Long version: Volkswagen presents the world's first 1-litre car

Concept

First 1-litre car embodies the maximum saving potential available today
In three years, Research and Development turned a vision into reality

At its 42nd Annual Meeting of Stockholders, Volkswagen is once again demonstrating its technical competence by presenting the world's first 1-litre car. Even during the development of the first 3-litre car, which was launched on the market in the summer of 1999 and has since sold more than 22 000 units, the objective was to successfully put the most economical series-production vehicle ever on the market at an acceptable price. This has been accomplished. The 1-litre car is the potentiation of this idea.
The objective was to develop a vehicle with a fuel consumption of no more than one litre per 100 kilometres, using all technical possibilities available. The principal point was to show how state-of-the-art technology can be used to reduce fuel consumption and still come up with a safe, usable and roadworthy vehicle.
Volkswagen's Research and Development division enthusiastically took up the challenge to design the world's most economical car, and created a ready-to-drive car in just three years. Volkswagen's study is registered for use on public highways, and the journey from Wolfsburg to Hamburg demonstrates that the 1-litre car is technically feasible and offers driving pleasure of a very special kind. Project manager Dr. Thomas Gänsicke: "It really is a fascinating experience to drive through the night at 100 km/h with the fuel consumption indicator showing just 1.0 ltr./100 km, and nothing but the stars above your head."
The key objectives in the development were to minimise all driving resistances through lightweight construction and outstanding aerodynamics, and to develop new tyres and running gear components, taking ergonomics, current safety standards and familiar control functions into account.
However, the target, a fuel consumption level of one litre per 100 kilometres, meant abandoning conventional vehicle concepts. With a width of just 1.25 metres, the 1-litre car is extraordinarily narrow, the driver and passenger sit in tandem, the transversely installed engine is centrally located in front of the rear axle, the plastic bodywork has the highly aerodynamic shape of a teardrop.
In close cooperation with numerous suppliers, existing components were examined, assessed and modified, and brand new concepts were advanced. This was the case in particular for the wheels/tyres, the starter-alternator, the bodywork and the lighting.
The sports-car-like 1-litre car will thus be the technological forerunner of future vehicle generations.

Engine

Volkswagen 1-litre car – One-cylinder diesel engine with just 0.3 litre displacement

With a displacement of 299 cc, the diesel engine generates an output of 6.3 kW/8.5 bhp
High-tech unit with unit injection technology weighs a mere 26 kilograms

Even in the initial concept phase of the 1-litre car, different drive concept simulations showed that diesel was the only real option for the drive system, as only this combustion principle meets the maximum requirements for optimum energy exploitation. Here, the experience of the technical development team that created the three-litre Lupo was of great benefit. However, a 3-cylinder engine was out of the question for a fuel consumption level of just one litre per 100 kilometres. A 2-cylinder engine was also quickly dismissed. The final solution was a one-cylinder naturally-aspirated diesel

engine with a displacement of just 0.3 litres. The direct injection diesel engine makes use of the most efficient injection system available today: a unit injection element with 6-hole jet and pre-injection. It provides a high working pressure of 2,000 bar.
The one-cylinder SDI engine in the 1-litre car is not a mere derivative of the familiar engines, but is rather a completely new, technically highly sophisticated development. Two overhead camshafts actuate roller rocker fingers which in turn actuate three valves, two inlet valves and one exhaust outlet valve. These are then fed from the engine through a titanium exhaust system with reduced backpressure.
The two overhead camshafts are driven by a strengthened toothed belt. The engine is an aluminium monobloc construction. That means that the cylinder head and crankcase of the compression-ignition engine are cast as a single piece. But that is not the end of the lightweight construction, for also here, all technically feasible stops have been pulled. The fuel pump housing is made of magnesium. The trapezoidal connecting rod is made of particle-reinforced titanium. The success of these measures becomes evident on the scales: dry (i.e. without operating fluids like oil and water), the engine weighs in at an unbelievably light 26 kilograms. Ready for operation, including the starter-alternator, it is just 12 kilograms more.
Besides the reduction in weight, various measures were taken inside the engine to optimise fuel consumption. To minimise frictional resistance, the running area of the cylinder has been laser alloyed, roller rocker fingers reduce friction in the valve drive, even the tension of the piston rings has been reduced.
The centrally mounted one-cylinder SDI diesel engine is transversely installed in front of the rear axle, has a displacement of 299 cc and generates its maximum output (6.3 kW / 8.5 bhp) at 4,000 rpm. The maximum torque of 18.4 Newton metres is delivered at 2,000 rpm.
Even with this apparently low output and power development, the extremely light vehicle weight (which is comparable to that of an average touring motorcycle) and the excellent aerodynamics (with a drag coefficient of 0.159 – much better that a motorcycle and far better any series production vehicle) provide for a lively performance. For example, the 1-litre car reaches a top speed of 120 km/h.
Moreover, Volkswagen's economical wunderkind is suitable for everyday use despite the extremes of its design. And that includes its range. It is not difficult to calculate the range available with the 6.5 litre tank: the two-seater can travel up to 650 kilometres on a single filling.

Gearbox

Volkswagen 1-litre car – Newly conceived automated direct shift gearbox

Starter-alternator, start-stop system and freewheel function help save fuel
Six-speed gearbox selects gears sequentially and automatically

Due to the small installation space available for the engine-gearbox unit, new approaches were also required in the power transmission system. Here, a compact automated sequential 6-speed gearbox with a specially tuned shift program is used. This optimises power transmission, reducing fuel consumption.
It was not possible to simply take a gearbox off the shelf, for once again, the motto was: save weight. And so the gearbox housing is made of magnesium, all gears and shafts are hollow, and bolts are made of titanium. In addition, a special high-lubricity oil ensures the 6-speed gearbox, which weighs a mere 23 kilograms, always runs smoothly.
The gearshift mechanism is electro-hydraulically actuated via finely-tuned sensors, eliminating the need for a clutch pedal. There is also no need for a gear lever, for upshifts and downshift are made fully automatically. Here, the best possible engine and gearbox shift points are selected for optimum fuel economy. Gear selection – forwards, reverse or neutral – is made using a turn switch on the right-hand side of the cockpit.
The automated gearbox is coupled to a start-stop system, which includes a freewheel function. In overrun mode, the vehicle switches the engine off. The vehicle then rolls without the engine running. Development engineers call this gliding – alluding to the silent flight of a glider. The engine starts up again immediately when the magnesium accelerator pedal is depressed. A specially developed starter-alternator makes sure the engine is immediately restarted. Positioned between the engine and gearbox and using a dual clutch system, this works as both current generator and flywheel. In gliding mode, both clutches are open. When the driver presses the accelerator pedal again, the clutch between the engine and the starter-alternator is closed, causing the still turning flywheel to restart the engine without consuming any electrical current. Apart from this, the crankshaft starter-alternator,

which eliminates the need for a conventional alternator and starter motor, has a so-called boost function which is able to supply additional power to supplement the power of the engine. But that is not all the starter-alternator does. While braking, the negative acceleration energy is fed into the alternator and recovered (recuperation).

Bodywork

Volkswagen 1-litre car – A shape made by the wind

$_c$d figure of 0.159 makes full use of the aerodynamic possibilities
Two-seater body with high crash safety in extremely lightweight construction

Both the silhouette of the 1-litre car and its front view are more reminiscent of a narrow sports car than of a typical research vehicle. The reason: In order to achieve a consumption of one litre, the engineers not only had to do wonders with the drive unit – they also had to exploit the aerodynamic possibilities to the utmost ($_c$d = 0.159). Since the 1-litre car was to be a two-seater, but the frontal area had to be kept as small as possible, the only option was to arrange the two seats in line ahead, as in a racing bobsleigh or a glider. Entry is effected via a 1.5-metre-long gullwing door, which is drawn down on the left side to make the process more convenient.
The wheels have also been sheathed. The rear wheels disappear entirely behind their trim, and the front wheels are equipped with all-over wheel caps in carbon fibre. Even the side cooling air inlets only open when the engine needs cooling, and otherwise stay shut. Viewed from above, the teardrop shape of the body and the steep cut-off at the rear are clearly visible. The necessary downthrust on the rear axle is provided by an aerodynamically optimised underbody trim and a diffuser on the rear end.
In order to achieve the lowest possible $_c$d figure, there was never any question of exterior mirrors. However, the 1-litre car's rear visibility is ensured via cameras in the side turn signals. These show the road behind on two small LCD monitors located left and right of the circular central instrument. For parking, the picture is taken from the centrally-mounted rear-view camera in the third brake light, which shows the area directly behind the vehicle.
For the bodywork and the frame, a lightweight solution was used which also takes optimum account of the bearing structure: A combination of a magnesium spaceframe and an outer skin of carbon fibre composite material. With a weight of altogether some 74 kilograms, this version is 13 kilograms lighter than a combination of aluminium spaceframe with carbon fibre outer skin.
Even details such as door locks have been dispensed with, their place being taken by the most up-to-date electronic locking technology. The system automatically unlocks the entry hood when the driver approaches with the sensor. As in a top-range sports car, the engine is brought to life with a starter button.
The passive safety level corresponds to that of a GT sports car registered for racing. With the aid of computer simulations (CAE = Computer Aided Engineering), all kinds of crash types were investigated and the vehicle designed accordingly. So-called crash tubes, with integrated pressure sensors for airbag control in the front end of the car, absorb the entire deformation energy, leaving the footwell unaffected. The aluminium fuel tank – with a filler opening designed for automated robotised filling – is located in the collision-protected area behind the passenger.
Furthermore, active safety is provided by the latest-generation four-channel ABS and the electronic stability program ESP.

Running gear

Volkswagen 1-litre car – Entirely newly-developed lightweight running gear

Double-wishbone front axle weighs no more than eight kilograms
De-Dion principle rear axle; each wheel weighs only 1.8 kilograms

The shape of the tandem two-seater itself hints at a sports car, and the running gear, the seating position and the mid-engine are further clues that a different concept has been consciously pursued here than that of a traditional passenger car. The low sitting positions of the driver and passenger furthermore favour agile handling and a low centre of gravity, the sporty matching of the running gear ensures a low level of lateral inclination, and in extreme cases the ESP cuts in to lend a hand.

The front axle of the 1-litre car is a work of art in itself. The noblest materials, worked in fine detail, make this type of suspension almost a kind of precision engineering. In design terms it is a double-wishbone axle, with the upper wishbone in magnesium and the lower one and the pivot bearings in aluminium. The wheel hubs are made of titanium, and the balls in the lightweight-construction wheel bearings are ceramic. The knock-out here is the weight: the entire front axle construction including spring-damper unit weighs just eight (!) kilograms.
The driven rear axle has an entirely different construction, being designed on the De-Dion principle. The driven suspension has numerous elements of lightweight construction: the leaf springs are made of glass fibre, the transverse tube and the wheel mountings of aluminium, and the wheel hubs of titanium. The drive shafts and the wheel bearings are integrated in the axle.
The direct mechanical steering with its flat-top steering-wheel (whose magnesium skeleton gives it a weight of only 540 grams) is also a minor miracle of lightweight construction. The steering box is made of magnesium, the fabricated hollow rack of aluminium and titanium. Titanium pinions and aluminium track-rods with titanium pivot pins further contribute to the total weight of the steering gear being only 1870 grams.
Safe braking is assured by four alloy disc brakes and alloy brake calipers, combined with the latest-generation anti-lock brake system. An electronic parking brake on the rear axle ensures safe parking of the vehicle. The entire brake system adds only 7.8 kilograms to the lightweight construction total.
Volkswagen has also gone new and extreme ways in minimising the rolling resistance. In close cooperation with a tyre manufacturer, a wheel-and-tyre combination has been developed which puts the least possible mass in the way of propulsion. Like the body, the wheel is made of carbon fibre composite, and at 1.8 kilograms is more than 50 per cent lighter than a traditional wheel. The special tyre mixture and the tread have been designed in such a way that the driving resistance is reduced by 30 per cent in comparison with a standard tyre of the same size. In addition, the wheel bearings (made of titanium) have been specifically designed to be yet lower-friction for this car.

Electrics

Volkswagen 1-litre car – Top-quality electronics with low energy consumption

Headlights with Bi-Xenon and daylight beam
Rear light clusters and turn signals in LED technology

A further element in fuel saving is the optimisation of the electrical consumers in the vehicle. The aim was to omit none of the important functions, but always to develop the technologically most sophisticated and naturally the lightest solution.
Thus the 1-litre car has Bi-Xenon headlights whose dipped beam is only 32-Watt – but which have a light output of a traditional 60-Watt headlight, and have the advantage that, on account of this low output, no headlight washer system is necessary. The entire headlight element is made of polycarbonate, and weighs only 1,500 grams complete. The daylight beam, all turn signals and the rear light clusters are in LED technology.
The interior is illuminated by LED-fed prismatic rods located at the sides, the opened hood is well-lit in the dark by an electroluminescent foil.
Further technical highlights are the camera system with its displays integrated in the cockpit, the automatic access recognition for unlocking the gullwing door and the push-button starting (Kessy = Keyless Entry, Start and Exit System).
A starter-alternator is used to generate energy, and it incorporates a special function: When the driver depresses the magnesium brake pedal, the braking energy is fed into the alternator and thus recovered (recuperation). Energy storage is via a nickel-metal hydride battery. The on-board network is designed in CAN-Bus technology.

Interior

Volkswagen 1-litre car – A mixture of bobsleighing and gliding

Driver and passenger seated comfortably in line ahead
Monitors in the cockpit and external cameras instead of mirrors

The interior with its uncluttered, sporty design has plenty of room for two people who, once the turret-like glass roof (made of polycarbonate with integrated sun protection) has been raised, can enter conveniently. The seats too are examples of extremely lightweight construction. Their frames are in magnesium, and instead of classic upholstery the seats have firm yet comfortable fabric covers (M-flex).
The passenger can place his feet comfortably on footrests located left and right of the driver's seat. The driver meanwhile looks through the flat-top steering-wheel with airbag at the cockpit in the style of a modern jet. Left and right of the centrally-placed circular instrument are the monitors relaying the pictures from the two rear-view cameras. In front of these, on the right side the turn switch for gear selection and electric parking brake, and the starter button, are located; on the left the regulator for heating and ventilation, and the light switch.
On account of the optimum energy efficiency, only a small amount of superfluous heat is generated with which to heat the passenger compartment. Heating is therefore provided by an electric four-stage PTC element which is available immediately after starting, such as is used in the Phaeton, together with a four-stage fan.

Technical data

Volkswagen 1-litre car – The research car's key figures

1-litre car

Engine	
Principle	1-cylinder naturally-aspirated diesel with unit injection
Cubic capacity	299 cc
Bore x stroke	69 mm x 80 mm
Compression ratio	16.5: 1
Valves per cylinder	3
Valve timing	Twin overhead camshafts
Engine weight (dry)	26 kg
Output	6.3 kW (8.5 bhp) at 4,000 rpm
Torque	18.4 Nm at 2,000 rpm
Performance / consumption	
Top speed	120 km/h
Consumption	0.99 litres / 100 kilometres
Body, wheel, tyre dimensions	
Length x width x height	3,646 x 1,248 x 1,110 mm
Wheelbase	2,205 mm
Track front / rear	1,000 / 810 mm
Fuel tank volume	6.5 litres
Vehicle weight	290 kg
Luggage space volume	80 litres
Drag coefficient $_c$d / area	0.159 / 1.0 m^2
Tyres front / rear	95/80 R 16 / 115/70 R 16

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