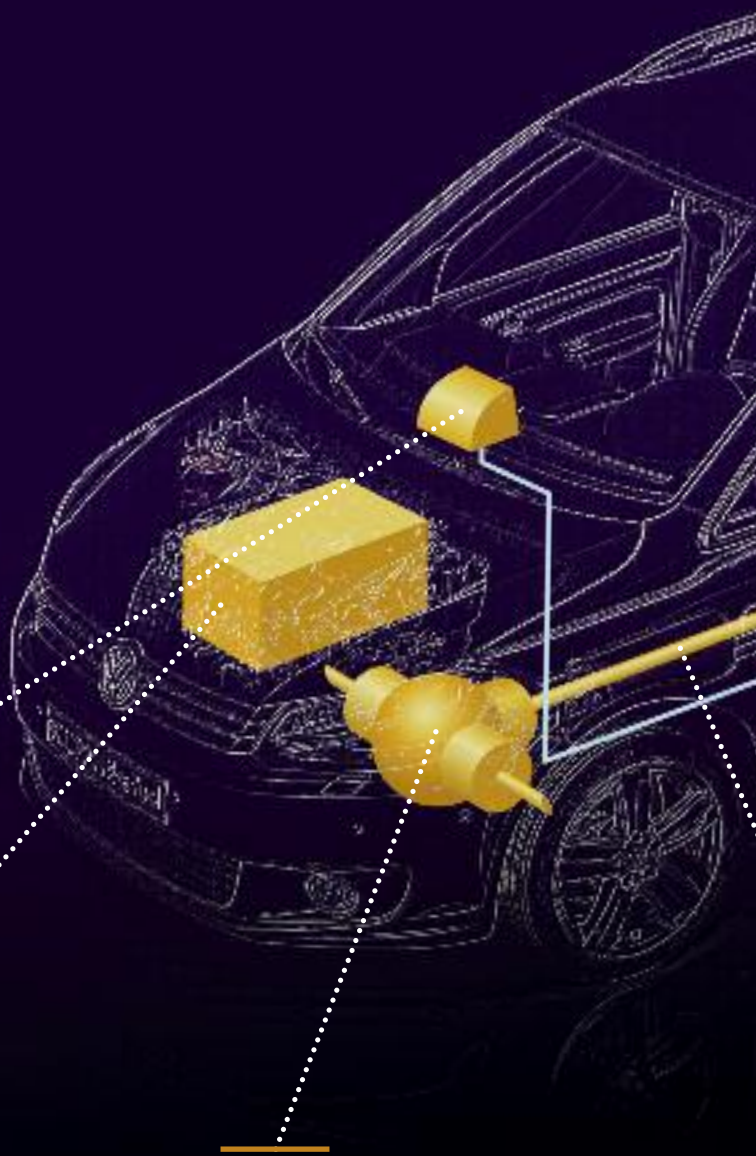
A CLEVER technology – the

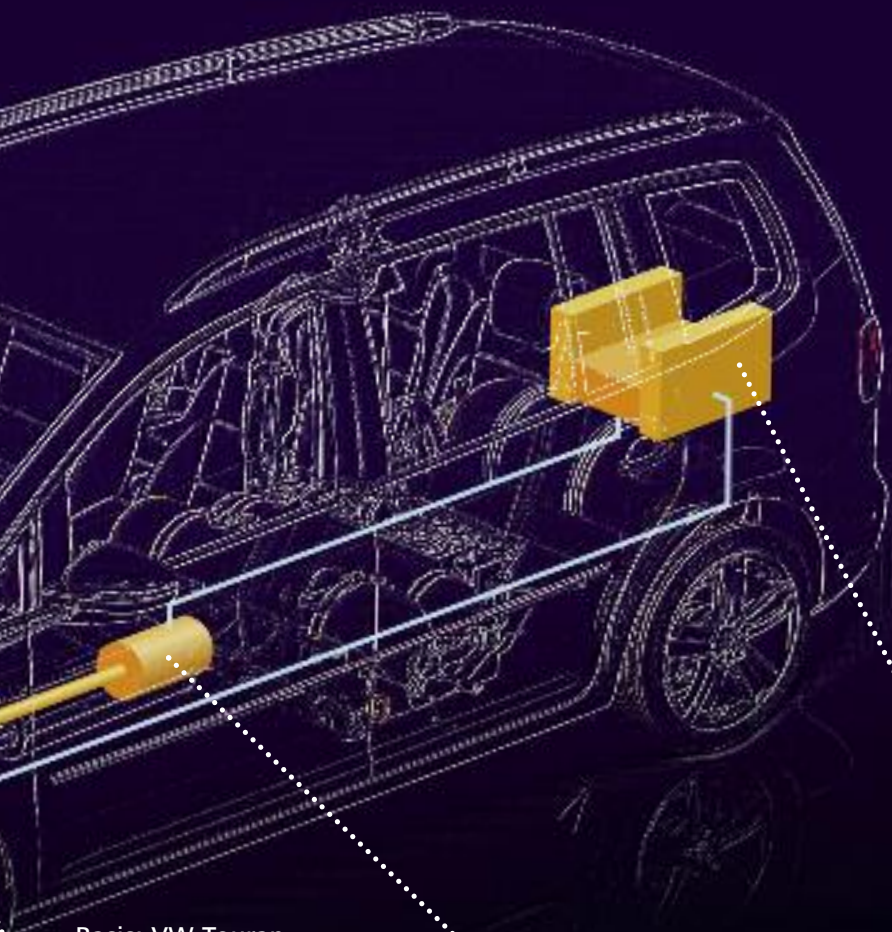


Display for monitoring the driving status.

1.4 litre natural gas turbo engine from VW, output 110 kW.

Manual gearbox from VW Tiguan, four-wheel drive version.

Hybrid drive under the X-ray



Basis: VW Touran

Drive shaft – normally leads to a driven rear axle. However, it is used "in the opposite direction" in the Empa hybrid: in this case the electric motor feeds energy into the drive.

Electric motor, output of 30 kW.

Electric storage consisting of Li-ion batteries, inverter and power electronics.