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TWIN-CHARGER STRATIFICATION INJECTION (TSI)

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Abstract- *After MPFI (Multi Point Fuel Injection), Volkswagen has come up with new emerging technology called TSI (Twin-charger Stratification Injection). TSI engines combine what Volkswagen has learned from TDI diesel tech and FSI Fuel Stratified Injection engines. The* Volkswagen TSI engine *is smaller than most regular engines. This reduces fuel consumption and CO2 emissions, while still offering maximum power. TSI is available on an increasing number of our cars, from Polo to Passat. The benefits are quite clear when you compare them to older MPI systems: high specific torque is available from much lower revs and maintained at most rpms. This makes cars equipped with these engines are more lively at lower revs, which in turn makes them more economical and cleaner. The TSI engine combines direct injection with turbocharging and in some cases even twin charging i.e. turbocharging and supercharging together for better boost. Two other important components for a successful TSI are an intercooler to reduce the volume of the air coming into the engine and thus allow more of it to come in and reduced friction.*

Key Words: **MPFI, TSI, Twin charging, Torque**

1. INTRODUCTION

TSI stands for Twin-charger Stratification Injection. It is the new series of engines Volkswagen has come up with. TSI technology, a combination of maximum power coupled with minimum consumption, is nothing short of revolutionary.

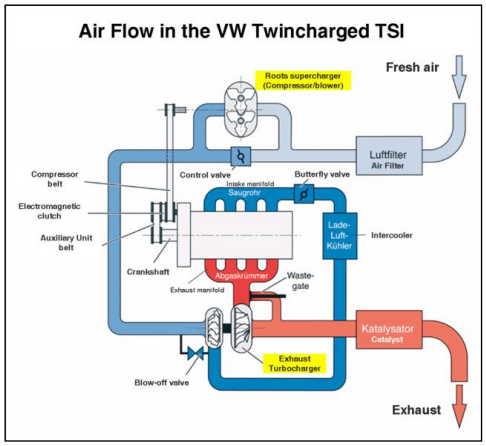

Fig- 1: Layout of TSI

A pioneering technology, it employs a compact, high powered engine resulting in less consumption of fuel. Its unique Direct Petrol Injection combined with a turbocharger enhances the engine's combustion efficiency to deliver a power output, much higher than that of conventional engines. Designed to deliver maximum torque even from low engine speeds, TSI technology offers the twin benefit of not only increasing your driving pleasure, but also reducing fuel consumption significantly.
Awarded the International Engine of the Year as well as the Best Green Engine awards, TSI technology is ever-evolving, with even further improvements in the pipeline.

2. EARLIER SYSTEMS

In earlier days, the engines were equipped with naturally aspirated intake air systems. When piston reciprocates in cylinder, during its downward movement suction is crated which causes air to get sucked inside the cylinder (due to negative pressure created inside the cylinder). This is how naturally aspirated systems work.

After some years, a newer technology of gasoline injection came up. Still it is being used in most of the Automobiles. It is well known by the name multi Point Fuel Injection i.e. MPFI. Fuel injection is a system for admitting fuel into an internal combustion engine. It has become the primary fuel delivery system used in automotive engines, having replaced carburettors during the 1980s and 1990s. A variety of injection systems have existed since the earliest usage of the internal combustion engine.

The primary difference between carburettors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburettor relies on suction created by intake air accelerated through a Venturi tube to draw the fuel into the airstream.

Modern fuel injection systems are designed specifically for the type of fuel being used. Some systems are designed for multiple grades of fuel (using sensors to adapt the tuning for the fuel currently used). Most fuel injection systems are for gasoline or diesel applications.

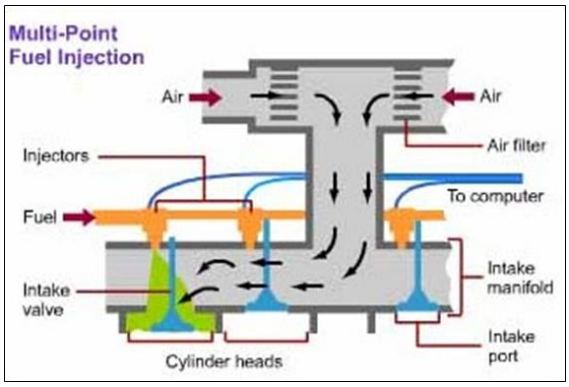

Fig- 2: Layout of MPFI system

The figure above shows how MPFI is equipped.

Now coming to TSI, here the air being admitted to cylinder is pressurized by either turbocharging or by both turbocharging and supercharging (Twin charging).

The fuel (Gasoline) is injected with latest injectors. In twin chargers, the air is first pressurized by a supercharger driven by Crankshaft through gearing. Initially as the engine speed is less turbocharger can't work efficiently. So to cater for this supercharger is introduced. As engine speed increases the power to supercharger is cut by an electromagnetic clutch as hence a turbocharger comes into action. It then blows air under pressure into the cylinder.

3. TSI TECHNOLOGY

Here are the main advantages of TSI -

3.1 Combining driving pleasure and economy

In developing TSI technology it was their aim to create engines that offer significant benefits by reducing fuel consumption and CO2 emissions while offering impressive power delivery.

3.2 Advantages resulting from "downsizing"

The recipe for the success of Volkswagen's TSI engines is to be found in "downsizing." Maximum power is obtained with minimum fuel consumption from a smaller engine. The reduction in engine size has brought better efficiency, as there is less power loss resulting from friction. The smaller engines also have the advantage of being lighter from the outset, so there's less weight to shift in the vehicle. Volkswagen's TSI engines take full advantage of these effects.

3.3 Gas direct injection plus charging

Pioneering technology used in TSI engines combines direct fuel injection with a turbocharger or charge compression with a turbo and a supercharger, enabling them to deliver impressive performance figures and torque as well as the full spectrum of driving pleasure despite their smaller size. Combustion of fuel is particularly efficient, with the result that power output of TSI engines is considerably higher than that of conventional, naturally aspirated engines.

3.4 Torque at all engine speeds

Volkswagen TSI engines are designed to deliver maximum torque from engine speeds as low as 1500 or 1800 rpm. This translates into driving pleasure and fuel economy. The driver can make use of superb power delivery across a wide range of engine speeds, and TSI engines can be combined to excellent effect with higher, fuel-saving gear ratios.

The unique feature of TSI twin charger technology, which Volkswagen is the only manufacturer in the world to offer, is the combination of petrol direct injection and a twin supercharger. The two components of the twin charger, a supercharger and a turbocharger, work in such a way that they perfectly complement each other. From idle speed up to an engine speed of approx. 2,400 rpm, the supercharger operates continuously whenever there is a suitable power demand from the driver.

Within the speed range of about 2,400 to 3,500 rpm, the supercharger is engaged as required, for instance for overtaking. The boost pressure is increased further by the in-line exhaust turbocharger. From 3,500 rpm upwards, only the turbocharger boosts the charge pressure in the cylinder. Each stage of the twin charger is thus always operated in its optimum range.

The twin charger gives the TSI engine a flat torque curve right from idling speed and across a broad speed range, as well as outstanding maximum power combined with very low fuel consumption. For engines with a lower power rating, Volkswagen uses the TSI turbocharger technology. Like the TSI twin charger, this system delivers a superb high torque at low engine revs with extremely good fuel economy. As with the TDI engines before, Volkswagen has again succeeded in combining driving pleasure and economy with its TSI technology.

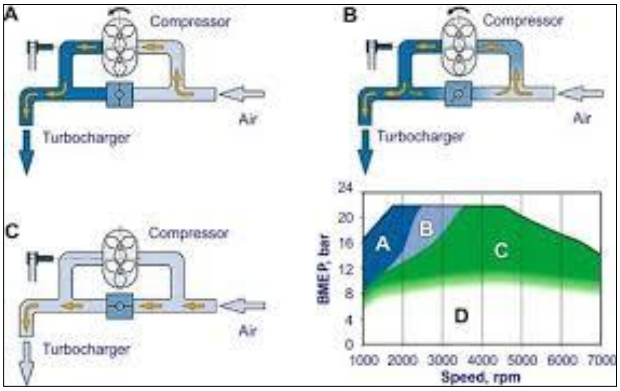

Fig- 3: Torque variation with RPM

4. STEPPING UP THE PRESSURE

Once upon a time, everything was easier. Big engines were more powerful and small engines were less powerful. Displacement was the key, as petrol engine 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 and TSI is the answer to this conundrum.

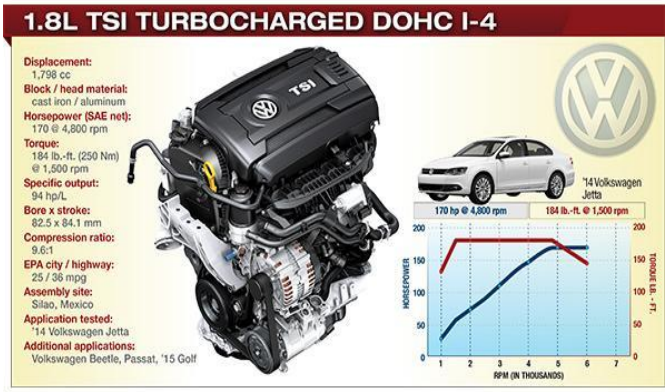

Fig- 4: TSI I-4 Performance

People still like to talk about engine displacement, although as a metric it is really a thing of the past. What counts today is 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.

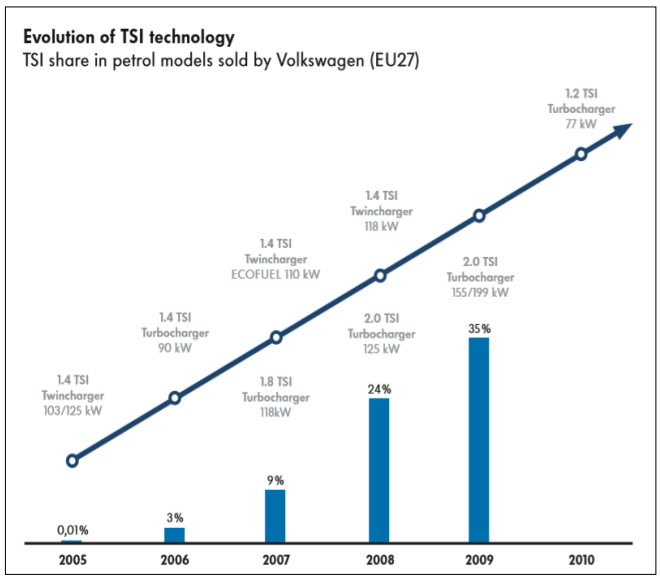

Fig- 5: Evolution of TSI

5. VARIANTS IN TSI ENGINE SERIES

When comparing an older 1.6 105 hp MPI automatic with the new 1.2 105 hp TSI DSG, Volkswagen found that emissions had dropped by a very impressive 50 grams. In addition, unlike a hybrid engine powertrain which can't keep up with with highway speeds once the battery is drained, TSIs have no such downside. In fact, the PFI (Performance Feel Index developed by the automaker) figures are even better due to increased torque. Saving money without forfeiting performance sound too good to be true which is why we need to examine Turbo Stratified Injection further.

The first driving principle behind the system is direct fuel injection. Volkswagen uses the latest injector technology to shoot the fuel directly into each of the cylinder's combustion chamber at higher pressures. The TSI engine combines direct injection with turbocharging and in some cases even twin charging, as some performance-oriented 1.4 TSI engines are equipped with both a supercharger and a turbocharger working together for better boost, as the engine-driven supercharger operates at lower revs, with the turbocharger powered by the exhaust gases joining in as engine speed rises. Two other important components for a successful TSI are an intercooler to reduce the volume of the air coming into the engine and thus allow more of it to come in and reduced friction.

An easily overlooked element of TSI technology has always been downsizing: 3-cylinder engines replacing 4-cylinder one, 1.2s replacing 1.6s, V6s replacing V8s and so on.

Volkswagen never stops inventing new technology to make their TSI engines competitive. The older 1.4 122 hp pioneered a new injector system with six fuel bores, while the latest 1.4 140 hp has a better cooling system and Active Cylinder Management, which is basically an advanced form of cylinder deactivation.

a) 1.2 TSI/TFSI

Displacing 1,196 cc, the 1.2 TSI engines all have the same 71mm bore and 75.6mm stroke. They have a cast aluminum alloy block for lightness and die-forged steel crankshaft for strength. This family of four-cylinder turbocharged engines is produced by Skoda Auto at the Mlada Boleslav. All use demand-controlled injectors which eliminate the need for a return fuel system. The single turbocharger offers 1.6 bars of pressure and is equipped with a front-mounted intercooler.

The 1.2 TSI is widely available across all subcompact and compact Volkswagen group cars. This includes the VW Polo, Golf, Beetle, Jetta, Gold Cabriolet, Golf Plus, Caddy, Touran in various power outputs. The list SEAT and Skoda modules is just as extensive and includes the Ibiza, Leon, Altea XL, Skoda Fabia, Rapid, Roomster and Yeti. Audi also offers it on the A1 and A3.

The 1.2 TSI engine was presented in December 2009 for the Volkswagen passenger vehicles and gradually began being

introduced on SEAT and Skoda models the next year with three different output versions of the engine, with increased performance and production costs.

The cheapest TSI engine currently on offer is the 86 hp (63 kW) at 4,800rpm and 160 Nm (118 lb-ft) from 1,500rpm. It was first offered on the Golf 6 as an alternative for the 1.6 MPI, entering production under the CBZA internal name. A 90 PS (66 kW) version of the same 8-valve engine was launched on the Polo 5 in 2011. It delivers its output 300rpm lower but has the same 160 Nm (118 lb-ft) torque levels. 1.2 TSI engines also offer 105 hp and 175 Nm (129 lb-ft) of torque on select models. These engines have four valves per cylinder and offer improved performance.

b) 1.4 TSI/TFSI

The 1.4-liter four-cylinder engine has been with VW for a very long time, but in 2005 at the Frankfurt Motor Show they put a performance spin by unveiling the Twin charger version. Based on the EA111 that has been around since the original VW Polo and the Audi 50, the new engine used a turbocharger and a supercharger to offer 170 PS, replacing the 2.0 FSI naturally aspirated unit. At engine speeds, just above idle, the belt-driven supercharger provides a boost pressure until the engine reaches 3,500rpm.

Just like the EA211 1.4 FSI, the TSI engine displaces 1,390cc with a bore of 76.5mm and a stroke of 75.6mm. It's been offered on the Golf since 2005, as well as a number of compact cars from the VW Group. Engine outputs vary from 122 hp all the way to 180 hp offered on performance models like the SEAT Ibiza Cupra, Polo GTI and Fabia RS. The newly developed generation of the 1.4 TSI is built under the code name EA211. It produces 140 hp using a single turbo, has the latest TSI Green tech and offers Cylinder on Demand.

C) 1.8 TSI/TFSI

The newer EA888 family of four-cylinder 1.8-liter turbo engines were designed and developed by Audi's engineers for optimum performance and efficiency. Like the EA113 generation of engines they replaced, they use iron because this has better acoustic damping properties compared to aluminum. Expected to be universally available for all markets on five continents, the 1.8 TSI is widely believed to be the ideal solution for the US market's aging 2.5-liter four-cylinder units.

The generation of 1.8 TSI engines is still in production. Commonalities are limited to FSI direct injection, cooling systems and spacing between the cylinders.

6. AWARD-WINNING TECHNOLOGY

Since 2006, the TSI engine has received the coveted Engine of the Year award 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 liter class.

German motoring organization ADAC awarded TSI technology its Gelber Engel 2008b 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' and the 'Automotive Researchers and Journalists' awarded first place to TSI engines. That same year, the TSI engines also won the renowned Techno Best technology award in Istanbul. The award is presented under the auspices of "Auto Best", the motoring organization of emerging markets in Central and Eastern Europe, by a jury of leading journalists.

7. ENVIRONMENTAL COMMENDATION

TSI technology is also a key component in the Power train 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. In the medium term, however, the internal combustion engine will remain the dominant power train 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 trans-missions and a start-stop system of the type already used in a number of Blue Motion- Technology models.

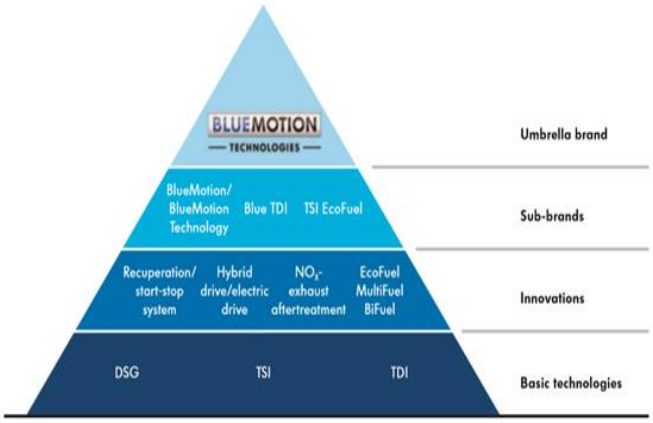

Fig- 6: Environmentally friendly products and technologies under one umbrella brand

8. 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.

8.1 Reduction of fuel consumption through:

– Downsizing (smaller engine displacement)
– Turbo charging or twin-charging
– Reduction of friction losses

8.2 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)

8.3 Greenhouse effect – less CO2 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)

8.4 Resource conservation and environmental protection through:

– Oil system with optimized volume
– Cylinder head with optimized weight (1.4 TSI)
– Crankshaft with optimized weight (1.2 TSI)
– Reduced contributions to summer smog and acidification

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 CO2 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 average of 150,000 kilometers, 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.

9. THE ENGINES ASSESSED

This Environmental Commendation for the TSI engine describes and analyses the environmental impacts of various petrol engines. To this end, they have compared the current 1.2-litre and 1.4-litre TSI units with conventional normally aspirated petrol engines. The results are based on Life Cycle Assessments drawn up in accordance with the standards DIN EN ISO 14040 and 14044. All the definitions and descriptions required for preparing these Life Cycle Assessments were drawn up in accordance with the above standards and are explained below.

9.1 Aim and target group of the assessment

Volkswagen has been producing Life Cycle Assessments for over ten years to provide detailed information on the environmental impacts of vehicles and components for our customers, shareholders and other interested parties within and outside the company.

The objective of the Life Cycle Assessment in this case was to compare the environmental profiles of various types of petrol engine. To this end, we compared the 1.2-litre and 1.4-litre TSI units with their respective normally aspirated predecessors.

9.2 Function and functional unit of the vehicle systems assessed

The "functional unit" for the assessment was defined as the production of propulsion power over a total distance of 150,000 kilometers in the New European Driving Cycle (NEDC). The key technical data of the engines compared are listed in Table. In order to ensure comparability and to calculate the reduction in fuel consumption caused solely by the change in engine technology, it was necessary to base the assessment of the service life phase on fuel consumption simulations. For this purpose, the engines were "virtually installed" on the same reference vehicle, a Golf VI with 6-speed manual gearbox, and the resulting consumption figures for the entire vehicle were determined on the basis of otherwise unchanged assumptions.

Since the 1.8 and 2.0 TSI engines have a rather small share in the TSI segment, the study at hand concentrates on the engines with 1.4 and 1.2 liters of cubic capacity. As displayed below, these engines realize much lower fuel consumption than their predecessors despite their higher output and torque values.

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 [cm³]	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

Fig- 7: Engine Assessment

10. STATISTICAL DATA

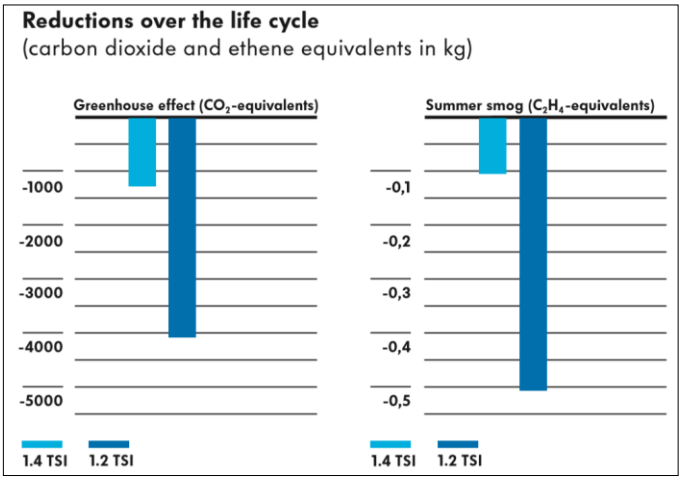

Fig- 8: Reduction of CO_2 and ethane equivalent over life cycle

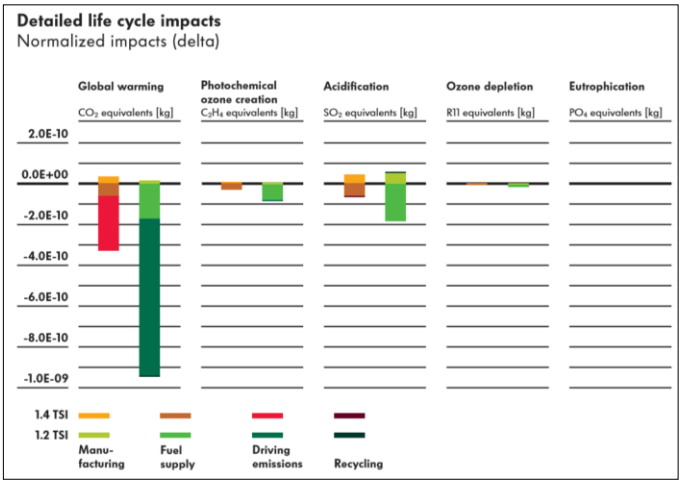

Fig- 9: Detailed life cycle impacts

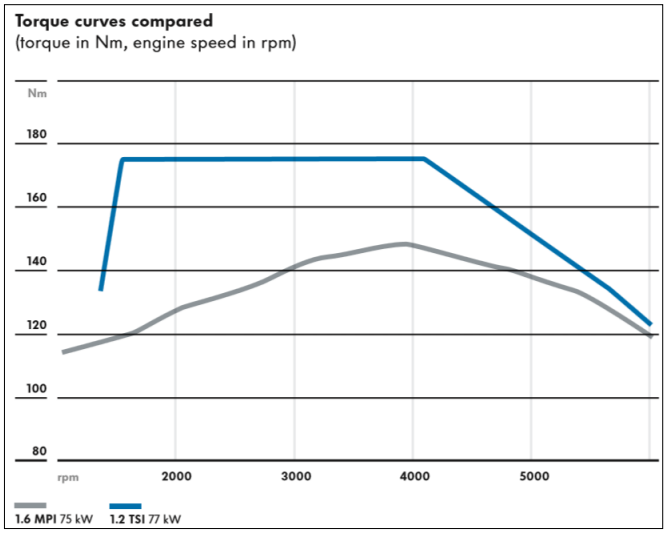

Fig- 10: Torque curves compared

The indicator substance for the greenhouse effect is carbon dioxide (CO2). All substances that contribute to the greenhouse effect are converted into CO2 equivalents through an equivalence factor. Thus methane (CH4) has a greenhouse potential 25 times higher than CO2. In concrete terms this means that the emission of 1 kg of CO2 and 1 kg of CH4 leads to a net greenhouse effect of 26 kg CO2 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.

11. 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 Eco Fuel, 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 Eco Fuel 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 kilometers (in the New European Driving Cycle – NEDC) Coupled with the 7-speed DSG, the natural gas Passat even beats the magic figure for its class of 120 g CO2/km. 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 "Twin charger" 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 TSI was selected as the standard engine for the Eco Fuel 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 kilometers.

The Passat TSI Eco Fuel 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 Eco Test to be awarded five stars. To the date,

Europe's largest motoring organization has subjected some 800 vehicles to its Eco Test, 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. CO2 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 Eco Fuel 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 kilometer, the Passat Eco Fuel 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.

12. CONCLUSION

Volkswagen TSI engines not only fulfill high expectations in terms of economy and driving performance but are also one of the basic technologies of Blue Motion- Technologies brand, representing an important step towards sustainable mobility for everyone. The Life Cycle Assessment of the TSI engine documents all the progress that has been made in this area compared with conventional normally aspirated petrol engines.

Compared with normally aspirated engines, TSI engines offer lower fuel consumption and emissions during their service life, as well as comparable environmental impacts during the manufacturing and recycling phases. The overall environmental profile of the TSI engine therefore represents a substantial improvement over that of a normally aspirated petrol engine.

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