



# The Golf

## Environmental Commendation

### Background Report



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## The Life Cycle Assessment of the Golf

Volkswagen's objective is to develop vehicles in such a way that, in their entirety, they present better environmental properties than their predecessors. To document the environmental performance of its vehicles and technologies, Volkswagen uses Environmental Commendations. Our Environmental Commendations provide our customers, shareholders and other stakeholders inside and outside the company with detailed information about how we are making our products and production processes more environmentally compatible and what we have achieved in this respect [Volkswagen AG 2009a, Volkswagen AG 2009b]. The Commendations are primarily based on detailed Life Cycle Assessments (LCA) in accordance with ISO 14040/44, which have been verified by independent experts, in this case from TÜV NORD. As part of an integrated product policy, the LCA considers not only individual environmental aspects, such as the driving emissions of the vehicle, but its entire life cycle. This means that all processes from manufacturing via service life to recycling and disposal are examined.

Since 1996, Volkswagen has been drawing up Life Cycle Assessments of its vehicles and individual components with the aim of enhancing their environmental compatibility. The environmental improvement of the Golf is an especially important step for us as we advance towards sustainable mobility for all. This Environmental Commendation presents the results of a comprehensive Life Cycle Assessment and documents the continuous progress achieved by Volkswagen in the field of environmental product optimisation.

For the Life Cycle Assessment of the Golf we compared three diesel-engined models the Golf 1.6 TDI (77 kW), Golf BlueMotion (1.6 TDI, 77 kW) and Golf BlueMotion Technology (1.6 TDI, 77 kW) with a similarly powerful predecessor. For the petrol models, a Golf 1.6 MPI (75 kW) was compared with a similarly engined successor with 1.2-litre TSI engine (77 kW), the 1.2 TSI BlueMotion Technology (77 kW) and the Golf BiFuel, operated on LPG (75/72 kW).

The evaluation of these vehicles' environmental profiles is not based solely on emissions during their service life, i.e. the „driving time“, but on the entire life cycle from production through to recycling. It emerged relatively quickly that the successor models presented improvements – some of them quite significant – in almost all the environmental impact categories. The biggest advances were made in those areas where the quantitative environmental impacts are greatest: global warming (greenhouse effect), acidification and photochemical ozone creation potential (summer smog). In the water eutrophication and ozone depletion categories the impact of the vehicles assessed was very minor by comparison. It was also found that the improvements were primarily due to reduced fuel consumption – which also means a lower environmental impact from the fuel production process – and the resultant lower driving emissions. Lightweight design and the use of smaller engines with the same output were also beneficial.

Compared to its predecessor the current Golf is slightly larger, but despite the wide range of safety and comfort requirements that it meets, it is no heavier. Significant improvements have been achieved in fuel consumption and the related CO<sub>2</sub> emissions. In terms of fuel efficiency, the BlueMotion version in particular reveals the level of potential we have been able to exploit. Compared to its predecessor, the new Golf presents a much better balance sheet over its entire life cycle with regard to global warming and photochemical ozone creation potential, thereby attaining the environmental goal set by the Technical Development department. The production of the new model causes slightly higher CO<sub>2</sub> emissions, but the savings during its subsequent service life rapidly compensate for this increase.

During the service life of 150,000 kilometres assumed for the analysis, the three diesel models emit 18.9 metric tons (1.6 TDI), 16.1 metric tons (BlueMotion Technology) and 14.9 metric tons (BlueMotion) of carbon dioxide. In terms of global warming effect over the entire vehicle life cycle this corresponds to savings of about 10 percent for the 1.6 TDI and 17 percent for the BlueMotion Technology compared to the predecessor model. The BlueMotion model achieves even greater savings, at 21 percent. During its service life, the Golf BiFuel emits about 22.4 metric tons of CO<sub>2</sub> while the petrol engined 1.2 TSI emits 20.1 metric tons and the Golf 1.2 TSI BlueMotion Technology 18.2 tons of CO<sub>2</sub>. The petrol-engined models therefore achieve reductions in emissions of 18, 20 and 27 percent respectively.

The overall reduction in emissions of greenhouse gases over the full life cycle is significant, since the Golf 1.6 TDI BlueMotion, for example, emits approximately six metric tons less CO<sub>2</sub> than its predecessor. The true scale of this reduction is illustrated by the fact that the entire production process for a Golf 1.6 TDI generates slightly less than six metric tons of greenhouse gases. In overall terms, we have therefore achieved our objective of continuing the technical development of our vehicles at the same time as improving their environmental compatibility.

## The Golf models assessed

Volkswagen's Environmental Commendation for the Golf describes and analyses the environmental impacts of selected Golf models. To this end, we compared selected diesel and petrol models from the current Golf series (Golf VI)<sup>1</sup> with their respective predecessors (Golf V). The results are based on Life Cycle Assessments in accordance with the standards DIN EN ISO 14040 [ISO 2006] and 14044. All the definitions and descriptions required for preparing these Life Cycle Assessments were drawn up in accordance with these standards and are explained below.

### Objective and target group of the assessment

Volkswagen has been conducting Life Cycle Assessments for over ten years to provide detailed information on the environmental impacts of its vehicles and components for our customers, shareholders and other stakeholders within and outside the company. The objective of the present Life Cycle Assessment was to describe the environmental profiles of the current Golf models with diesel and petrol engines and compare them with their predecessors.

For the Life Cycle Assessment of the Golf, we compared the 1.9 TDI (77 kW)<sup>2</sup> with its almost equally powerful successor, the 1.6 TDI (77 kW)<sup>3</sup> and the especially economical Golf BlueMotion Technology (1.6 TDI, 77 kW)<sup>4</sup> and Golf BlueMotion (1.6 TDI, 77 kW)<sup>5</sup>. For the petrol models we compared a Golf with a 1.6-litre MPI engine (75 kW)<sup>6</sup> with a similar successor model, equipped with a 1.2-litre TSI engine (77 kW)<sup>7</sup> and the 1.2 TSI BlueMotion Technology (77 kW)<sup>8</sup> as well as the Golf BiFuel (75/72 kW) operated on LPG.<sup>9</sup>

### Function and functional unit of the vehicle systems assessed

The functional unit used for the Life Cycle Assessment is the transport of passengers (5-seater) over a total distance of 150,000 kilometres in the New European Driving Cycle (NEDC), with comparable utilisation characteristics (e.g. performance) – see technical data in Table 1.

<sup>1</sup> The current models represent the Golf range available when this report was finalised.

<sup>2</sup> 5.1 l/100km (NEDC) 135 g CO<sub>2</sub>/km

<sup>3</sup> 4.5 l/100km (NEDC) 119 g CO<sub>2</sub>/km

<sup>4</sup> 4.1 l/100km (NEDC) 107 g CO<sub>2</sub>/km

<sup>5</sup> 3.8 l/100km (NEDC) 99 g CO<sub>2</sub>/km

<sup>6</sup> 7.4 l/100km (NEDC) 176 g CO<sub>2</sub>/km

<sup>7</sup> 5.7 l/100km (NEDC) 134 g CO<sub>2</sub>/km

<sup>8</sup> 5.2 l/100km (NEDC) 121 g CO<sub>2</sub>/km

<sup>9</sup> 9.2l/100km (NEDC) 149 g CO<sub>2</sub>/km (using LPG fuel)

**Table 1: Technical data of vehicles assessed**

	<b>Golf V 1.9 TDI</b>	<b>Golf VI 1.6 TDI</b>	<b>Golf VI 1.6 TDI BlueMotion Technology</b>	<b>Golf VI 1.6 TDI BlueMotion</b>	<b>Golf V 1.6 MPI</b>	<b>Golf VI 1.2 TSI</b>	<b>Golf VI 1.2 TSI BlueMotion Technology</b>	<b>Golf VI BiFuel</b>
Engine capacity [cm <sup>3</sup> ]	1896	1598	1598	1598	1595	1197	1197	1595
Output [kW]	77	77	77	77	75	77	77	75/ 72*
Gearbox	5-speed- manual	5-speed- manual	5-speed- manual	5-speed- manual	5-speed- manual	6-speed- manual	6-speed- manual	5-speed- manual
Fuel	Diesel	Diesel	Diesel	Diesel	Petrol (Super)	Petrol (Super)	Petrol (Super)	Petrol (Super)/ LPG
Emission standard	Euro 4	Euro 5	Euro 5	Euro 5	Euro 4	Euro 5	Euro 5	Euro 5
Maximum speed [km/h]	187	189	190	190	184	190	190	188/ 185*
Acceleration 0-100 km/h [s]	11.3	11.3	11.3	11.3	11.4	10.6	10.5	11.9/ 12.1*
Max. torque [Nm] at rpm	250/ 1900	250/ 1500- 2500	250/ 1500- 2500	250/ 1500- 2500	148/ 3800	175/ 1500- 4100	175/ 1500- 4100	148 at 3800 rpm/ 144 at 3800 rpm*
Unladen weight [kg] <sup>10</sup>	1326	1314	1318	1314	1248	1233	1234	1322
Luggage capacity [l]	350/1305	350/1305	350/1305	350/1305	350/1305	350/1305	350/1305	350/1305
Fuel tank capacity [l]	55	55	55	55	55	55	55	55/ 38*

\* Using LPG fuel

**Scope of Assessment**

The scope of the assessment was defined in such a way that all relevant processes and substances are considered, traced back to the furthest possible extent and modelled at the level of elementary flows in accordance with ISO 14040. This means that only substances and energy flows taken directly from the environment or released into the environment without prior or subsequent treatment cross the boundaries of the system. The material fractions generated during recycling are the only exception.

The vehicle manufacturing phase was modelled including all manufacturing and processing stages for all vehicle parts and components. The model included all Steps from the extraction of raw materials and the manufacture of semi-finished products right through to assembly.

Regarding the vehicle's service life, the model includes all relevant processes from fuel production and delivery through to driving. The analysis of the fuel supply process includes shipment from the oilfield to the refinery and the refining process, as well as

<sup>10</sup> Unladen weight with 68 kg driver, 7 kg luggage and fuel tank 90% full, determined in accordance with directive 92/21/EEC [EU 1992] in the version currently in force (04/2009).

transport from the refinery to the filling station. Vehicle maintenance is not included in the assessment as previous studies demonstrated that maintenance does not cause any significant environmental impacts [Schweimer und Levin, 2000] [Schweimer und Roßberg, 2001].

The recycling phase has been modelled in accordance with the VW SiCon process. In contrast to conventional recycling approaches, this process allows non-metallic shredded residual material to also be recycled and used as a substitute for primary raw materials [Krinke et al. 2005a]. This VW SiCon process allows around 95 percent of the vehicle by weight to be recycled.

In this Life Cycle Assessment, no environmental credits were awarded for secondary raw material substitution. Only the environmental impacts of the recycling processes required were included. This corresponds to a worst case assumption, since in reality secondary raw material from vehicle recycling is returned to the production cycle. This recycling and substitution of primary raw materials could avoid consumption of primary raw materials and the environmental impact of their production. Fig. 1 is a schematic diagram indicating the scope of the Life Cycle Assessment. Europe (EU-15) was chosen as the reference area for all processes in the manufacture, service-life and recycling phases.

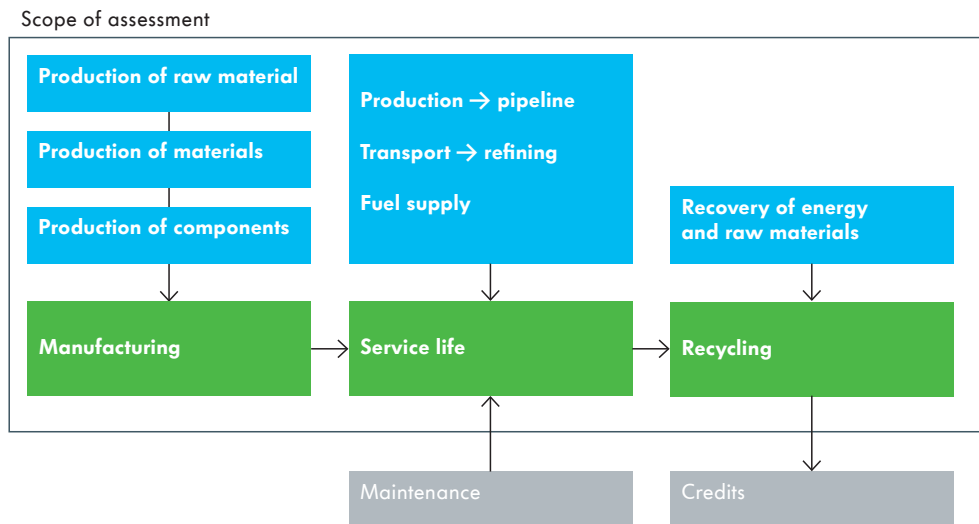


Fig. 1: Scope of the Life Cycle Assessment

### Environmental Impact Assessment

The Impact Assessment is based on a method developed by the University of Leiden in the Netherlands (CML methodology) [Guinée and Lindeijer 2002]. The assessment of environmental impact potentials in accordance with this method is based on recognised scientific models. A total of five environmental impact categories<sup>11</sup> were identified as relevant and were then assessed in this study:

- eutrophication potential
- ozone depletion potential
- photochemical ozone creation potential
- global warming potential for a reference period of 100 years
- acidification potential

The above environmental impact categories were chosen because they are particularly important for the automotive sector, and are also regularly used in other automotive-related Life Cycle Assessments [Schmidt et al. 2004; Krinke et al. 2005b]. The environmental impacts determined in the Life Cycle Assessments are measured in different units. For instance, the global warming potential is measured in CO<sub>2</sub> equivalents and the acidification potential in SO<sub>2</sub> equivalents (each in kilograms). In order to make them comparable, a normalisation process is required. In this Life Cycle Assessment the results were normalised with reference to the annual average environmental impact caused by Western Europe (EU15). For example, in the global warming category, the impact caused by Western Europe was about 4.4 billion metric tons of CO<sub>2</sub> equivalents (see Table 2).

**Table 2: EU 15 normalisation factors in accordance with CML 2001**  
(in thousand metric tons)

Environmental category	per capita	Unit
Eutrophication potential	15906	PO <sub>4</sub> equivalents
Ozone depletion potential	31	R11 equivalents
Photochemical ozone creation potential	7228	C <sub>2</sub> H <sub>4</sub> equivalents
Global warming potential	4440050	CO <sub>2</sub> equivalents
Acidification potential	21553	SO <sub>2</sub> equivalents

This normalisation allows statements to be made regarding the contribution of a product to total environmental impacts within Western Europe. The results can then be presented in one graph using the same scale. This approach also makes the results more comprehensible and allows environmental impacts to be compared.

<sup>11</sup> A more detailed description of these environmental impact categories is given on the internet at [www.environmental-commendation.com](http://www.environmental-commendation.com).

In Table 2, we have listed the normalisation factors for the individual impact categories used for the CML 2001 method. In this context it must be pointed out that the normalisation does not give any indication of the relevance of a particular environmental impact, i.e. it does not imply any judgement on the significance of individual environmental impacts.

### **Basis of data and data quality**

The data used for preparing the Life Cycle Assessment can be subdivided into product data and process data. “Product data” describes the product itself, and among other things includes:

- Information on parts, quantities, weights and materials
- Information on fuel consumption and emissions during utilisation
- Information on recycling volumes and processes.

“Process data” includes information on manufacturing and processing steps such as the provision of electricity, the production of materials and semi-finished goods, fabrication and the production of fuel and consumables. This information is either obtained from commercial databases or compiled by Volkswagen as required.

We ensure that the data selected are as representative as possible. This means that the data represent the materials, production and other processes as accurately as possible from a technological, temporal and geographical point of view. For the most part, published industrial data are used. In addition, we use data that are as up-to-date as possible and relate to Europe. Where European data are not available, German data are used. For the various models assessed, we always use the same data on upstream supply chains for energy sources and materials. This means that differences between the latest models and their predecessors are entirely due to changes in component weights, material compositions, manufacturing processes at Volkswagen and driving emissions, and not to changes in the raw material, energy and component supply chains.

The Life Cycle Assessment model for vehicle production was developed using Volkswagen’s slimLCI methodology (Koffler et. al. 2007)<sup>12</sup>. Vehicle parts lists were used as data sources for product data, and the weight and materials of each product were taken from the Volkswagen material information system (MISS). This information was then linked to the corresponding process data in the Life Cycle Assessment software GaBi. Material inputs, processing procedures and the selection of data in GaBi are standardised to the greatest possible extent, ensuring that the information provided by slimLCI is consistent and transparent. SlimLCI methodology thus not only ensures highly detailed modelling but also high quality standards for LCA models. For the modelling of the vehicle’s service life, representative data for upstream fuel supply chains were taken from the GaBi database. It was assumed that fuel used in Europe was transported over a distance of 200 kilometres on average.

<sup>12</sup> For more information about how Volkswagen draws up Life Cycle Assessment, visit [www.environmental-commendation.com](http://www.environmental-commendation.com)

For the regulated emissions CO<sub>2</sub>, NO<sub>x</sub> and HC, direct driving emissions were modelled in accordance with the Euro 4 and Euro 5 emission standards (see Table 1 and Table 3).

**Table 3: Relevant emission limits in accordance with Euro 4 and Euro 5**

Emission limit	Euro 4		Euro 5	
	Petrol [g/km]	Diesel [g/km]	Petrol [g/km]	Diesel [g/km]
Carbon monoxide emissions (CO)	1.00	0.50	1.00	0.50
Nitrogen oxide emissions (NO <sub>x</sub> )	0.08	0.25	0.06	0.18
Hydrocarbon emissions (HC)	0.10		0.10	
of which NMHC			0.068	
NO <sub>x</sub> + HC emissions		0.30		0.23
Particulate emissions		0.025	0.005*	0.005

\* with direct injection

This model too represents a worst case assumption, since actual emissions are in some cases far below the applicable statutory limits (see Table 4). This means that the regulated service-life emissions indicated in the graphs are higher than those that actually occur. The fuel consumption of the vehicles was calculated in each case from the measured CO<sub>2</sub> emissions and is shown in Table 4. All consumption figures and emissions were determined on the basis of EU Directives 80/268/EEC and 70/220/EEC [EU 2001; EU 2004] and regulation 692/2008 [EU 2008] for type approval and correspond with the values presented to the German Federal Motor Transport Authority (Kraftfahrtbundesamt) for type approval. A fuel sulphur content of 10 ppm was assumed.<sup>13</sup>

<sup>13</sup> In some countries, fuel with a sulphur content of 10 ppm is not yet available. However, even if the sulphur content were higher, the contribution of sulphur emissions during the vehicle's service life would still remain negligible.

**Table 4: Fuel consumption and emissions of vehicles assessed**

	<b>Golf V 1.9 TDI</b>	<b>Golf VI 1.6 TDI</b>	<b>Golf VI 1.6 TDI BlueMotion Technology</b>	<b>Golf VI 1.6 TDI BlueMotion</b>	<b>Golf V 1.6 MPI</b>	<b>Golf VI 1.2 TSI</b>	<b>Golf VI 1.2 TSI BlueMotion Technology</b>	<b>Golf VI BiFuel</b>
Fuel	Diesel	Diesel	Diesel	Diesel	Petrol (Super)	Petrol (Super)	Petrol (Super)	Autogas (LPG)
Fuel consumption (urban/ highway/ combined) [l/100 km]*	6.3/4.5/ 5.1	5.7/3.9/ 4.5	5.2/3.5/ 4.1	4.7/3.4/ 3.8	9.9/6.1/ 7.4	7.1/4.9/ 5.7	6.5/4.5/ 5.2	12.7/7.2/ 9.2
Emission standards	Euro 4	Euro 5	Euro 5	Euro 5	Euro 4	Euro 5	Euro 5	Euro 5
Carbon dioxide emissions, combined [g/km]	135	119	107	99	176	134	121	149
CO [g/km]	0.034	0.1825	0.1755	0.2991	0.759	0.6569	0.4309	0.399
HC [g/km]					0.07	0.0468	0.0352	0.044
of which NMHC [g/km]						0.0406	0.0302	0.032
NO <sub>x</sub> [g/km]	0.179	0.1474	0.1055	0.1179	0.04	0.0334	0.0131	0.0355
NO <sub>x</sub> + HC [g/km]	0.191	0.1743	0.1264	0.1525				
Particulate emissions [g/km]	0.002	0.00063	0.00006	0.00001		0.0025	0.00314	

\* Total average consumption (NEDC)

Vehicle recycling was modelled on the basis of data from the VW SiCon process and using representative data from the GaBi database.

In sum, all information relevant to the aims of this study was collected and modelled with a sufficient degree of completeness.<sup>14</sup> The modelling of vehicle systems on the basis of vehicle parts lists ensures that the model is complete, especially with respect to the manufacturing phase. In addition, as the work processes required are automated to a great extent, any differences in the results are due solely to changes in product data and not to deviations in the modelling system.

<sup>14</sup> Completeness, as defined by ISO 14040, must always be considered with reference to the objective of the investigation. In this case, completeness means that the main materials and processes have been reflected. Any remaining gaps in the data are unavoidable and apply equally to all the vehicles compared.

## Model assumptions and findings of the Life Cycle Assessment

All the framework conditions and assumptions defined for the Life Cycle Assessment are outlined below.

**Table 5: Assumptions and definitions for the Life Cycle Assessment**

<b>Aim of the Life Cycle Assessment</b>
<ul style="list-style-type: none"> <li>• Comparison of the environmental profiles of predecessor and successor versions of selected Golf models with petrol and diesel engines</li> </ul>
<b>Scope of assessment</b>
<b>Function of systems</b> <ul style="list-style-type: none"> <li>• Transport of passengers in a five-seater car</li> </ul>
<b>Functional unit</b> <ul style="list-style-type: none"> <li>• Transport of passengers in a five-seater car over a total distance of 150,000 kilometres in the New European Driving Cycle (NEDC), with comparable utilisation characteristics (e.g. performance)</li> </ul>
<b>Comparability</b> <ul style="list-style-type: none"> <li>• Comparable performance figures</li> <li>• Cars with standard equipment and fittings</li> </ul>
<b>System boundaries</b> <ul style="list-style-type: none"> <li>• The system boundaries include the entire life cycle of the cars (manufacture, service life and recycling phase).</li> </ul>
<b>Cut-off criteria</b> <ul style="list-style-type: none"> <li>• The assessment does not include maintenance or repairs</li> <li>• No environmental impact credits are awarded for secondary raw materials produced</li> <li>• Cut-off criteria applied in GaBi data records, as described in the software documentation (<a href="http://www.gabi-software.com">www.gabi-software.com</a>)</li> <li>• Explicit cut-off criteria, such as weight or relevance limits, are not applied</li> </ul>
<b>Allocation</b> <ul style="list-style-type: none"> <li>• Allocations used in GaBi data, as described in the software documentation (<a href="http://www.gabi-software.com">www.gabi-software.com</a>)</li> <li>• No further allocations are used</li> </ul>

### Data basis

- Volkswagen vehicle parts lists
- Material and weight information from the Volkswagen Material Information System (MISS)
- Technical data sheets
- Technical drawings
- Emission limits (for regulated emissions) laid down in current EU legislation
- The data used come from the GaBi database or were collected in cooperation with VW plants, suppliers or industrial partners

### Life Cycle Inventory results

- Life Cycle Inventory results include emissions of CO<sub>2</sub>, CO, SO<sub>2</sub>, NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, as well as consumption of energy resources
- The impact assessment includes the environmental impact categories eutrophication potential, ozone depletion potential, photochemical ozone creation potential, global warming potential for a reference period of 100 years and acidification potential
- Normalisation of the results to average impact per inhabitant values

### Software

- Life Cycle Assessment software GaBi, and GaBi DfX Tool and VW slimLCI interface as support tools

### Evaluation

- Evaluation of Life Cycle Inventory and impact assessment results, subdivided into life cycle phases and individual processes
- Comparisons of impact assessment results of the vehicles compared
- Interpretation of results

# Results of the Life Cycle Assessment

## Results of the Life Cycle Inventory

The information on the life cycle inventories is divided into the three life cycle phases: manufacturing, service life and recycling. The service life differentiates between the environmental impact caused by the upstream fuel supply chain and direct driving emissions. The contribution shown for recycling only indicates the impacts of recycling processes but does not include any environmental impact credits for secondary raw materials produced.

### Diesel models

Fig. 2 clearly shows that the emissions of the Golf V 1.9 TDI, such as carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO) and nitrogen oxides (NO<sub>x</sub>), are mainly generated during the service life of the car. In contrast, both methane (CH<sub>4</sub>) emissions and primary energy demand are dominated by the fuel supply phase – from well to pump. As a result of the low sulphur content assumed for the fuels used, the manufacturing phase accounts for the greater part of overall sulphur dioxide (SO<sub>2</sub>) emissions. CO<sub>2</sub> emissions over the entire life cycle of the Golf V 1.9 TDI reach about 28.3 metric tons. The total energy demand amounts to just under 400 GJ.<sup>15</sup>

## Life Cycle Inventory

Golf V 1.9 TDI [77 kW] (predecessor)

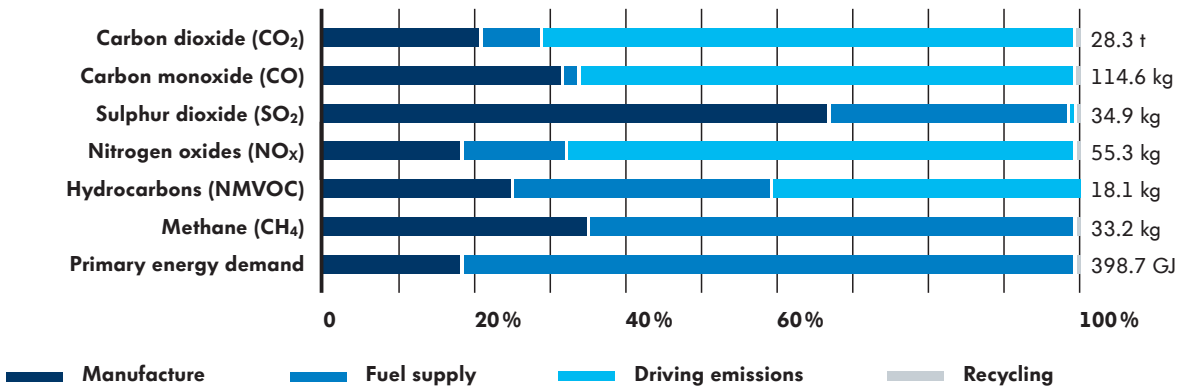


Fig. 2: Life Cycle Inventory data for Golf V 1.9 TDI [77 kW] (predecessor model)

In qualitative terms, the life cycle inventories for the current Golf models with 1.6-litre engine show only slight differences (see Figures 3 to 5). However, the lower energy demand and emissions of the three models, compared with their predecessor, are clearly evident. Thus, compared with its predecessor the energy requirement for the 1.6 TDI is reduced from almost 400 GJ to approx. 355 GJ and CO<sub>2</sub> emissions are only 25.3 metric tons instead of 28.3 metric tons. The Golf BlueMotionTechnology turns in even better figures. Over the entire life cycle it only requires about 329 GJ of energy

<sup>15</sup> On account of more recent data and more advanced calculation methods, results may vary from those published in earlier Environmental Commendations for the same models.

and produces only 23.5 metric tons of CO<sub>2</sub> emissions. The Golf BlueMotion outperforms even these figures, with energy requirements of slightly less than 315 GJ and CO<sub>2</sub> emissions of only 22.3 metric tons, which equates to a drop of around six metric tons of CO<sub>2</sub> compared to its predecessor.

### Life Cycle Inventory Golf VI 1.6 TDI [77kW]

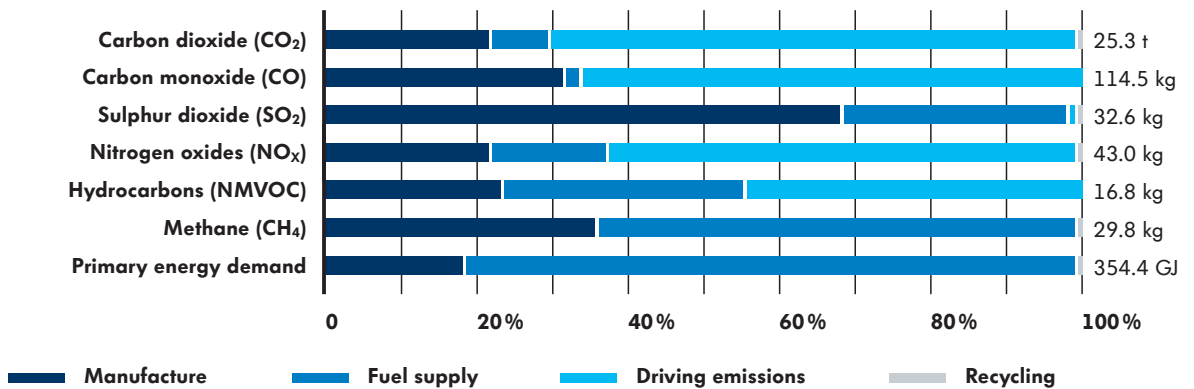


Fig. 3: Life Cycle Inventory data for Golf VI 1.6 TDI [77 kW]

### Life Cycle Inventory Golf VI 1.6 TDI BlueMotion Technology [77 kW]

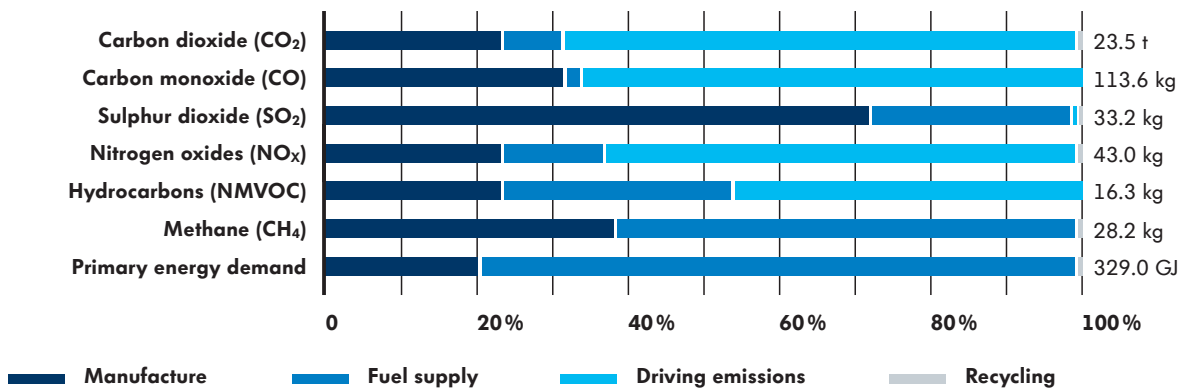


Fig. 4: Life Cycle Inventory data for Golf VI 1.6 TDI BlueMotion Technology [77 kW]

### Life Cycle Inventory

Golf VI 1.6 TDI BlueMotion [77 kW]

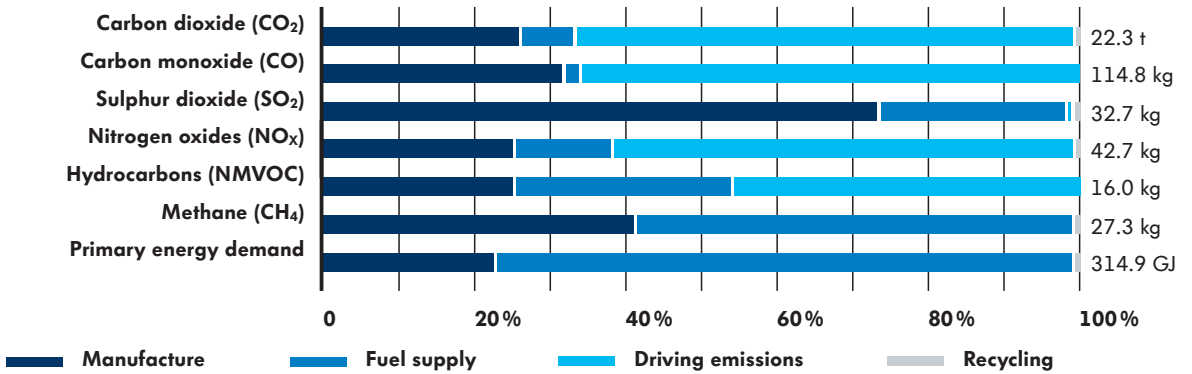


Fig. 5: Life Cycle Inventory data for Golf VI 1.6 TDI BlueMotion [77 kW]

### Petrol models

The next three graphs, Figures 6, 7 and 8, show the results of the Life Cycle Inventories for the three petrol-engined models assessed. Figure 9 then shows the results for the Golf BiFuel run on LPG. It is evident that, for the petrol-engined cars, the proportion of the total environmental impact resulting from the manufacturing phase is less than for the diesel models. On the one hand this is due to the fact that the production of petrol-engined models causes a lower environmental impact than that of diesel models in absolute terms, and on the other to the fact that the service life accounts for a higher proportion of the total environmental impact, owing to the higher fuel consumption of petrol-engined models.

### Life Cycle Inventory

Golf V 1.6 MPI [75 kW] (predecessor)

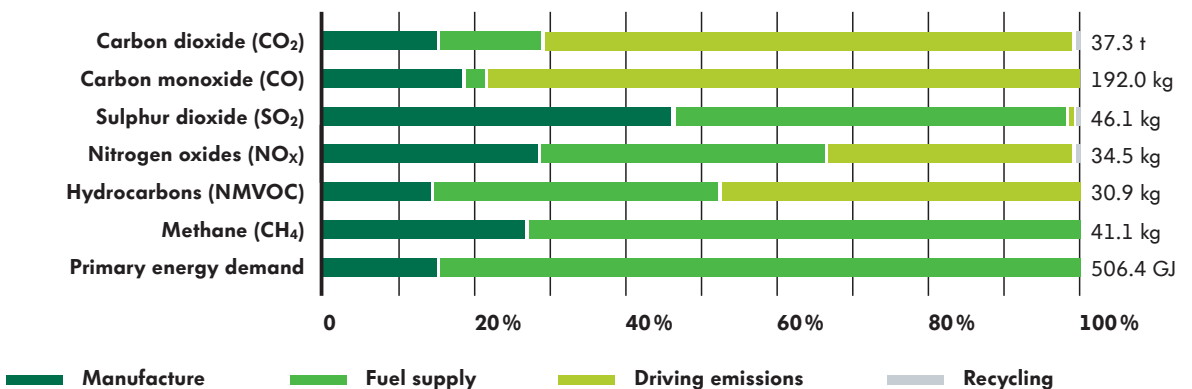


Fig. 6: Life Cycle Inventory data for Golf V 1.6 MPI [75 kW] (predecessor model)

The Golf V 1.6 MPI causes total CO<sub>2</sub> emissions of 37.3 metric tons and has a total energy demand of approx. 506 GJ (see Fig. 6). The successor model with 1.2-litre TSI engine causes 7.7 metric tons less CO<sub>2</sub> emissions and also has significantly lower energy requirements of just under 400 GJ (see Fig. 7). This is a direct result of its lower fuel consumption compared with the predecessor model. The significant influence of the service life phase – i.e. fuel supply and driving emissions – on the final result means that the considerably reduced consumption also leads to a reduction in all the other Life Cycle Inventory parameters.<sup>16</sup>

### Life Cycle Inventory Golf VI 1.2 TSI [77 kW]

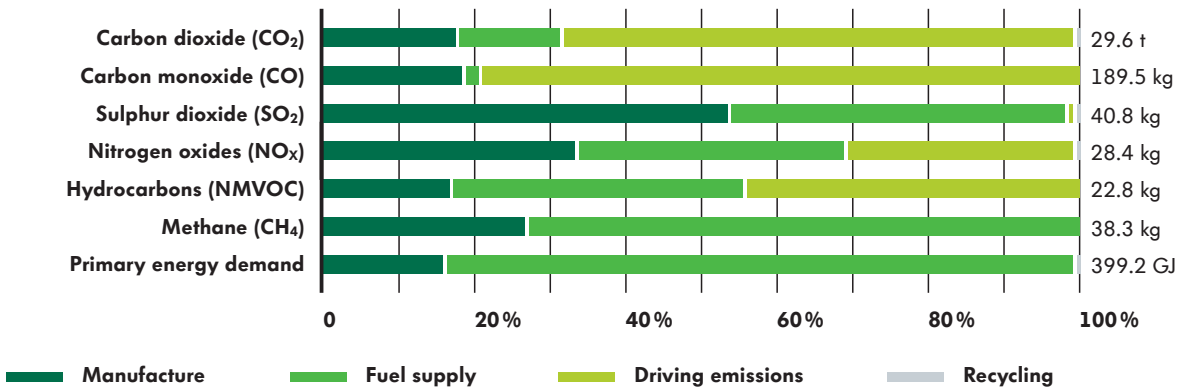


Fig. 7: Life Cycle Inventory data for Golf VI 1.2 TSI [77 kW]

The Golf 1.2 TSI BlueMotion Technology outperforms even these very good results. Its energy requirements of 369.7 GJ and CO<sub>2</sub> emissions of 27.3 metric tons are below the values for the predecessor model by an even clearer margin (see Fig. 8).

<sup>16</sup> In contrast to the Euro 4 standard, the Life Cycle Inventory for the current models subject to the Euro 5 standard indicates that the service life contributes a significant share of the methane emissions. Under the provisions of the Euro 4 standard, a limit is only imposed on total hydrocarbon emissions (HC). In Fig. 6, these are all included in NMVOC driving emissions. For vehicles type-approved to Euro 5 requirements, there is also an explicit limit for non-methane hydrocarbons (NMHC). The difference between this limit and the HC limit is the model value for the methane driving emissions of the current models in Figures 7, 8 and 9.

### Life Cycle Inventory

#### Golf VI 1.2 TSI BlueMotion Technology [77 kW]

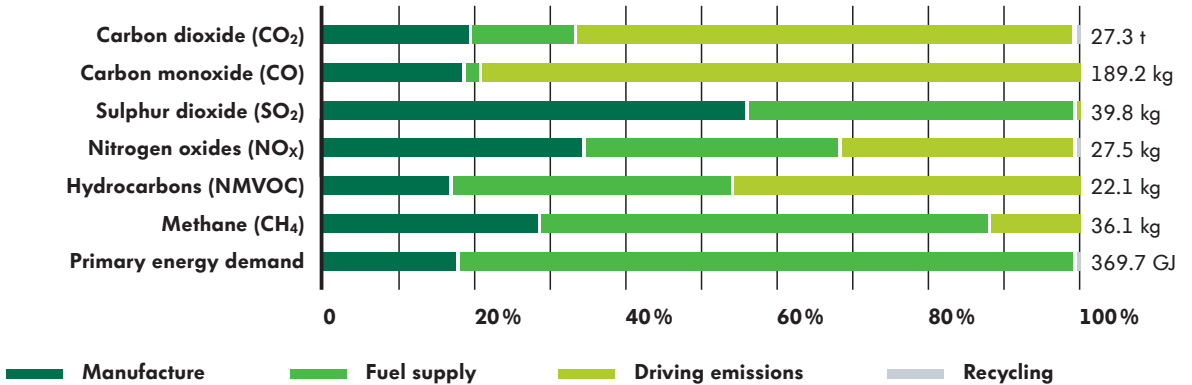


Fig. 8: Life Cycle Inventory data for Golf VI 1.2 TSI BlueMotion Technology [77 kW]

The Golf BiFuel, which operates on LPG, also clearly outperforms the predecessor model, with CO<sub>2</sub> emissions of 30.3 metric tons and energy requirements of slightly less than 439 GJ (see Fig. 9).

### Life Cycle Inventory

#### Golf VI BiFuel [75 kW/ 72 kW]

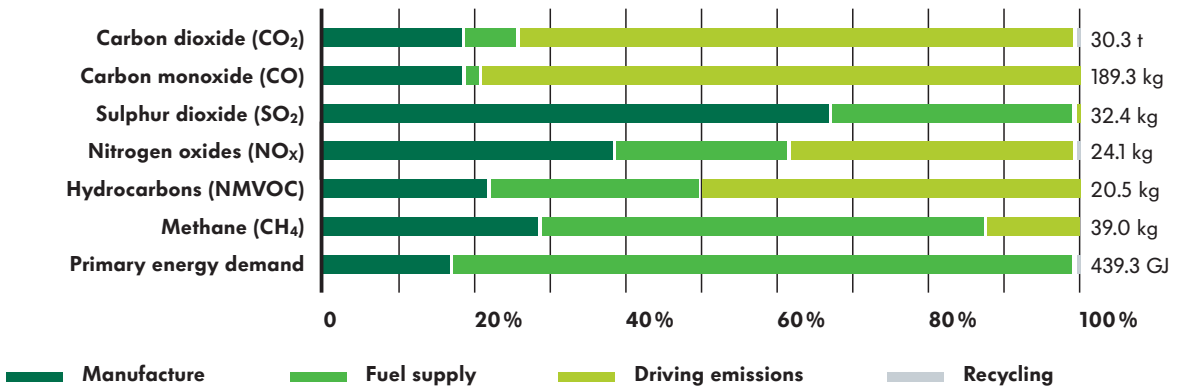


Fig. 9: Life Cycle Inventory data for Golf VI BiFuel [75 kW/72 kW]

### Comparison of Life Cycle Impacts

On the basis of the Life Cycle Inventory data, Life Cycle Impact Assessments are drawn up for all the environmental impact categories. The interactions of all the emissions recorded are considered and potential environmental impacts are determined based on scientific models<sup>17</sup>.

<sup>17</sup> You will find information on the environmental impact categories used here on the Internet at [www.environmental-commendation.com](http://www.environmental-commendation.com).

**Diesel models**

Fig. 10 clearly shows that all the current models achieve improvements over their predecessors in almost all the environmental categories with the exception of ozone depletion potential. The higher values in this category result from the fact that the current models are equipped with air conditioning systems. The higher emissions of ozone-depleting substances are chiefly due to emissions during the production of air conditioner refrigerant.

With reference to overall environmental impacts in the European Union, Fig. 10 clearly shows that all the vehicles considered here make their largest contributions in the categories of global warming (greenhouse effect), acidification and photochemical ozone creation potential (summer smog). Contributions to the categories eutrophication and ozone depletion potential are smaller. Consequently, the notes below focus on the first three environmental impact categories.

**Comparative environmental profiles normalised**

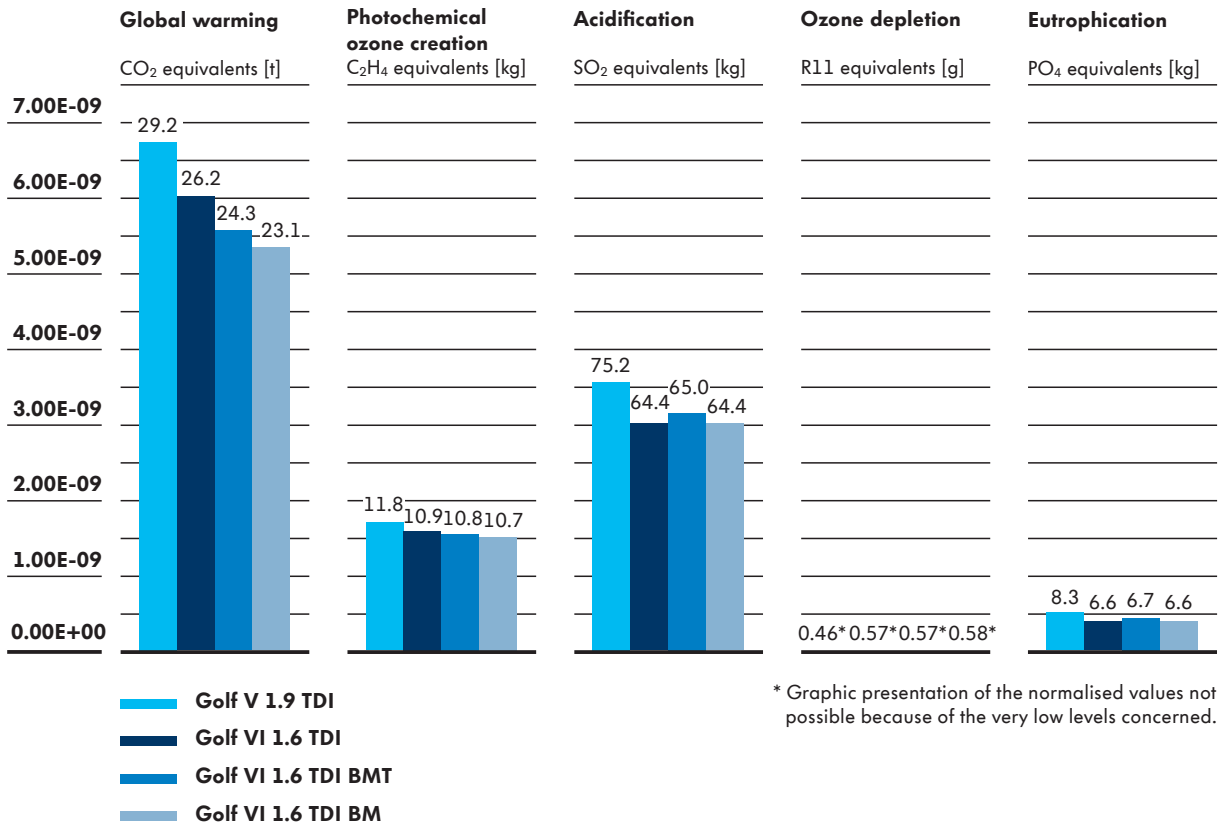


Fig. 10: Environmental impacts of the Golf V 1.9 TDI and its successors, the Golf VI 1.6 TDI, 1.6 TDI BlueMotion Technology and BlueMotion (absolute)

As Fig. 11 below shows, the environmental impacts of the current model in all three categories considered are lower than those of the predecessor model – the Golf 1.9 TDI. The reduction of ten percent in global warming potential in the case of the Golf 1.6 TDI corresponds to savings of around three metric tons of CO<sub>2</sub> equivalents. In the case of the Golf 1.6 TDI BlueMotion Technology, the saving is almost five metric tons of CO<sub>2</sub> equivalents (17 percent) thanks to the additional systems used (regenerative braking and engine start-stop system). The Golf 1.6 TDI BlueMotion achieves the greatest saving over its predecessor, at 21 percent.

Thus, in terms of global warming potential, the savings with the Golf 1.6 TDI BlueMotion Technology and Golf 1.6 TDI BlueMotion are considerably more significant. In relation to acidification potential, however, the savings are somewhat lower. This is due to the production of the additional components installed from the BlueMotion Technologies range (e.g. regenerative braking and engine start-stop system).

### Comparative environmental profiles normalised

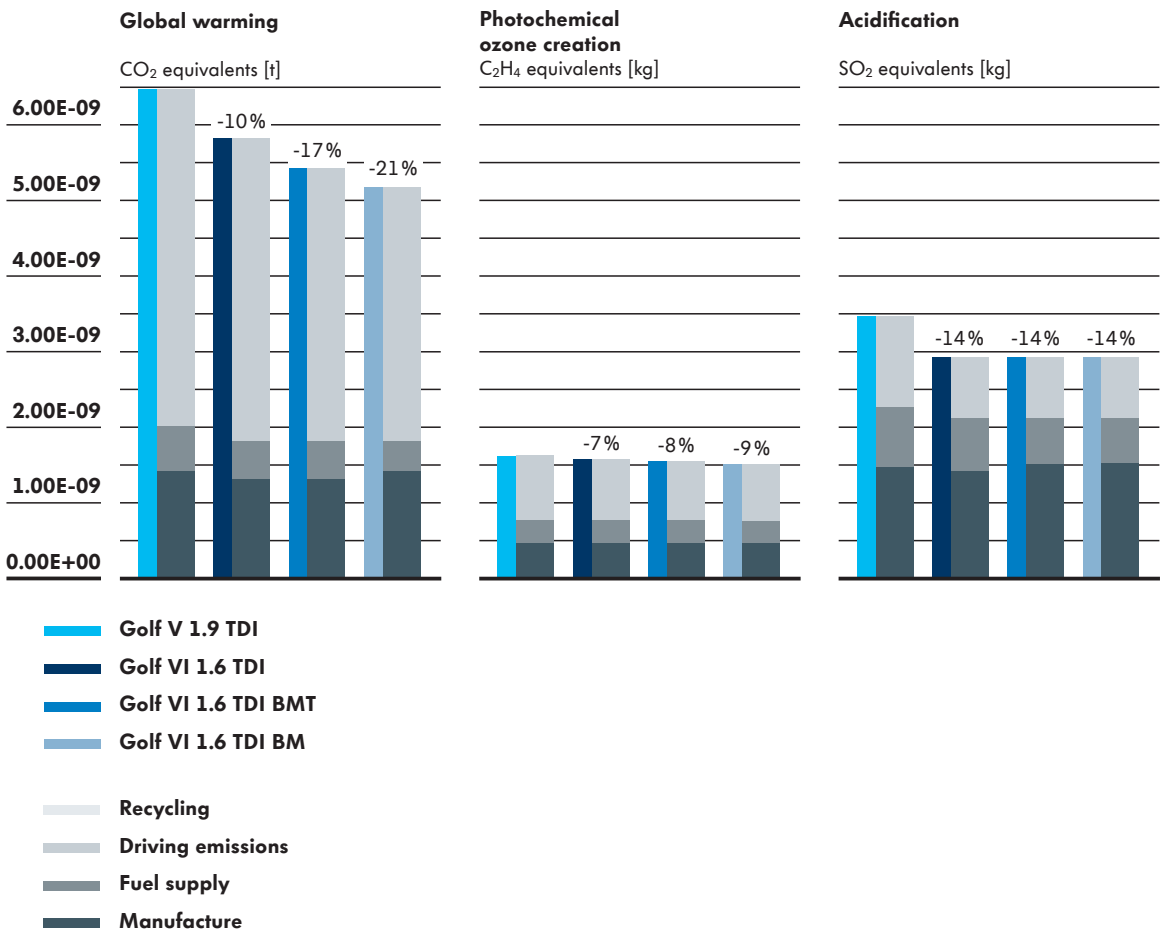


Fig. 11: Environmental impacts of the diesel-engined predecessor and the current Golf VI 1.6 TDI, 1.6 TDI BlueMotion Technology and BlueMotion (relative)

Fig. 11 also indicates how these various reductions are achieved, in that the relative environmental impacts are allocated to the individual life cycle phases. As already shown by the Life Cycle Inventories, the most relevant changes occur during the service life of the vehicle and as a result of the corresponding impact on fuel production. Most of the improvements therefore result either directly (lower driving emissions) or indirectly (less fuel production) from lower fuel consumption.

Fig. 12 below shows the environmental impacts described in relation to each other and over the entire life cycle of the vehicle. The relations between manufacture, service life and recycling with regard to the individual environmental impacts are clearly visible. Global warming potential in particular is influenced mainly by vehicle use (highest increase over service life).

### Comparison of environmental impacts over the full life cycle normalised

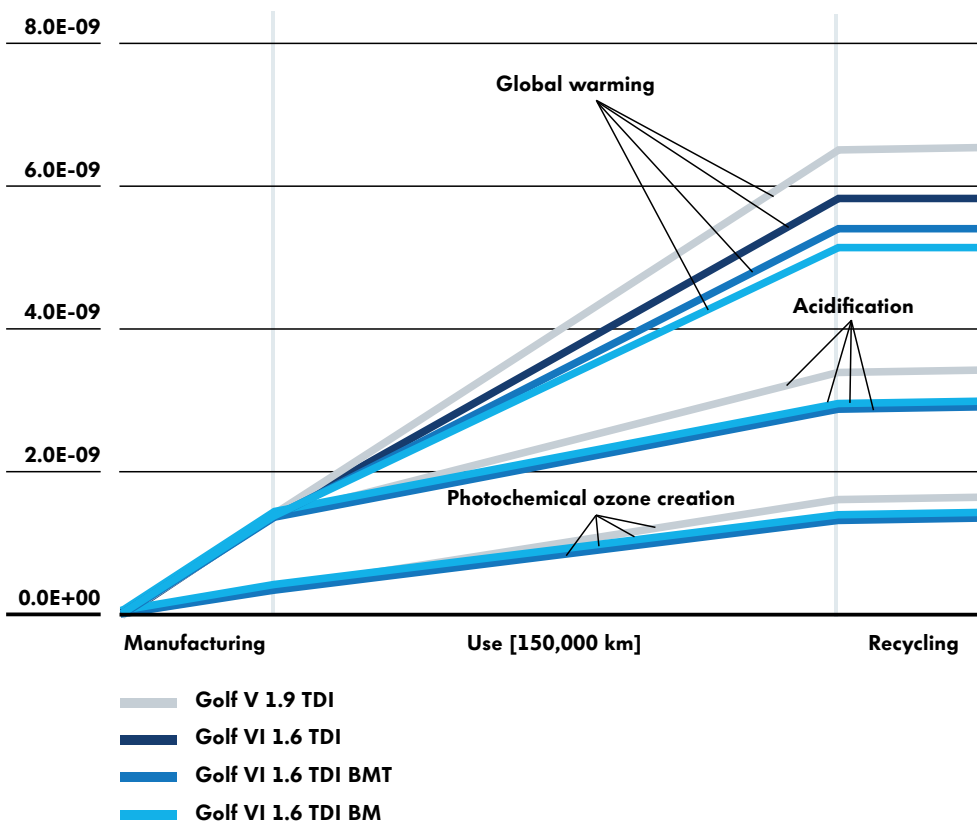


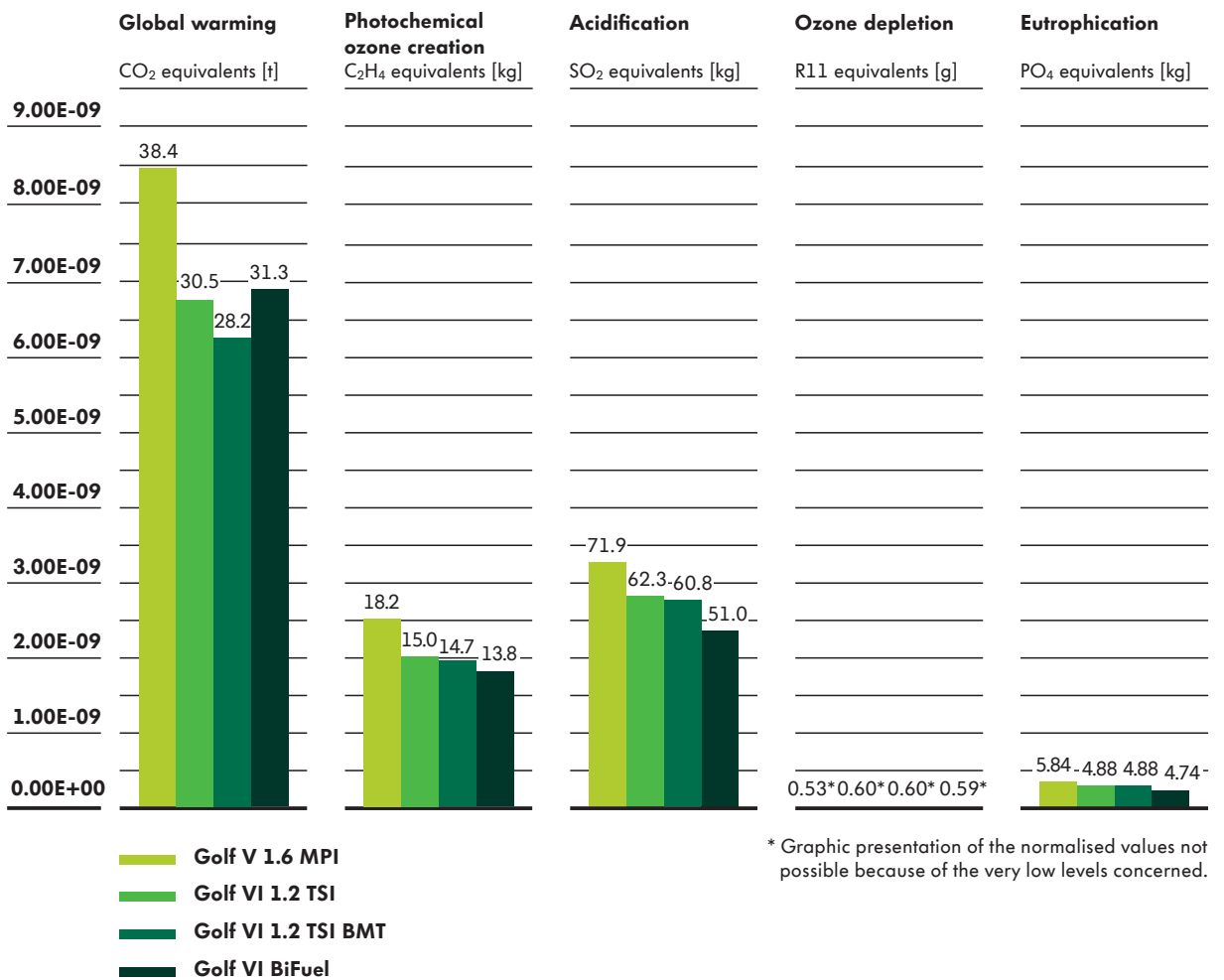
Fig. 12: Comparison of environmental impacts over the full life cycle – diesel models

Acidification and photochemical ozone creation potential, by contrast, are distributed more evenly over all the phases of the life cycle. The significant savings in these categories are chiefly due to the more stringent exhaust emission standard applied to the current models.

**Petrol models**

A comparison of the petrol vehicles also shows that the current models represent an improvement over their predecessor in all categories except ozone depletion potential (see diesel models). Here too, greatest potential environmental impacts are in the areas of photochemical ozone creation, global warming and acidification potential (see Fig. 13).

**Comparative environmental profiles normalised**



**Fig. 13: Environmental impacts of the Golf V 1.6 MPI and its successors, the Golf VI 1.2 TSI, 1.2 TSI BlueMotion Technology and BiFuel (absolute)**

During its entire life cycle, the greenhouse gas emissions of the Golf 1.2 TSI are significantly lower than those of the predecessor model. Overall, for the assumed distance driven of 150,000 kilometres, greenhouse gas emissions show a reduction of almost eight metric tons of CO<sub>2</sub> equivalents per vehicle. An even greater saving of more than ten metric tons of CO<sub>2</sub> equivalents is achieved by the new Golf VI 1.2 TSI BlueMotion Technology. The saving in the case of the Golf BiFuel, running on LPG, is about 7.1 metric tons of CO<sub>2</sub> equivalents.

Fig. 14 indicates the changes in environmental impacts between the Golf 1.6 MPI and its successors. The diagram shows that photochemical ozone creation potential has been reduced by 18 percent and acidification potential by 13 percent for the Golf 1.2 TSI. Global warming potential over the entire life cycle is even reduced by 20 percent. With the Golf 1.2 TSI BlueMotion Technology, the savings are even more pronounced, with photochemical ozone creation potential down 19 percent and acidification potential down 15 percent. In terms of global warming potential, the reduction of 10.2 metric tons of CO<sub>2</sub> equivalents described above corresponds to a drop of 27 percent. The savings achieved by the Golf BiFuel of 18 percent in global warming potential are slightly lower. On the other hand, the BiFuel achieves greater savings in terms of acidification potential (29 percent) and photochemical ozone creation potential (25 percent), as a result of lower emissions during the production of LPG fuel.

### Comparative environmental profiles in detail normalised

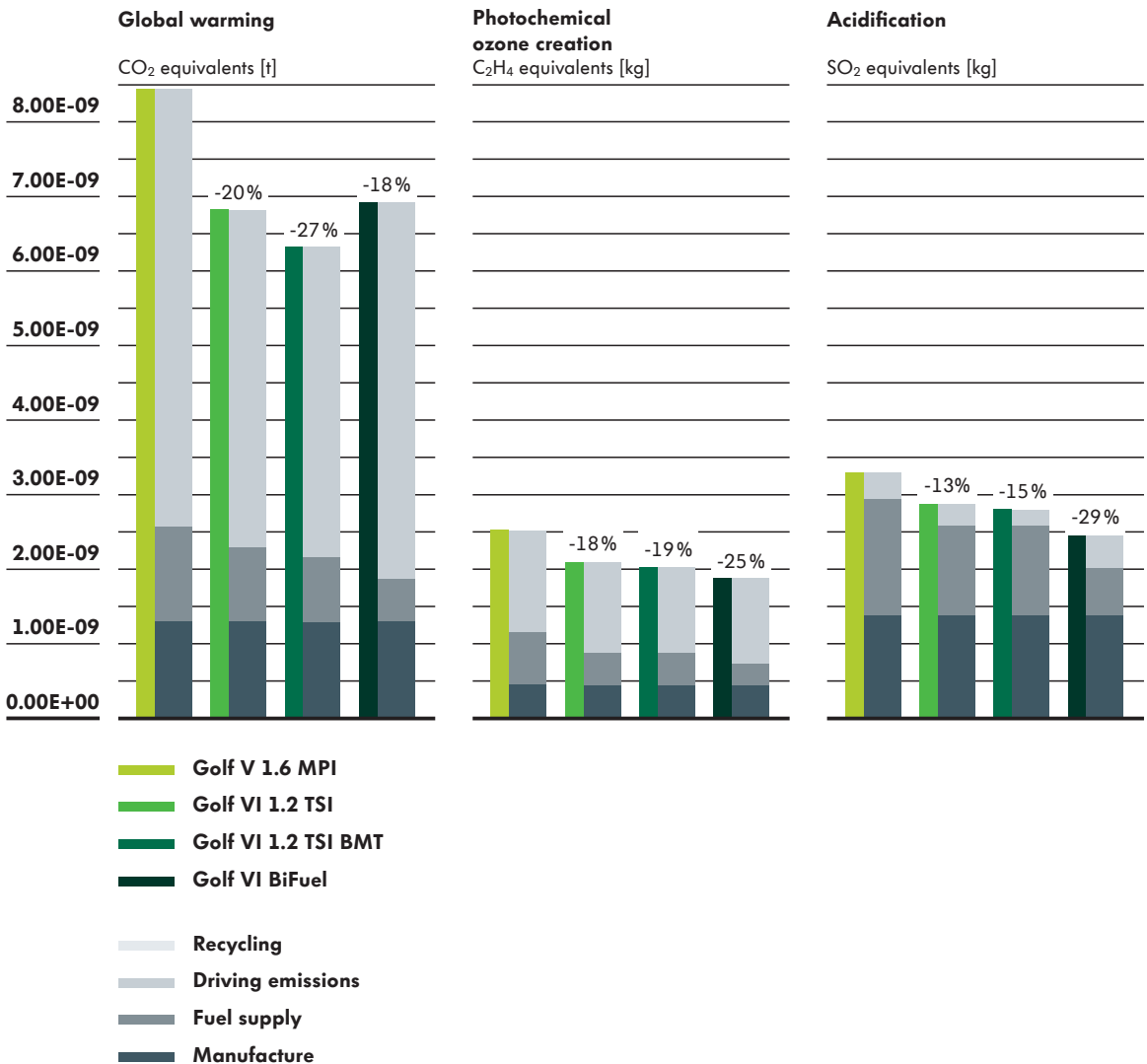


Fig. 14: Environmental impacts of the petrol-engined predecessor and the current Golf VI 1.2 TSI, 1.2 TSI BlueMotion Technology and BiFuel (relative)

Fig. 14 indicates the sources of these improvements in detail. As with the diesel models, the lower fuel consumption of the current models is the main factor in reducing the environmental impact. It can clearly be seen that the driving emissions and the contribution to emissions associated with fuel supply are both lower in the case of the current models. The only exception is the manufacturing phase. Depending on the model and the individual impact category, the manufacture of the current models may result in a slightly higher environmental impact. This is a result of the additional components installed from the BlueMotion Technologies range and of the BiFuel system. However, improvements in the service life emissions and fuel production process easily outweigh these increases. In the case of the petrol models too, the recycling phase has only a negligible environmental impact.

The service life of the petrol models is even more predominant in terms of global warming potential than in the case of the diesel models (see Fig. 15). The lower values for the Golf 1.2 TSI, Golf 1.2 TSI BlueMotion Technology and Golf BiFuel are clearly evident. The benefits in terms of acidification and photochemical ozone creation potential are also due to lower fuel consumption and the associated reduced environmental impact of fuel production for the current models, as well as to the more stringent exhaust emission standard met by the two conventionally-fuelled models.

### Comparison of environmental impacts over the full life cycle normalised

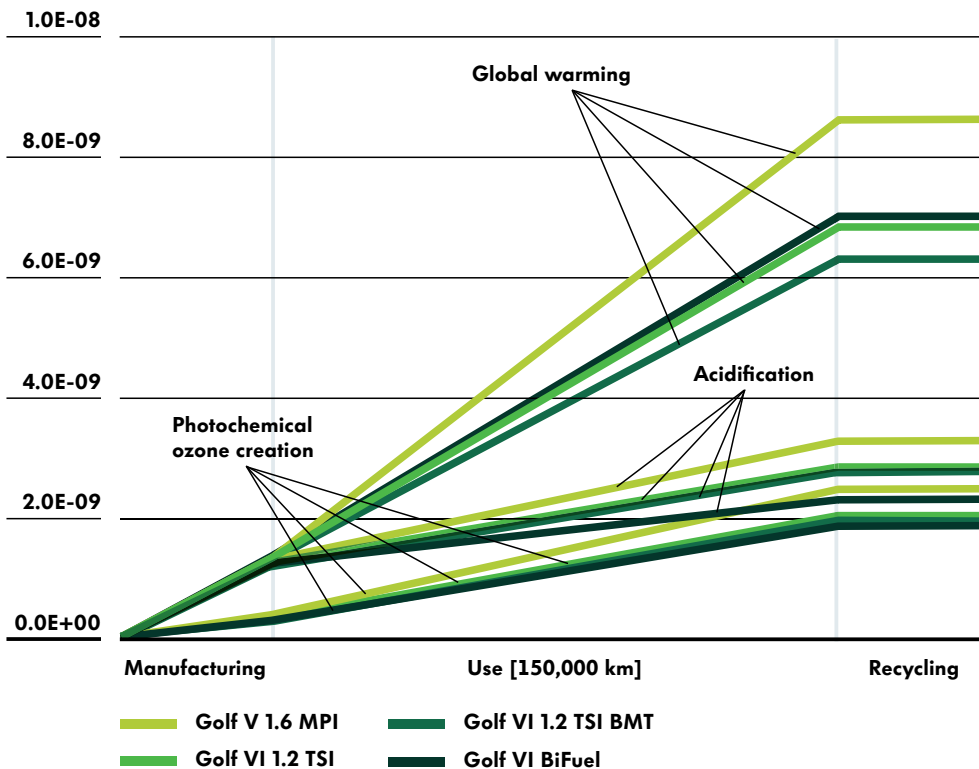


Fig. 15: Comparison of environmental impacts over the full life cycle – petrol models

## Certification

The statements made for the Golf Environmental Commendation are supported by the Life Cycle Assessment of the Golf. The certificate of validity confirms that the Life Cycle Assessment is based on reliable data and that the method used complies with the requirements of ISO standards 14040 and 14044.



**CERTIFICATE OF VALIDITY**

**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 Golf (Model Year 2011)**

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 5779

Certification office of the TÜV NORD CERT GmbH

Essen, dated 2010-11-12

  
Dr. Winfried Hinz  
Environmental verifier

TÜV NORD CERT GmbH      Langemarckstrasse 20      45141 Essen      [www.tuev-nord-cert.com](http://www.tuev-nord-cert.com)

The detailed report of TÜV NORD can be found in the appendix.

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## List of abbreviations

AP	Acidification potential
CFC	Chlorofluorocarbons
CH <sub>4</sub>	Methane
CML	Centrum voor Milieukunde Leiden (Centre for Environmental Sciences, Netherlands)
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
DIN	Deutsche Industrienorm (German Industrial Standard)
DPF	Diesel particulate filter
DSG®	Dual-clutch gearbox
EN	European standard
EP	Eutrophication potential
EU 15	15 member states before the eastern European expansion of the European Community
GJ	Gigajoule
GWP	Global warming potential
HC	Hydrocarbons
IMDS	International Material Data System
KBA	Kraftfahrtbundesamt (Federal Motor Transport Authority)
kW	Kilowatt
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MISS	Material Information System
MPI	Intake-tube multipoint injection petrol engine
N <sub>2</sub> O	Nitrous oxide
NEDC	New European Driving Cycle
NH <sub>3</sub>	Ammonia
Nm	Newton metre
NMVOG	Non-methane volatile organic compounds (hydrocarbons without methane)
NO <sub>x</sub>	Nitrogen oxides
ODP	Ozone depletion potential
PAN	Peroxyacetylnitrate
PO <sub>4</sub>	Phosphate
POCP	Photochemical ozone creation potential
ppm	Parts per million
PVC	Polyvinyl chloride
R11	Trichlorofluoromethane (CCl <sub>3</sub> F)
SET	Simultaneous engineering team
SF <sub>6</sub>	Sulphur hexafluoride
SO <sub>2</sub>	Sulphur dioxide
TDI	Turbocharged direct injection diesel engine
TSI	Turbocharged direct injection petrol engine
VDA	Verband der Automobilindustrie e.V. (Association of the German Automotive Industry)
VOC	Volatile organic compounds

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# Appendix

Hanover, 12.11.2010  
TNC Umweltgutachter-H

# **Report**

## **Critical Review of Life Cycle Assessment**

### **Golf - Environmental Commendation, Model Year 2011**

Report No.: 8000376889/1300

Client: Volkswagen AG  
38436 Wolfsburg

Author of Life Cycle : Volkswagen AG  
Assessment K-EFUP  
Dr. Warsen

External reviewers : Dr. Winfried Hirtz

Length of report: 9 pages

## 1 General

### 1.1 Object and Terms of Reference

Volkswagen AG, Department K-EFUP, Environment Affairs Product, has drawn up a comparative Life Cycle Assessment " Golf - Environmental Commendation" .

Volkswagen AG, Department K-EFUP Environment Affairs Product, commissioned TÜV NORD CERT Umweltgutachter GmbH to carry out a critical review of the Life Cycle Assessment as an independent body in accordance with DIN ISO 14040 and DIN ISO14044.

The review was carried out for TÜV NORD Umweltgutachter GmbH by Dr.-Ing. Winfried Hirtz, Environmental Verifiers licensed under the Environmental Audit Act

Under the terms of reference, the objective of the critical review was to verify the reliability, transparency, relevance and representative nature of the methods used for Life Cycle Assessment with respect to

- Objective and scope of assessment
- Life Cycle Inventory
- Life Cycle Impact Assessment and
- Evaluation of assessment

### 1.2 Procedure

Taking into account the general quality criteria (chiefly transparency, reproducibility, quality of the computer programs and data used, and information on the sources of data), the procedure used for the critical review was as follows:

- Review of the objective and scope of the assessment, especially the function and functional equivalence of system boundaries and cut-off criteria (space, time, technology), allocation procedures together with the allocation and distribution rules adopted, and the selection of significant parameters and materials.

- Review of the Life Cycle Inventory drawn up, especially with regard to the input/output analyses (major process chains), the input and output data used and the reliability of such data, the systematic nature, completeness and plausibility of the input/output analysis, the sensitivity analysis and the assessment of errors, the plausibility and reliability of computer programs, and the consideration of up-stream process chains, by-products and secondary post-use effects
- Review of the Life Cycle Impact Assessment, concentrating on the selection of impact categories (with respect to subject areas and problems) and the concentration of data with reference to impact categories
- Review of the evaluation and the comparative statements made on the basis of the evaluation

System representations, data files and other representative documents were inspected and compared on a random sample basis and some data collection and calculation procedures were reproduced on the computer, in some cases with targeted variation. For example, data regarding the previous model were viewed with respect to limit values, consumption and the utilisation phase. In the case of the current models, the overall vehicle assessment of various models in comparison to the previous model were considered, e.g. Golf TDI 77 kW, Blue Motion, Blue Motion Technology and For the benzine car in comparison with a 1,2 TSI, 1,2 TSI Blue Motion Technology and additionally a LPG car named Golf BiFuel. In general, duplication of effort was avoided during the critical review. Relevant literature concerning life cycle assessment techniques was taken into consideration.

## **2 Result of Critical Review**

### **2.1 Objective of Assessment**

The objectives of the Life Cycle Assessment are defined clearly and unambiguously; external and internal target groups for the assessment are also stated. The presentation adopted for the Environmental Commendation for the Golf provides sufficient appropriate information to make the intended environmentally holistic approach clear and comprehensible.

## 2.2 Scope of Assessment

The Life Cycle Assessment considers the manufacture, use and disposal of VW Golf motor vehicle model year 2011. Various variants were considered. The scope and system boundaries of the assessment are clearly and unambiguously defined in relation to the entire system with respect to space, time and technology. The boundaries are compatible with the selected function unit and are defined over the life cycle.

Environmental impact is presented and assessed in the categories greenhouse gas emissions (CO<sub>2</sub> equivalent), photochemical ozone creation potential (POCP), acidification potential (AP), eutrophication potential (EP) and ozone depletion potential (ODP). As the impacts in this particular assessment are generally concerned with the greenhouse effect and POCP, these are described in more detail.

Within the scope of the assessment, all relevant materials, components and processes were logged, analysed and finally grouped together for the subsequent Life Cycle Inventory into four main modules appropriate for the object of the assessment:

- Manufacture and raw material production
- Fuel provision and transport
- Utilisation phase / Driving emissions
- Recycling (VW-SiCon)

In the case of the Golf, the kerb weight should be seen in terms of the admission value and can have a different effect on the overall assessment depending on different equipment levels. In the calculation, the basis of comparison was always the previous model with the same level of equipment.

The wide variety of components and processes brought together in the computer program modules, which is a result of the technology, have been transformed into standard components of today's technological generation without changing any other aspects. In our opinion this is a useful procedure which serves the aims of the assessment. The graphs and tables in the assessment confirm the systematic nature and completeness of the procedure selected.

The effects and factors considered negligible for the definition of the Life Cycle Assessment system are explained and, where appropriate, listed. In particular, the post-use segment is mentioned and reference is made to Volkswagen's VW-SiCon recycling system. The procedure describes the recycling of the materials contained in the various components and the effects of recycling on emissions.

In summary it can be stated that all relevant factors have been identified and taken into consideration within the area investigated in accordance with the state of the art of Life Cycle Assessments.

### **2.3 Life Cycle Inventory**

The input/output analyses for the main modules mentioned above were carried out and the Life cycle Inventory for the Life Cycle Assessment was documented using a computer system. The calculations themselves were performed using the internationally recognized software package "GaBi".

#### **2.3.1 Data sources**

The main processes in the individual areas have been modelled realistically. The data sources are based on generally accepted files, they are comprehensible and representative as regards this Life Cycle Assessment. The data basis of the "GaBi" system is extremely comprehensive. The data can be understood and traced.

#### **2.3.2 Plausibility and completeness review**

The computer system reflects the system boundaries systematically and is consistent with the assessment area defined. Boundaries are drawn at points where no (significant) impact on the results of the individual areas or the overall assessment is expected (see also the sensitivity analyses conducted). The data are of high quality and are highly symmetrical. The data used is drawn from databases (IMDS) into which the available information regarding the individual components and parts lists which are

used is entered. This information is regularly verified by means of information requested from manufacturers.

All four Life Cycle Inventory areas (raw material production, fuel provision, vehicle utilisation and recycling/disposal) were verified on the basis of random samples. The correctness and plausibility of the calculations and the results were verified by reviewing selected parameters (e.g. GWP (global warming potential), POCP, AP, material input transportation, recyclability etc.) In this way, the links between the various areas and the hierarchy of data used for the assessment calculations were verified with respect to the process plans, the inclusion of partial assessments and the data basis.

Different data are new or adapted in GaBi or are made by Volkswagen. So the new data like the glass panes old/new are compared, the introduction of vulcanisation in GaBi, the change of procedures like deep-drawing instead of blanking are considered. The data for painting are new and come from Volkswagen. Remark: Therefore the results of Golf VI in this study can be lightly different in comparison with the previous environmental commendation. LPG in the use phase is an extra process for this study and has been validated. The data come from a bachelor study (made for Volkswagen) and includes the ratio of refinery process and "waste product".

For the Blue Motion (new model) are checked especially the production of wheel rim (steel and aluminium), and use phase. For the Bifuel and TSI 1,2 are calculated the complete plan for the total balance. Key aspects for the TSI1,2, A5 MPI (NO<sub>x</sub>) were verified with the calculations to the environmental effects. The weight of the thermo-plastic PE was compared for two models and checked with the part lists.

The data for final assembly are the data from Wolfsburg 2005, it should be checked, if an actualisation of data could be made.

In order to ensure that the data used could be traced back to the original data sources, both the calculations and the documentation were investigated and found to be very clear and transparent.

The environmental auditor made suggestions concerning supplements to the documentation, which was then changed on site (e.g. landfilling, data links between the different variants, descriptions as a basis for further calculations, figures description,

normation with EU 25+3). By the completion of the project, the derivation of all the data was entirely comprehensible and traceable.

All significant parameters are available and representative and have been systematically derived and duly assessed. The assessments and the underlying data collection and calculation procedures are transparent and traceable.

### **2.3.3 Allocations**

Allocations arise in connection with vehicle production; they are included in a database and it was possible to represent them appropriately. They are represented in the computer system completely, clearly and plausibly.

To the extent that allocations are imported to the process plan from databases, the data basis is adequate. Allocations from the databases have already been taken into consideration in the process plan.

### **2.3.4 Error assessments**

Separate error assessments were drawn up for the manufacturing phase. In view of the numeric stability and proven quality of the data used, there is no need to include the separate error assessments (see also 2.3.5). The error assessment for the manufacturing phase amounts to approximately 2% over the life cycle regarding CO<sub>2</sub> emissions and use of primary energy.

### **2.3.5 Sensitivity Analysis**

Sensitivity analyses were not carried out because the variants had the same level of equipment. In addition, the same calculated and therefore lesser values result for the equipment variants

In order to verify this statement, calculations regarding sensitivities and the associated parametering were performed at the client's premises. There were no indications that special sensitivity calculations were needed. This also has a basis in the experience of VW AG from the many studies that have been drawn up.

#### 2.4. Life Cycle Impact Assessment

The Life Cycle Impact Assessment is based on the results of the Life Cycle Inventory and is an integral part of the process plans.

In order to carry out a Life Cycle Impact Assessment on the basis of data and information derived from the Life Cycle Inventory, it is necessary to compress the data for defined impact categories.

Taking into consideration the objectives of the assessment, the functional unit selected and the (standard) technologies used in the assessment area, the following impact categories were defined:

- GWP            global warming potential
- ODP            ozone depletion potential
- AP             acidification potential
- NP             nitrification potential
- POCP         photochemical ozone creation potential

The impact categories were therefore selected in accordance with the objectives and scope of the Life Cycle Assessment.

These quantifiable impact categories represent the system assessed and the technologies used in terms of key local, regional and global categories. Individual data were properly allocated to the various categories. Data was aggregated in accordance with the environmental impact concerned; this approach is already defined in the computer program used in accordance with the scientific dose-effect relationship.

The calculations were checked. The factors stored in the computer program are internationally recognized. With reference to the objectives of the assessment, other impact categories are of secondary importance.

Data compression within these categories has been carried out on the basis of generally accepted equivalence factors in a way which is clear, reliable and easy to follow. The presentation and discussion of the results for the case of the Golf examined in the Life Cycle Assessment and covered by the Environmental Commendation is balanced and consistent.

## 2.5 Evaluation

The evaluation section of the Life Cycle Assessment includes specific recommendations for users and target groups.

The evaluation of the results of the Life Cycle Inventory and Life Cycle Impact Assessment which was submitted to us is based consistently and appropriately on the objectives defined for the Life Cycle Assessment.

Further statements and recommendations are strictly separated from the Life Cycle Assessment itself.

### 3 Summary of the critical review

The critical review of the Life Cycle Assessment "Golf - Environmental Commendation" conducted by the undersigned in accordance with the requirements of international standards DIN EN ISO 14040:2006 and DIN EN ISO 14044:2006 may be summarised as follows:

- The methods used for drawing up the Life Cycle Assessment are in accordance with the requirements of DIN EN ISO 14040:2006 / DIN EN ISO 14044:2006. The methods are scientifically well-founded and are in accordance with the state of the art of Life Cycle Assessments.
- The data used are adequate, appropriate and well-founded with reference to the objective of the assessment.
- The evaluations take into consideration the objective of the assessment and the limitations which were identified.
- The Life Cycle Assessment is consistent and transparent.

A certificate of validity has been issued concerning the critical review which was conducted (cf. Appendix). The report of the critical review will become part of the detailed version of the Life Cycle Assessment.

A handwritten signature in blue ink, appearing to read "W. Hirtz". The signature is written in a cursive style and is positioned above a long, thin blue horizontal line that extends across the page.

Dr. Winfried Hirtz

Environmental Verifier  
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**Group Research**  
**Environment Affairs Product**  
**P.O. Box 011/1774**  
**38436 Wolfsburg**  
**Germany**

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