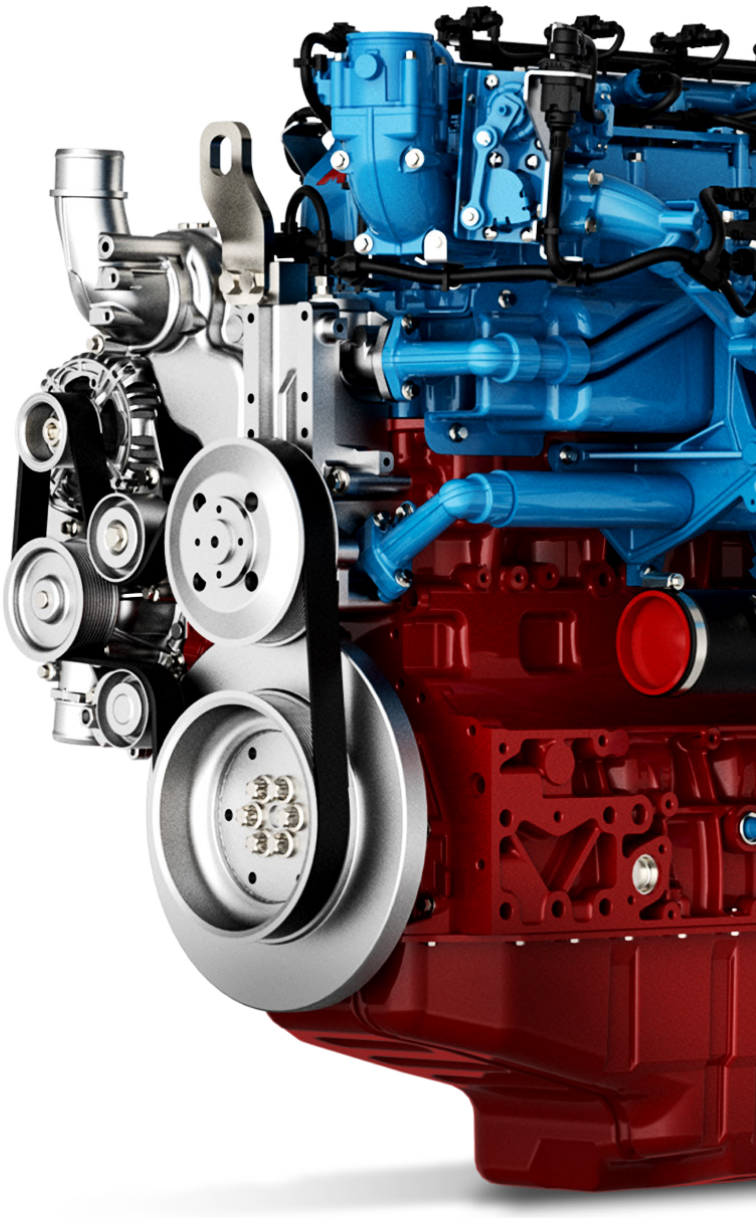
THE HYDROGEN ENGINE

A technology of tomorrow in production today



The engine company. DEUTZ®

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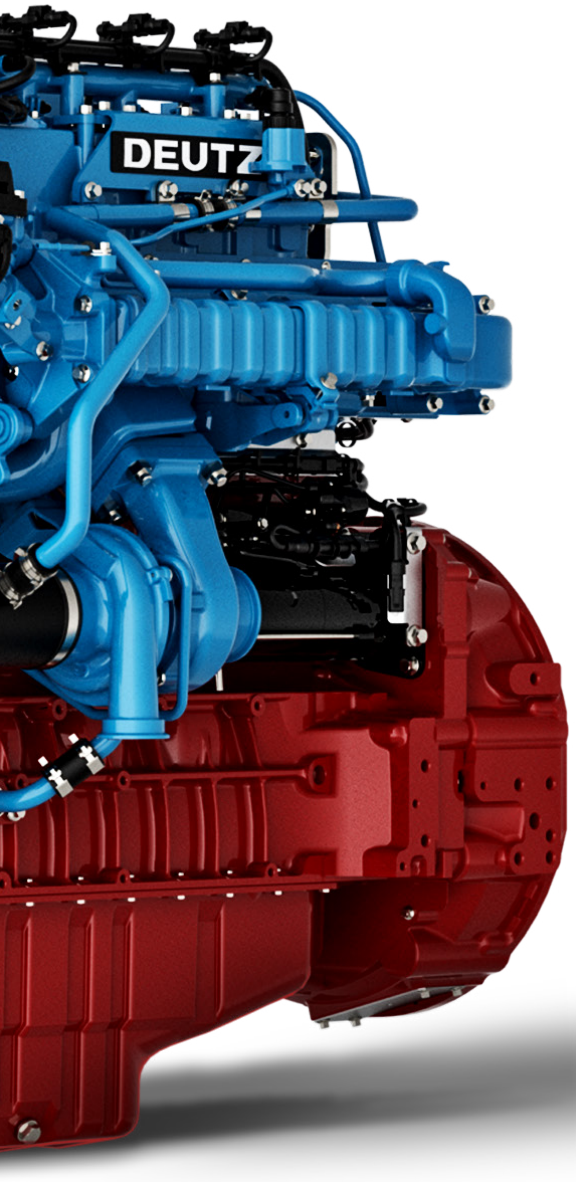


HYDROGEN FUEL

Technology of tomorrow having an impact today

Hydrogen holds huge promise as a future energy source. And even today, it has the potential to reduce environmental impacts when used as a fuel. This is why DEUTZ has been intensively involved in the pioneering technology of hydrogen combustion engines for many years now. So intensively that it already has one in commercial production. But first things first.

Why hydrogen? The background

Countries around the world are going to enormous lengths to achieve the global climate targets. And alternative drive systems are playing a key role in their endeavors – including in Germany. Indeed in June 2020, the German government launched a national hydrogen strategy to help it to meet the climate targets for 2030.

Using hydrogen as an energy source will be pivotal in efforts to reduce carbon emissions. The goal is to cut emissions by 55 percent by 2030 and by up to 95 percent by 2050 in all energy-intensive sectors. The strategy provides extensive support for all hydrogen-based technologies. This includes their deployment in drive systems for vehicles, where hydrogen's chemical energy is converted into usable energy either electrochemically, via fuel cells, or thermodynamically, via combustion engines.[1]

Politicians have identified hydrogen as a promising solution for the future as they seek to cut carbon emissions in the automotive sector and end our dependency on fossil fuels. But how does the hydrogen combustion engine actually work?

[1] NOW GmbH (2021). Wasserstoffverbrennungsmotor als alternativer Antrieb: Metastudie [Hydrogen combustion engine as an alternative drive system: meta-study] (Schrank, M., Langer, V., Jacobsen, B., von Unwerth, T., & Götze, U. (eds.)).


55%
LESS
EMISSIONS
BY 2030

How does a hydrogen engine work?

The hydrogen engine is essentially a gas engine. This means it is based on the same principles as conventional combustion engines. In other words, on the classic Otto, or four-stroke, cycle. The difference is that hydrogen is burned instead of gasoline or diesel – and it produces water.

A pressure control valve on the engine brings the hydrogen arriving from the storage tank to a stable operating pressure and regulates the amount of fuel flowing in. The gaseous hydrogen, together with the intake air, is drawn into the piston chamber via a charge air line. The piston compresses the mixture in this chamber, increasing the temperature and pressure. The spark plug then ignites the compressed hydrogen-air mixture, which causes the gases to expand rapidly and push the piston downward. This movement converts the chemical energy into mechanical work and drives the engine. The piston then rises again and forces the combustion gases – in this case mainly water vapor – out of the cylinder and into the exhaust manifold.

Despite the differences between hydrogen and conventional fuels such as gasoline, gas (e.g. LPG, CNG), and diesel, key components such as the cylinder crankcase, cylinder head, and oil sump are largely the same. Only add-on parts – for example, the fuel routing and the fresh air and exhaust pipeline, including turbocharging, and the sensors and software – need to be modified to ensure optimum combustion of the hydrogen. These lines can be made slightly larger thanks to the higher air flow rate during lean-burn operation. However, the size and weight of the engine remain virtually unchanged. This inevitably raises the question as to whether the target applications for hydrogen engines are the same as for conventional combustion engines.

This inevitably raises the question

AS TO WHETHER THE TARGET APPLICATIONS FOR HYDROGEN ENGINES ARE THE SAME AS FOR CONVENTIONAL COMBUSTION ENGINES.

[2] Ebenda.

Where will the hydrogen engine be used?

AND WHY?

Analysis by Germany's National Organization for Hydrogen and Fuel Cell Technology shows that the hydrogen engine is particularly well suited to the off-highway sector, i.e. for heavy-duty applications with high performance requirements in often difficult environments. In applications where energy demand is consistently high – such as generators, trains, excavators, and bulldozers – the meta-study indicates that hydrogen engines offer considerable advantages while using existing infrastructure (service workshops, spare parts supply, etc.).

[3] Ebenda.

What is the current situation for

HYDROGEN INFRASTRUCTURE?

Most hydrogen generated to date has been ‘gray’, which means it has been steam-reformed from natural gas. It is referred to as ‘blue’ hydrogen if the carbon that is produced by natural gas reforming is not just separated but also captured, which is increasingly the case. However, the truly green hydrogen solution is electrolysis, the splitting of water into hydrogen and oxygen. This process is becoming increasingly energy-efficient, while the availability of green electricity for powering it is also increasing. ‘Green’ hydrogen is therefore experiencing an upswing. Nevertheless, the momentum still needs to be maintained both in terms of production in Europe and in imports from other regions of the world – and also when it comes to storage.

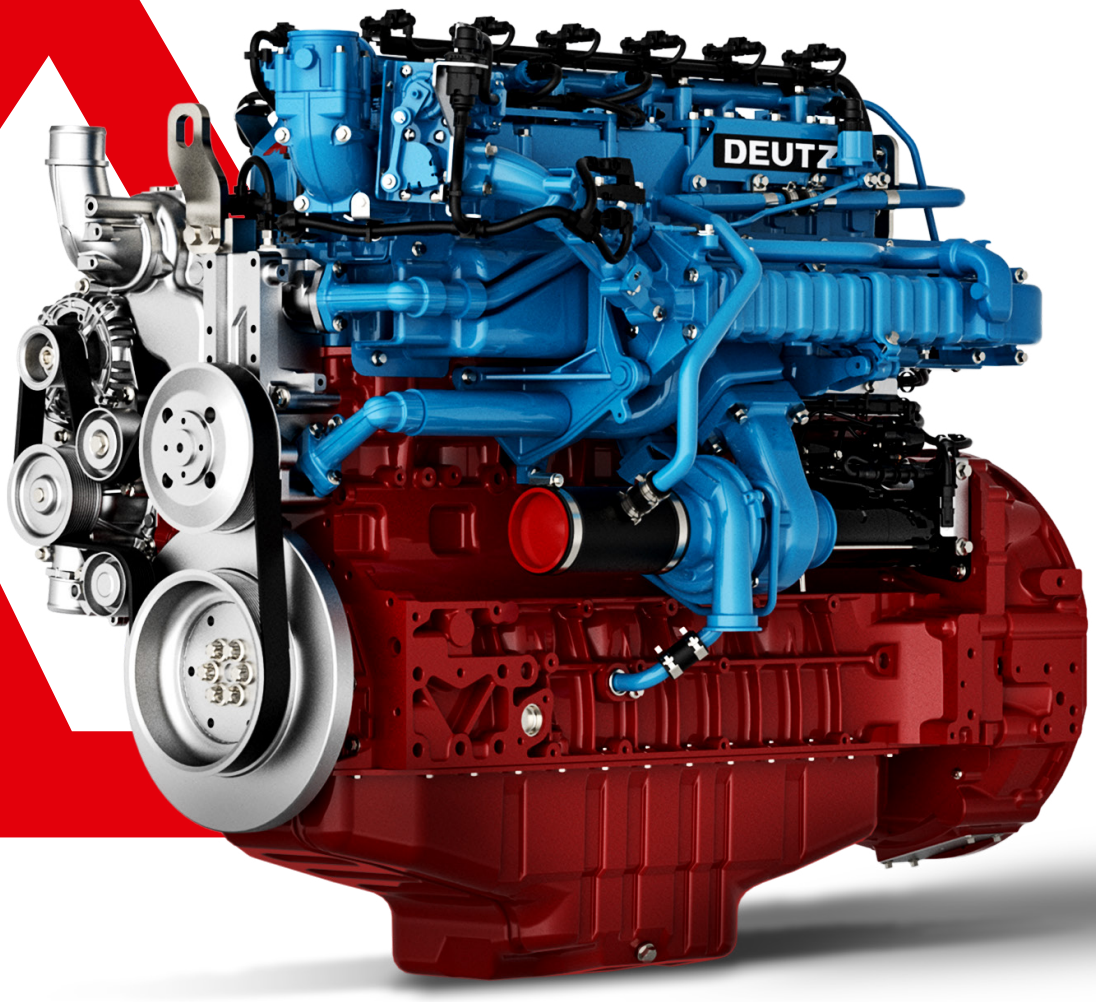
New storage technologies have been designed to hold large quantities of hydrogen safely and efficiently, at high pressure or in liquefied form. Reliable distribution, meanwhile, is being made possible by modern transportation solutions such as specialized hydrogen tankers and pipelines. The use of hydrogen is easy to plan, particularly for rail-bound applications. Policies and initiatives have been put in place to establish a 9,700-kilometer-long core network for transporting hydrogen in Germany. And in the EU alone, some €470 billion is to be invested in hydrogen production and infrastructure by 2050.[5]

[4] https://www.bmwk.de/Redaktion/DE/Schlaglichter-der-Wirtschaftspolitik/2024/02/07-wasserstoffnetze-energiewende.html

[5] https://www.eib.org/attachments/publications/unlocking_the_hydrogen_economy_en.pdf

TCG 7.8 H2

the hydrogen engine from DEUTZ



The **TCG 7.8 H2** is based on the DEUTZ diesel engines that have proven themselves millions of times over – except that it burns hydrogen. The six-cylinder engine delivers maximum dynamic capability and can effortlessly handle a wide range of load profiles. Unlike the fuel cell, it is – like all DEUTZ engines – resistant to extreme temperatures, vibrations, solar radiation, and dust. And the good news is that this innovative drive solution is already in series production.

CURRENT FIELDS

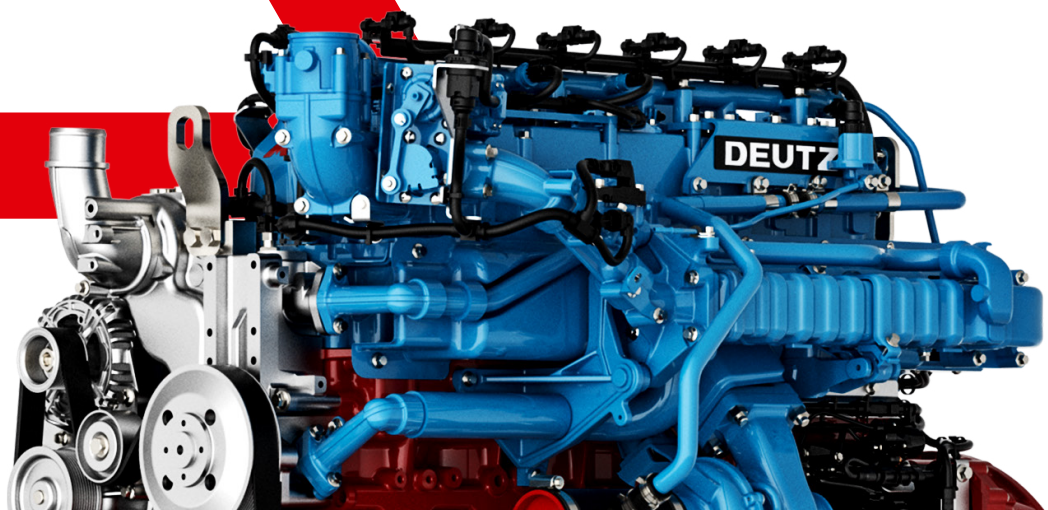
of application

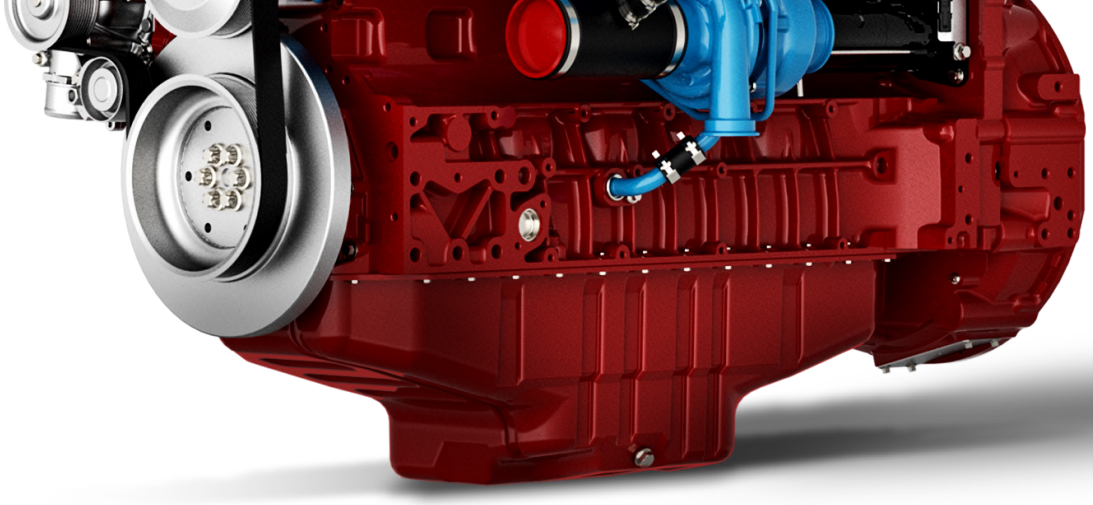
Off-Highway:
construction, agriculture, mining

Stationary power generation:
generators, combined heat and power plants

Rail applications:
regional trains,
special-purpose vehicles

Other applications
are in the pipeline





THE BENEFITS

of the TCG 7.8 H2 at a glance

+ Robust and proven **basic engine technology**
+ **Short time to market:** production-ready, fully tested H_2 engine
+ **Optimum energy efficiency** with maximum dynamic capability
+ **Powerful** ‘diesel-like’ performance
+ Infield repair **and diagnostic capability**
+ **Existing service network** through our authorized and trained dealers with spare parts availability to match
+ **Attractive** total cost perspective

WHAT TECHNOLOGY

features in DEUTZ's TCG 7.8 H2 engine?

DEUTZ combustion engines have been setting standards for over 160 years. And in recent years, the company has been investing heavily in alternative drive systems. The **TCG 7.8 H2** combines both. Indeed, 75 percent of this hydrogen combustion engine is based on the established TCD 7.8 diesel engine. It is just as powerful, durable, and reliable.

Basing the hydrogen engine on proven technology has several advantages. Firstly, there are no uncertainties in terms of its functionality, thanks to its tried-and-tested drive mechanism and its production readiness. Secondly, the costs involved with an investment in the **TCG 7.8 H2** once it is fully up and running will be comparable to those of a conventional combustion engine. DEUTZ also guarantees a high level of serviceability, including rapid and low-cost parts supply. Service engineers do not need to be retrained. All they require is a brief introduction to the new H_2 components.

AT A GLANCE

Technische Daten TCG 7.8 H2

Specification of the target engine	six-cylinder in-line engine
Displacement	7.755 liters
Bore/stroke	110/136 mm
Max. power output	220 kW at 2200 rpm
Max. torque:	1000 Nm at 1400–1600 rpm
H_2 consumption	up to approx. 19 kg/h at max. power output (12 kg/h, genset)
Hydrogen fuel quality	ISO 14687 min. 98% or higher
Pressure interface	27 bar
Power generation	approx. 150 kW @50 Hz / 1500 rpm (genset)
Efficiency	approx. 39% (up to 40% is targeted)
B10T rating	10,000 h
Certification	Stage-V-ready
Exhaust gas aftertreatment	DOC, DPF, SCR
Dimensions / weight	842 mm x 1062 mm x 1214 mm; approx. 740 kg, approx. 90 kg EAT

NEW COMPO-NENTS

What is the H2 engine equipped with?

DEUTZ has developed the piston group, the turbocharger, the PFI injectors and ignition system, the ECU, and the software either from new or on the basis of existing components. The more technically complex VTG variant was a deliberate choice for the turbocharger – a first in the diesel-hydrogen world. This compensates for rapid load changes and ensures an optimized constant speed response, with full power reached in just a few seconds. As a result, the **TCG 7.8 H2** offers a dynamic capability in heavy machinery and other vehicles that would be impossible with a conventional turbocharger. The engine is optionally equipped with an attached Power Pack – comprising a cooling system, fan, and air filter. At the customer's request, DEUTZ can also supply a system-based solution consisting of a hydrogen engine and tank module.

VTG variant

A FIRST IN THE DIESEL-HYDROGEN WORLD

MODULAR TANK SYSTEM

How does it work?

Because of its modular design, the standardized tank module is cost-effective even in small numbers. It allows custom tank systems with integrated interfaces to be assembled from certified, prefabricated hydrogen tanks. The tanks, which are produced by a renowned H_2 tank manufacturer, can withstand extreme conditions, are lightweight thanks to the composite material, and yet are also very robust. They store hydrogen in a gaseous state under high pressure (approx. 350 bar). The engine pressure control valve then brings the hydrogen to the required operational pressure of around 27 bar. All this means that DEUTZ is able to supply not just a powerful hydrogen combustion engine, but a complete hydrogen drive system.

TECHNICAL DATA OF THE TANK SYSTEM AT A GLANCE

Capacity of hydrogen system	4-80 kg
Tank technology	Type 4 – composite material
Hydrogen system pressure (nominal)	350 bar
Certificates / regulations	ECE R134 / PED
Permissible temperatures	-40 °C to +85 °C
System lifecycle	20 years*
H_2 system control	SW / HW / H_2 sensors
H_2 modular system concept	1–8 tanks
Accessories	ECU, protective cage, lines; valves, filler necks, filters
Services	engineering, certification, installation, and approval support

How does the hydrogen get into the tank?

First the good news. Hydrogen-powered vehicles and machinery can be refueled just as quickly as diesel vehicles. But it is not just fast refueling that is important, of course. The availability of hydrogen also needs to be guaranteed. Working in partnership with a leading hydrogen supplier, DEUTZ will be able to offer mobile hydrogen refueling systems in the future, paving the way for the creation of a local H_2 network. Infrastructure is also key when it comes to service, and DEUTZ is ideally positioned here.

Who will be providing the service?

Without reliable service, not even the most groundbreaking technology can be considered future-proof. So it is good to know that DEUTZ has a worldwide network of service workshops and partners that will provide exactly the same services for the **TCG 7.8 H2** as for all other DEUTZ engines. That means a lifetime warranty on genuine spare parts, customized solutions for the entire service life of your engine, extended warranties, and comprehensive telematics solutions. Thanks to its global network, DEUTZ offers predictability, peace of mind, and efficient support. The quality of the service is also on a secure footing, as the engineers were already familiar with 90 percent of the hydrogen ICE technology from basic engine mechanics. Training only needed to be provided in hydrogen management. This has already happened, so the service is in no way inferior to the engine itself in terms of readiness for the mass market. Indeed, DEUTZ has done a lot to ensure that service calls will be few and far between.

How safe is DEUTZ's new hydrogen technology?

Hydrogen is not just the lightest and most volatile of the elements. It is also extremely flammable and has a higher flame speed than gasoline or diesel, which means it burns faster. These properties place significant demands on the materials, design, and combustion control of the engine.

DEUTZ has worked closely with research institutes over a period of many years to analyze how materials are affected by hydrogen in order to exclude the possibility of embrittlement or corrosion. The engine has also passed extensive tests – lasting several thousand hours – including an examination of thermodynamic loads, explosion and fire safety, and performance at full load. In addition, long-term tests and trials are carried out under a wide range of conditions: from continuous operation of the entire system through to specific functional and safety checks of the individual systems and components. Customers can therefore expect a fully tested, high-performance engine that offers a long service life and operation time. In other words, a DEUTZ engine.

What needs to be considered when replacing an engine?

The DEUTZ **TCG 7.8 H2** has been designed as a drop-in engine. This means it can easily replace an existing engine to extend the useful life of the application and potentially give it a green footprint, too. However, the switch from conventional combustion engine to a DEUTZ hydrogen engine does require some major modifications to a vehicle's tank infrastructure. Because of the materials used, a hydrogen tank is generally seven to ten times larger than the tank of a diesel engine. DEUTZ will examine whether and how retrofitting to a hydrogen drive is possible on a case-by-case basis.

What emissions does the hydrogen engine produce?

As there are no specific emission limits for hydrogen engines as yet, DEUTZ is taking its lead from the limits for diesel engines. It is stage-V-ready and the certification process is close to being completed.

But should any such regulations come into force, the company is prepared, as its six-cylinder H_2 engine comes with an exhaust gas aftertreatment system as standard. This is because a hydrogen engine, when worked particularly hard, can also produce NOx emissions. That is why we use SCR-CAT (Selective Catalytic Reduction). The system eliminates this nitrogen oxide by injecting AdBlue into the exhaust gas flow, where it releases ammonia. The ammonia then reacts with NOx in the SCR catalytic converter to form harmless nitrogen and water.

The soot measurements of the **TCG 7.8 H2** are below the specified limits. It has not yet been decided whether hydrogen engines require a particulate filter (DPF). DEUTZ installs this as standard, but it can also be omitted at the customer's request. A diesel oxidizing catalytic converter (DOC) is also a possibility for the hydrogen engine as a means of counteracting the oxidation of carbon monoxide and unburnt hydrocarbons (CO and HC). The catalytic converter can transform the exhaust gases, even if only very small quantities are involved, into carbon dioxide and water.

WHY DEUTZ?

DEUTZ is the first engine maker in the world to put a fully tested hydrogen combustion engine into series production. The world's first engine manufacturer is thus actively driving the industry toward hydrogen – and it is doing so out of conviction.

The **TCG 7.8 H2** is not only efficient and reliable, it is also ready for the challenges of the future, including when it comes to service. Thanks to its well-established global network of suppliers and partners, DEUTZ is able to provide all maintenance and service activities. The familiar basic technology makes work easier for the service engineers worldwide.

It is no surprise that DEUTZ was the first manufacturer to go into commercial production. In fact, hydrogen actually featured in the first four-stroke engine developed by Nikolaus A. Otto in 1876. 'Illuminating gas' was used as fuel at the time, the main component of which was hydrogen.

DEUTZ has been developing and manufacturing combustion engines for over 160 years. The hydrogen drive solution builds on exactly those qualities that have come to characterize DEUTZ – while offering an alternative to diesel at no loss of performance.

The **TCG 7.8 H2** – the future of the combustion engine is here.