The TSI Engine
Environmental Commendation

Stepping up the pressure

Once upon a time, everything was easier. Big engines were powerful and small engines were less powerful. Displacement was the key, as petrol-engined cars usually needed big normally aspirated engines for effortless performance with high torque and brisk acceleration through the gears.

"Nothing beats cubic capacity – except more cubic capacity" was an unwritten law of technology for many years, at least where production models were concerned. If you wanted more performance, you had to buy a model with more power or better still a bigger car. But greater size and performance almost invariably meant higher fuel consumption.

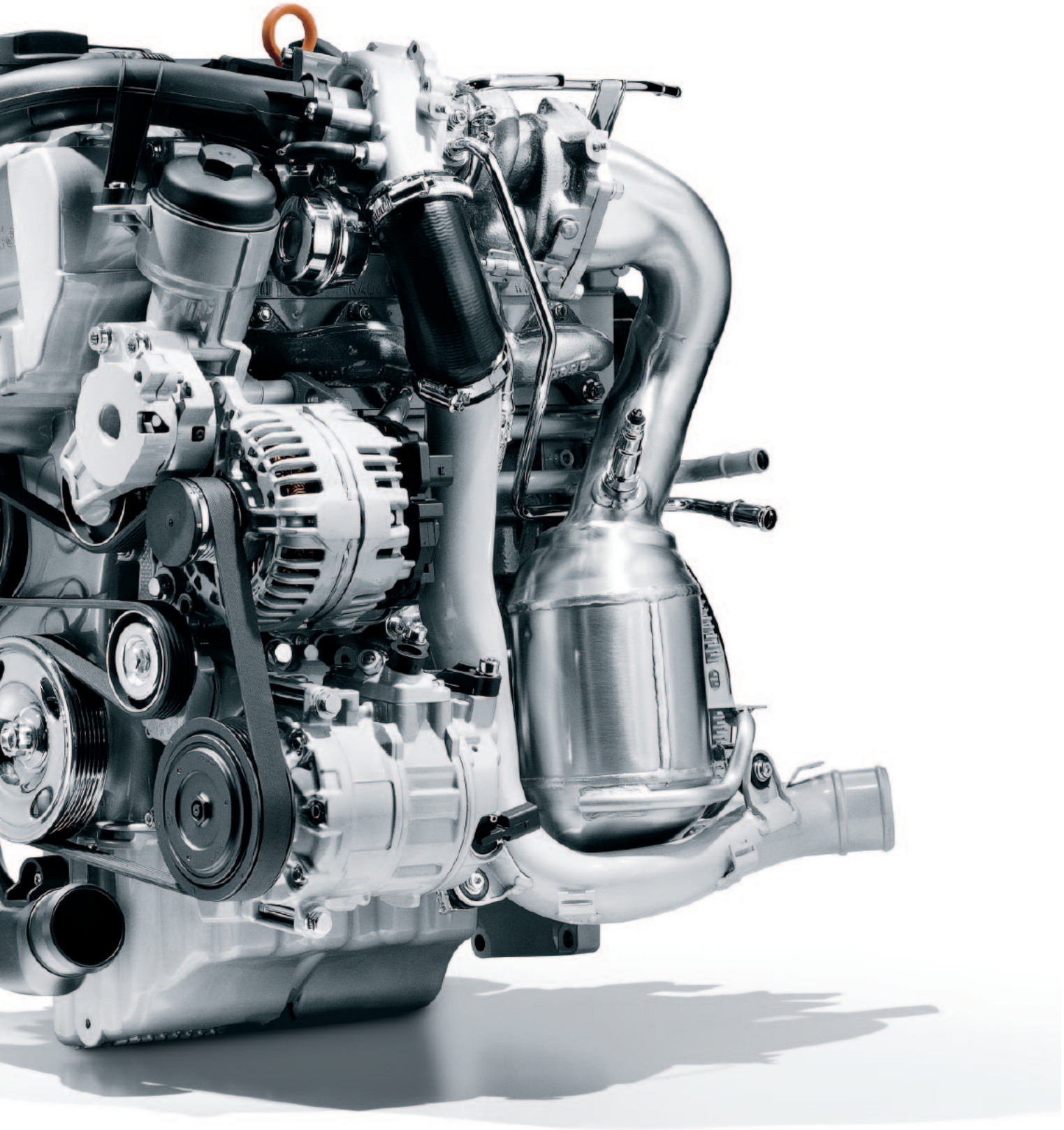
Until a few years ago, car-buyers faced a fundamental choice: they were forced to opt for good performance or reasonable fuel economy. Today, you can have both. All it takes is the right technology under the bonnet. Then you get higher performance and lower consumption.

People still like to talk about engine displacement, although as a metric it is really a thing of the past. What counts today is pressure – boost pressure to be more precise. Boost pressure is the factor that extracts high power and high torque from small engines, while at the same time making for low fuel consumption.

The Environmental Commendation

Our Environmental Commendations for new vehicle models and technologies highlight environmental progress compared with predecessor models and previous technologies. We use Environmental Commendations to inform our customers, our shareholders and other stakeholders within and outside the company how we are making our products and production processes more environmentally compatible and what we have achieved in this respect.

The underlying Life Cycle Assessment (LCA) not only covers the time when a TSI engine is in use but its entire life cycle from production through to use and disposal. This reflects the fact that we assume responsibility for the entire supply chain, including the producers of raw materials and parts for our products. We engage in dialogue with our suppliers to identify environmental measures that can be taken. We also provide training, enter into



cooperation arrangements and compile Life Cycle Assessments. This Environmental Commendation also indicates the impact of fuel production and product disposal on the environment. The information in this Environmental Commendation is based on a Life Cycle Assessment of the TSI engine which has been verified and certified by the technical inspection organisation TÜV NORD. The TÜV certificate confirms that the Life Cycle Assessment is based on reliable data and that the methods used to compile it comply with the requirements of ISO standards 14040 and 14044. You will find further information on the Internet at www.environmental-commendation.com and in the background report to the Environmental Commendation for the TSI engine, which can be downloaded from the same website.

Highly charged developments

A similar development took place several years ago when, at the beginning of the 1990s, Volkswagen launched the first generation of TDI engines. These diesel engines combined high torque with very low fuel consumption. The special feature of a TDI engine is the turbocharger, which provides more power and torque. At the same time, direct injection makes for considerably more efficient and economical combustion of the fuel. At the time, Volkswagen TDI engines achieved performance levels which, just a short time before, would have called for much larger engines. The second generation of TDIs was equipped with our even more economical pump-injector technology, while today's TDI engines from Volkswagen feature common rail injection systems that allow even smaller swept volumes without sacrificing performance.

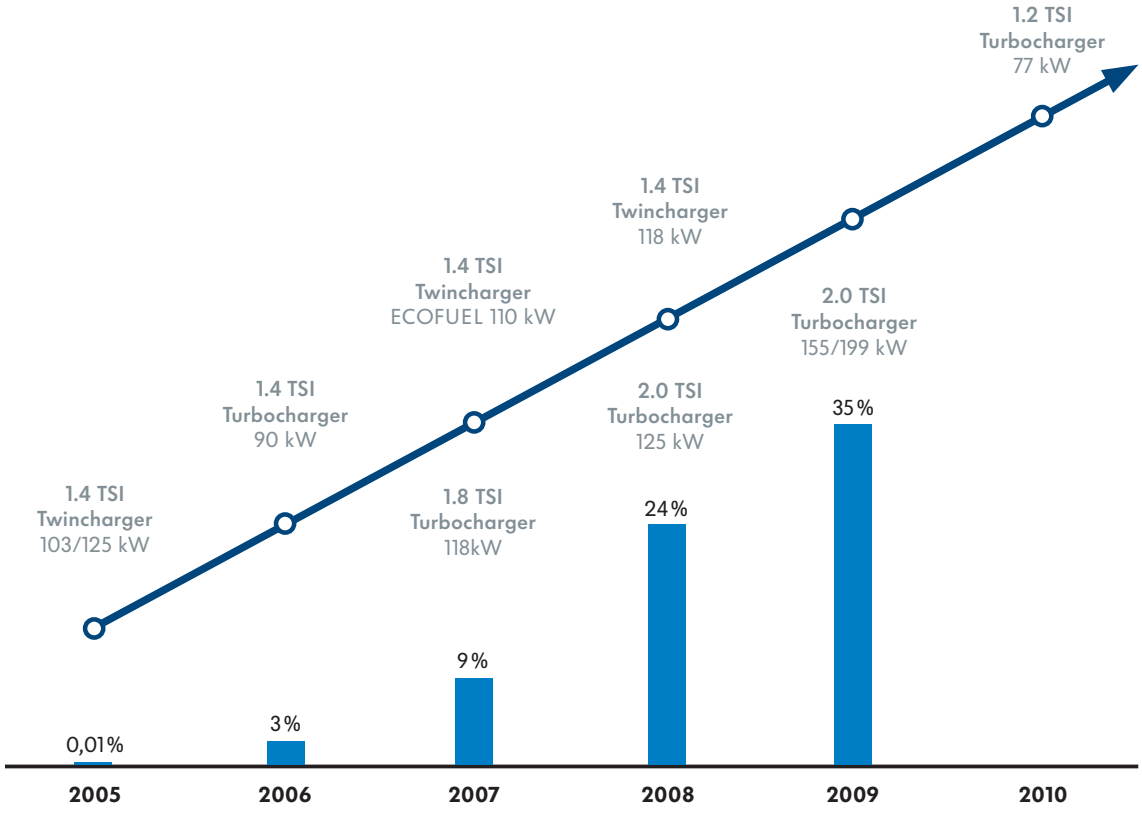
"Volkswagen TSI engines impressively demonstrate the effectiveness of lower capacity, direct injection and smart supercharging in ensuring outstanding performance combined with low emissions and fuel consumption – and all at reasonable cost."

Dr. Jens Hadler, Director of Powertrain Development at Volkswagen

Small engines with lower displacements are more efficient because they weigh less, have lower friction losses and reach maximum efficiency more often. While turbochargers have been the accepted solution for diesel engines of all sizes and power outputs for some time now, until a few years ago they were only installed in high-performance petrol engines. That was before climate protection concerns and the need for more efficient use of resources made turbocharging an attractive option for small engines, too.

At Volkswagen, this downsizing trend is symbolised by the three letters of the TSI brand. Despite their relatively low displacement, TSI power plants reach outputs that would have called for much larger engines only a short time ago. A four-cylinder TSI can replicate the power and torque figures of a larger normally-aspirated six-cylinder engine almost effortlessly. The results are emissions and consumption figures normally associated with a smaller engine combined with high power and torque. These engines use fuel far more efficiently than normally aspirated units with the same rated output.

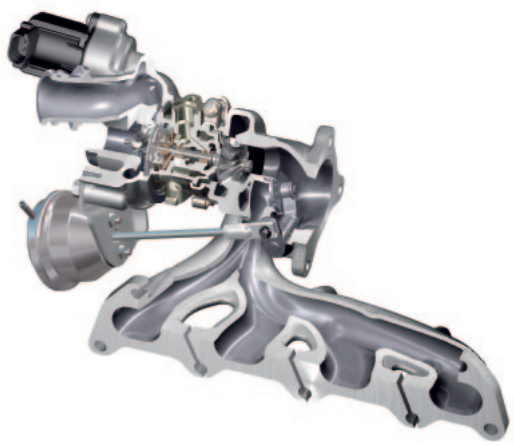
Evolution of TSI technology
TSI share in petrol models sold by Volkswagen (EU27)



November 2009

Volkswagen uses the "TSI" brand for all its direct-injection turbocharged or twin-charged petrol engines. In addition to a turbocharger, the "Twincharger" is fitted with a mechanical supercharger to ensure even torque generation. TSI engines are now available in a variety of size classes with power outputs ranging from 77 to 199 kW. The first TSI engine was the 1.4-litre Twincharger, introduced in 2006. This was followed by several other models with displacements of 1.4, 1.8 and 2.0 litres. The latest addition to the family is the 1.2-litre TSI with 77 kW.

And the downsizing process continues: even smaller engines are already being considered (see box on page 7).



The BlueMotion miracle

Greater efficiency, lower emissions and no loss of driving pleasure: under the BlueMotionTechnologies umbrella brand, Volkswagen offers technologies and products that make for environmentally compatible mobility coupled with dynamism and everyday usability. TSI engines are one of the basic technologies that make a key contribution to the brand.

BlueMotionTechnologies stands for the interaction of a large number of innovations such as TDI, TSI and DSG, which ensure mobility with lower fuel consumption and pollutant emissions. The highlights of BlueMotionTechnologies include the sub-brands TSI EcoFuel, BlueTDI and BlueMotion, as well as the models with the BlueMotionTechnology badge. The technical innovations that contribute to lower fuel consumption include start-stop systems, regenerative braking and dual-clutch (DSG) transmissions, as well as economical TSI engines. Four of the eleven Volkswagen models included by motoring organisation Verkehrsclub Deutschland (VCD) in its Cars and the Environment list of the most eco-friendly vehicles in 2009 are equipped with a TSI engine.[1]

Award-winning technology

Since 2006, the TSI engine has received the coveted Engine of the Year award[a] in the UK on four consecutive occasions. In 2009, the 1.4-litre TSI engine family received no less than three such "best engine" awards: along with the International Engine of the Year title, the jury of 65 journalists from 32 countries also named this engine Best Green Engine and Best Engine in the 1.0 to 1.4 litre class. German motoring organisation ADAC awarded TSI technology its Gelber Engel 2008[b] accolade in the category of "Innovation and the Environment". Volkswagen received two of the most important Japanese automobile industry awards for TSI engines in 2008 in the category Technology of the Year. Both the Car of the Year Committee[c] and the Automotive Researchers' and Journalists' Conference Jury[d] awarded first place to TSI engines. That same year, the TSI engines also won the renowned TechnoBest[e] technology award in Istanbul. The award is presented under the auspices of "AutoBest", the motoring organisation of emerging markets in Central and Eastern Europe, by a jury of leading journalists.

[a] www.ukipme.com/engineoftheyear
[b] www.adac.de/sp/gelber_engel/2008/default.asp
[c] www.jcoty.org
[d] www.npo-rjc.jp
[e] www.autobest.org/varianta/awards/awards2008.php

[1] www.vcd.org/auli_2009_2010.html

TSI technology is also a key component in the Powertrain and Fuel Strategy pursued by Volkswagen in its efforts to achieve sustainable mobility in the future. The major objectives are to reduce local emissions and concentrations of the greenhouse gas carbon dioxide, as well as to lay the foundations for secure energy supplies. In the future, vehicles will certainly be powered by the zero-emission electric motors that our engineers are already developing. In the medium term, however, the internal combustion engine will remain the dominant powertrain technology and we are working to exploit the considerable development potential of these engines. TDI and TSI engines already represent efficient, environmentally compatible technologies that achieve their full potential in combination with innovative DSG transmissions and a start-stop system of the type already used in a number of BlueMotion-Technology models.

"Downsizing will continue"

Two questions for Dr. Ulrich Hackenberg, Volkswagen brand Board Member for Development

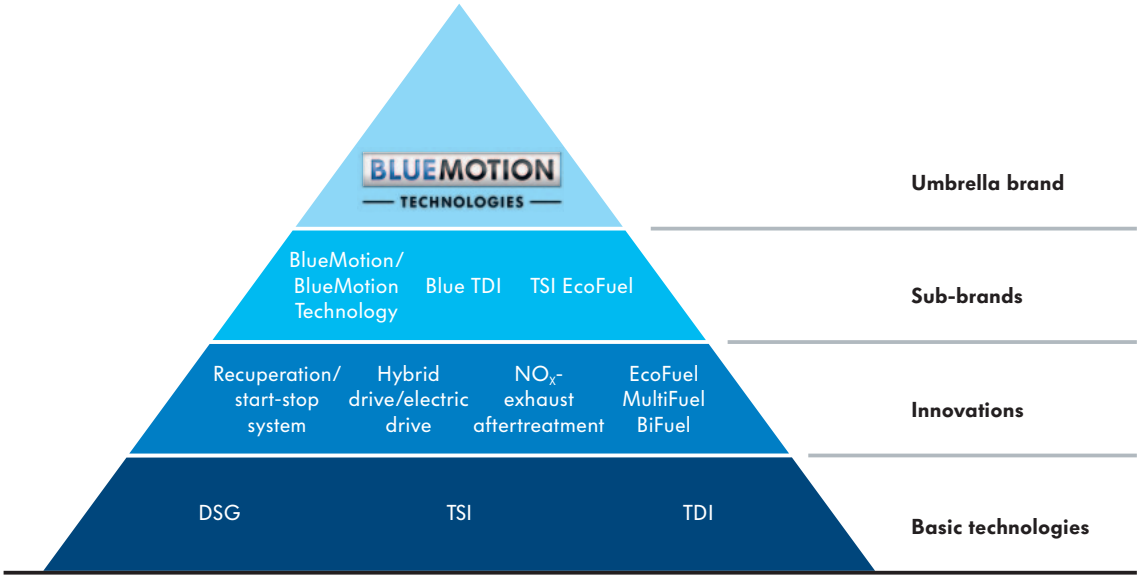
Dr. Hackenberg, what does the future hold for the TSI engine?

Volkswagen is already leading the field with its TSI and TDI engines as well as the DSG transmission, and we intend to extend our lead. We are currently developing a 1.0-litre TSI and a 1.2-litre diesel engine, each with three cylinders, and further engine size reductions are under consideration.

Will the TSI also form part of a hybrid powertrain?

The next generation of our Touareg SUV is to be launched in 2010 with a TSI engine combined with an electric motor. If necessary, this hybrid Touareg will be able to run on just the electric motor, without any local emissions.

Environmentally friendly products and technologies under one umbrella brand



Environmental Description, TSI®

Generally improved environmental profile throughout the engine life cycle compared with a normally aspirated petrol engine* due to higher efficiency, lower fuel consumption and reduced emissions.

Reduction of fuel consumption through:
- Downsizing (smaller engine displacement)
- Turbocharging or twin-charging
- Reduction of friction losses

Significant reduction in consumption
- 0.3 l/100 km less with the 1.4 TSI (90 kW)
- 0.9 l/100 km less with the 1.2 TSI (77 kW)

Greenhouse effect – less CO_2 emissions over full life cycle
- 1.3 metric tons less carbon dioxide (1.4 TSI)
- 4.1 metric tons less carbon dioxide (1.2 TSI)

Resource conservation and environmental protection through:
- Oil system with optimised volume
- Cylinder head with optimised weight (1.4 TSI)
- Crankshaft with optimised weight (1.2 TSI)
- Reduced contributions to summer smog and acidification

*All values are based on model calculations assuming the same conditions.

Making a difference

A Life Cycle Assessment in accordance with ISO 14040, which forms the basis of the Environmental Commendation for the TSI engines, can be divided into three phases. First of all, a Life Cycle Inventory is drawn up, in which all relevant types and quantities of material as well as types and amounts of energy that go into the production, use and recycling of the engine are quantified and documented. Then an evaluation of potential environmental impacts is performed, regarding, for example, the greenhouse effect, summer smog and acidification or eutrophication of water and soil. And finally the results are analysed. For the Life Cycle Assessment of the TSI engine, we compared the 1.4-litre TSI engine (90 kW)[2] with the almost equally powerful 1.6 FSI (85 kW). The new 1.2 TSI (77 kW) was compared with a 1.6-litre MPI engine (75 kW).

[2] The technical data of the engines assessed are shown in the table on page 9 and in the background report to this Environmental Commendation at www.environmental-commendation.com

Fuel consumption differences between the TSI and its predecessors refer in all cases to a Golf with six-speed manual gearbox. Only those reductions in consumption which are actually due to the TSI engine have been taken into consideration. All the other base conditions, such as transmission ratios, remain unchanged.

As part of its integral product policy, Volkswagen considers not only individual environmental aspects, such as fuel consumption or emissions, but the entire life cycle of a component. Among all environmental impacts, road traffic is mostly associated with the greenhouse effect and summer smog. We will therefore concentrate on these two categories at this point.

Within the environmental impact of the entire life cycle of an engine, the production and – even more so – the recycling phases have a comparatively low impact on the environment. The most relevant environmental impact occurs during the engine's service life, with direct driving emissions and fuel production accounting for the greatest impact. Not surprisingly, direct driving emissions are the main factor in terms of the greenhouse effect.

You will find a comprehensive analysis of all investigated environmental impacts in the background report to this Environmental Commendation at
www.environmental-commendation.com

KEYWORD Summer smog

On hot days, direct, intense sunlight turns atmospheric pollutants – particularly carbon monoxide, nitrogen oxides and hydrocarbons – into ground-level ozone, a potential irritant gas for plants, animals and humans alike.

Engines assessed

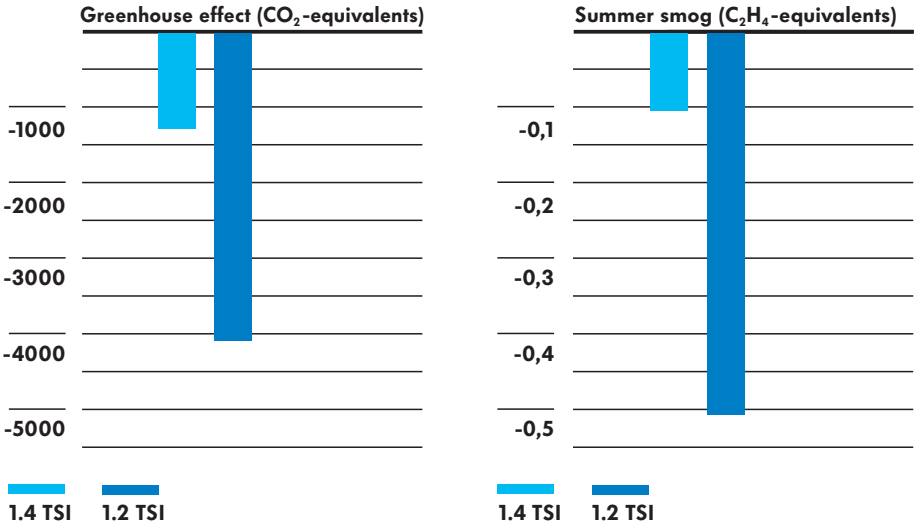
	1.6 FSI[a]	1.4 TSI[b]	1.6 MPI[c]	1.2 TSI[d]
Type	4 cyl. in-line	4 cyl. in-line	4 cyl. in-line	4 cyl. in-line
Valves per cylinder	4	4	2	2
Engine capacity [cm^3]	1598	1390	1595	1197
Output [kW]	85	90	75	77
Max. torque [Nm]	155	200	148	175
Drop in consumption [l/100km][e]	Reference	- 0.3	Reference	- 0.9
Engine weight [kg][f]	109.5	125.6	102.5	93.0

[a] Golf 1.6 FSI (85 kW), urban 8.8 / non-urban 5.5 / combined 6.7 l/100 km, 159 g CO_2/km
[b] Golf 1.4 TSI (90 kW), urban 8.2 / non-urban 5.1 / combined 6.2 l/100 km, 144 g CO_2/km
[c] Golf 1.6 MPI (75 kW), urban 9.7 / non-urban 5.6 / combined 7.1 l/100 km, 166 g CO_2/km
[d] Golf 1.2 TSI (77 kW), urban 7.1 / non-urban 4.9 / combined 5.7 l/100 km, 134 g CO_2/km
[e] All values are based on model calculations assuming the same conditions (Golf VI with 6-speed manual gearbox)
[f] Engine weight in accordance with DIN 70020-GZ

Quantifiable progress

Compared to their predecessors, the TSI engines present a much better balance sheet over their entire life cycle with regard to the greenhouse effect and summer smog, thereby attaining the environmental goal set by the Technical Development department at Volkswagen of improving the environmental properties of the engines compared with their predecessors. While CO_2 emissions during production of the TSI engines are slightly higher than for their predecessors, the savings potential of the new engines soon becomes evident during their subsequent service life. With an assumed lifetime kilometrage of 150,000 kilometres, the two TSI engines emit significantly less carbon dioxide: the larger of the two units emits 1.3 metric tons less carbon dioxide than its predecessor, and at 4.1 metric tons, the savings with the 1.2-litre engine are even more significant.

Reductions over the life cycle
(carbon dioxide and ethene equivalents in kg)

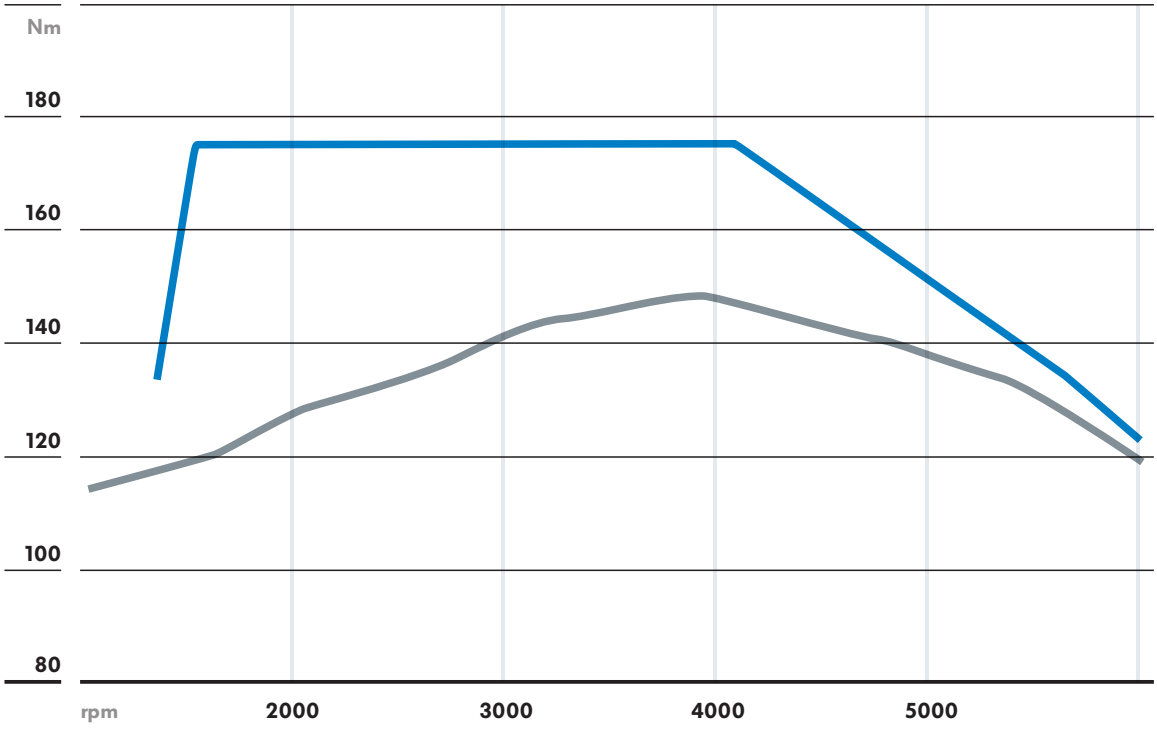


KEYWORD CO_2 equivalents

The indicator substance for the greenhouse effect is carbon dioxide (CO_2). All substances that contribute to the greenhouse effect are converted into CO_2 equivalents through an equivalence factor. Thus methane (CH_4) has a greenhouse potential 25 times higher than CO_2. In concrete terms this means that the emission of 1 kg of CO_2 and 1 kg of CH_4 leads to a net greenhouse effect of 26 kg CO_2 equivalents. All emissions that contribute to the greenhouse effect are measured in this way.

The true scale of this reduction is illustrated by the fact that the entire production process for a Volkswagen Polo generates approximately 4.7 metric tons of greenhouse gases. Also, thanks to reduced fuel consumption with the related savings on the fuel supply front, other environmental impacts, such as the contribution to the formation of summer smog, are also reduced.

Torque curves compared
(torque in Nm, engine speed in rpm)



1.6 MPI 75 kW **1.2 TSI** 77 kW

The Environmental Commendation

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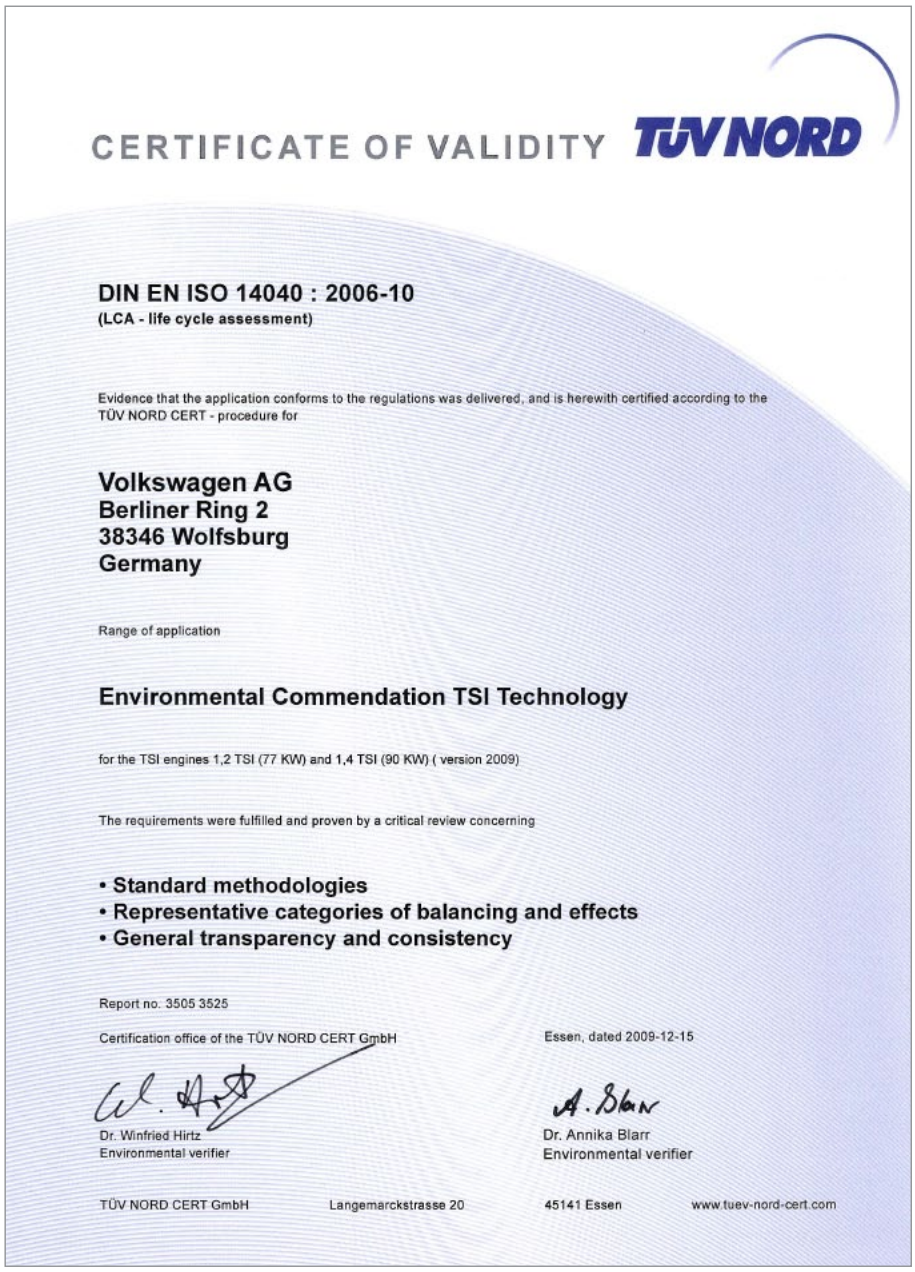


CERTIFICATE OF VALIDITY TÜV NORD

DIN EN ISO 14040 : 2006-10
(LCA - life cycle assessment)

Evidence that the application conforms to the regulations was delivered, and is herewith certified according to the TÜV NORD CERT - procedure for

Volkswagen AG
Berliner Ring 2
38346 Wolfsburg
Germany

Range of application

Environmental Commendation TSI Technology

for the TSI engines 1,2 TSI (77 KW) and 1,4 TSI (90 KW) (version 2009)

The requirements were fulfilled and proven by a critical review concerning

- **Standard methodologies**
- **Representative categories of balancing and effects**
- **General transparency and consistency**

Report no. 3505 3525

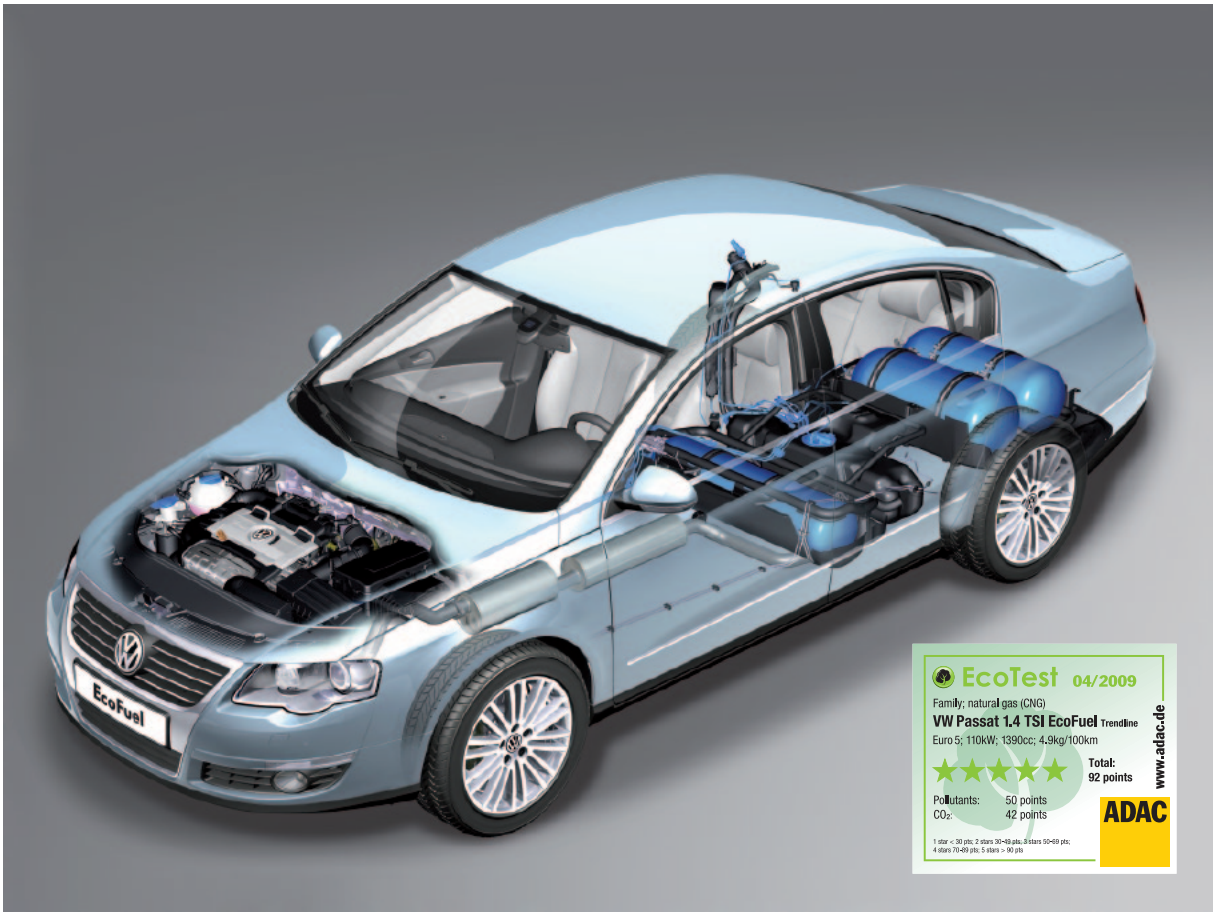
Certification office of the TÜV NORD CERT GmbH

Essen, dated 2009-12-15

Dr. Winfried Hirtz
Environmental verifier

Dr. Annika Blarr
Environmental verifier

TÜV NORD CERT GmbH Langemarckstrasse 20 45141 Essen www.tuev-nord-cert.com



An ideal combination

TSI engines from Volkswagen are not only outstanding performers when running on petrol but also when run on natural gas. The Passat 1.4 TSI EcoFuel, for example, has ushered in a new era of natural gas vehicles (NGVs). In contrast to previous NGVs, which were not exactly dynamic performers, the Passat EcoFuel is both dynamic and highly economical.

Despite its performance characteristics, the NGV version of Volkswagen's mid-range bestseller boasts a fuel consumption of only 4.5 kilograms of natural gas per 100 kilometres (in the New European Driving Cycle – NEDC).[3] Coupled with the 7-speed DSG, the natural gas Passat even beats the magic figure for its class of 120 g CO_2/km.[4] This is made possible by the very low emissions of the standard engine and the optimum adaptation of the engine control unit to operation on compressed natural gas (CNG).

The 1.4-litre TSI is a dual-fuel engine that can run on both natural gas and petrol and is equipped with a mechanical supercharger as well as a turbocharger. This "Twincharger" principle combines outstanding pulling power with high efficiency. The 1.4-litre unit in the Passat develops 110 kW on petrol and CNG. The 1.4-litre

[3] Passat 1.4 TSI EcoFuel (110 kW) urban 6.1 / non-urban 3.5 / combined (with 6-speed manual gearbox) 4.5 kg CNG/100 km, 123 g CO_2/km

[4] Passat 1.4 TSI EcoFuel (110 kW) urban 5.7 / non-urban 3.5 / combined (with 7-speed DSG) 4.4 kg CNG/100 km, 119 g CO_2/km

TSI was selected as the standard engine for the EcoFuel models as it offers considerable advantages in terms of cylinder charge at low engine speeds. Natural gas is an ideal fuel for turbo- and supercharged engines with high boost pressures because of its good anti-knock properties. As the engine control unit can switch automatically and imperceptibly from CNG to petrol operation, the Passat achieves a total range of over 900 kilometres.

The Passat TSI EcoFuel not only boasts outstanding performance, it also turns in an impressive set of environmental figures. It is the first car in the history of the ADAC EcoTest to be awarded five stars.[5] To date, Europe's largest motoring organisation has subjected some 800 vehicles to its EcoTest, widely considered one of the most demanding emissions tests for automobiles. At the ADAC Technology Centre, emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOX) and particulates (PM) are determined; with the same measurements being made for vehicles of all classes. In the „regulated emissions" category, the Passat achieved the best values ever recorded and was awarded the maximum score of 50 points. CO_2 emissions are determined as a function of the vehicle class. Here the test team reported outstanding results for the TSI engine, especially under acceleration in the autobahn cycle.

In environmental terms, CNG is certainly an attractive option. In natural gas mode, the TSI EcoFuel produces some 80 percent less carbon monoxide, 80 percent less nitrogen oxides and up to 23 percent less carbon dioxide than in petrol mode. That makes CNG the cleanest fossil fuel. And with fuel costs of only four

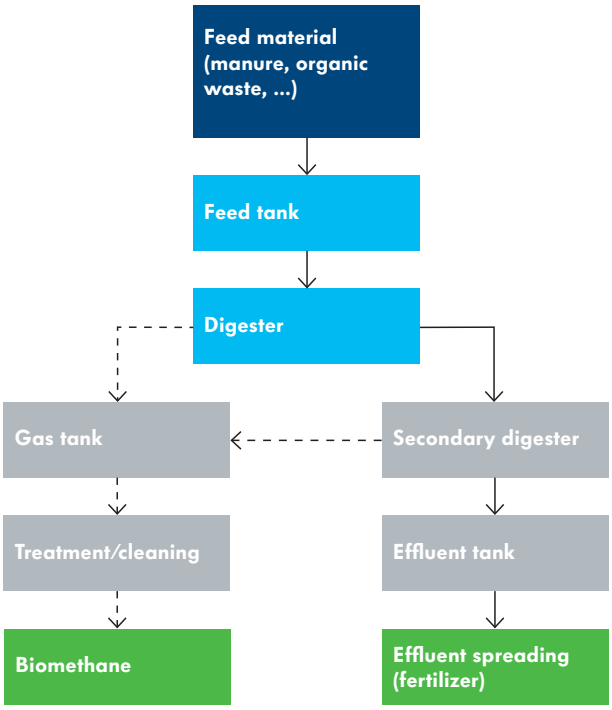
(euro-)cents per kilometre, the Passat EcoFuel also offers unbeatably low running costs.[6]

The environmental balance is even better if the vehicle is run on biomethane. Biomethane meets the same quality specifications as natural gas but is not a fossil fuel. It is produced by the fermentation of manure, energy crops such as maize, and organic waste. Unwanted substances such as carbon dioxide, hydrogen sulphide and other trace gases are then removed from this raw biogas to produce biomethane.

[5] www.adac.de/Tests/Autotest/Ecotest

[6] Natural gas price: € 0.91/kg (www.erdgasfahrzeuge.de; November 2009)

The biomethane production process



If biomethane is produced from organic waste, there is a further improvement in the environmental compatibility of the fuel. This is not just our opinion; a recent EU directive to promote the use of energy from renewable sources states that the CO_2 reduction potential of biogas from municipal organic waste as compressed natural gas is at least 73 percent[7].

There are also other reasons for using biomethane. It can be injected into the existing natural gas pipeline system without any problems and allows very high specific yields per unit area. With the yield of one hectare, a car could travel up to 67,000 kilometres[8]. Volkswagen is promoting this biofuel under the "SunGas" brand as part of its Powertrain and Fuel Strategy and supports the operation of the first biomethane filling station in Germany at Wendland in Lower Saxony. SunGas can be used without any restrictions in all NGVs produced by the Volkswagen Group.

Further information

- **Environmental Commendations: Polo, Golf, Passat and DSG**
- **Evolution not Revolution.** The Volkswagen Fuel and Powertrain Strategy
- **Making Zero Emissions Possible.** Fuel Cells and Electric Propulsion Systems from Volkswagen
- **Assuming Responsibility.** Volkswagen and CO_2
- **The Volkswagen AG Sustainability Report 2009/2010**
- **Moving ahead. Thinking. Acting.** Responsibility and Efficiency in the Vehicle Life Cycle

All these publications are available on the Internet at **www.mobility-and-sustainability.com**

You will find further information on the Environmental Commendation on the Internet at **www.environmentalcommendation.com**

You will find further information on BlueMotionTechnologies on the Internet at **www.bluemotion-technologies.com**

[7] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources

[8] According to data from Fachagentur Nachwachsende Rohstoffe e.V. (FNR - Agency for Renewable Resources)

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Environmental Commendation

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Environment Affairs Product
P.O. Box 011/1774
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December 2009
Art. No.: 915.1245.23.18
www.volkswagen.de

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