The Caddy
Environmental Commendation Background Report

The Life Cycle Assessment of the Caddy

It is the objective of Volkswagen to develop vehicles in such a way that, in their entirety, they present better environmental properties than their predecessors. Volkswagen uses Environmental Commendations to document the environmental performance of its vehicles and technologies. 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.

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. A vehicle not only causes environmental impact when it is in use but also during production and recycling. For this reason, the development brief for our products includes the Group environmental development goals as well as criteria such as safety, convenience and appearance.

This is why Volkswagen has been analysing vehicles and their individual components since 1996, using Life Cycle Assessments to enhance their environmental compatibility. The environmental improvement of the Caddy®* is an especially important step for us as we advance towards sustainable mobility for all. This Environmental Commendation presents the comprehensive results of our 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 Caddy we compared the two diesel-engined versions 1.6 TDI and 1.6 TDI BlueMotion Technology (75 kW) of the Delivery Van and Startline models with their similarly engined predecessors. All current models comply with the Euro 5 exhaust emissions standard.

The evaluation of the environmental profile is not solely based on emissions during a vehicle's service life, i.e. the „driving time", but on the entire life cycle from production through to recycling. The successor models relatively quickly revealed improvements – some quite significant – in almost all the environmental impact categories. The biggest advances were made in the areas where the quantitative environmental impacts are greatest: for instance global warming potential (greenhouse effect) as well as acidification and effects on local air quality (e.g. summer smog).

In contrast, the vehicles assessed only contributed very little to water eutrophication and ozone depletion. It was also found that these improvements were primarily due to reduced fuel consumption and the resulting lower driving emissions in combination with reduced environmental impact caused by the production of the fuel.

* The product name Caddy® is a registered trademark of Caddie S.A. and is used by Volkswagen Commercial Vehicles with the kind approval of Caddie S.A..

Significant improvements were achieved in fuel consumption and associated CO_2 emissions. As regards fuel economy, especially the BlueMotion Technology models in particular indicate the potential that is available. In terms of global warming potential and local air quality, the new Caddy presents a much better balance sheet over its entire life cycle thereby attaining the environmental goal set by the Technical Development department. While CO_2 emissions during production of the new model are slightly higher than for its predecessor, its subsequent service life rapidly compensates for this increase.

For the assumed lifetime mileage of 150,000 kilometres, our calculations indicate emissions of 22.1 metric tons of carbon dioxide for the1.6 TDI Delivery Van and 19.4 metric tons for the BlueMotion Technology model. For the Startline, values of 22.4 metric tons of CO_2 (1.6 TDI) and 20.1 metric tons (1.6 TDI BlueMotion Technology) were calculated. Over the entire life cycle, this equates to an overall reduction with regard to global warming potential of around nine and eight percent respectively for the two 1.6-litre models and about 18 and 15 percent respectively for the two BlueMotion Technology models. Lower consumption and the associated savings in relation to fuel production result in an additional reduction in environmental impacts, for example in terms of emissions that can give rise to summer smog.

The Caddy models assessed

Volkswagen‘s Environmental Commendation for the Caddy describes and analyses the environmental impacts of selected Caddy models. We compared selected diesel models from the new series[1] with their respective predecessors. The results are based on Life Cycle Assessments in accordance with the standards ISO 14040 [ISO 2006] and 14044. All the definitions and descriptions required for preparing these Life Cycle Assessments were drawn up in accordance with the standards mentioned above 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 vehicles and components for our customers, shareholders and other interested parties within and outside the company. The objective of this Life Cycle Assessment was to describe the environmental profiles of the latest Caddy Delivery Van and Startline (formerly Life) models with diesel engines and compare them with their predecessors.

For the Life Cycle Assessment of the Caddy, we compared the 1.9-litre TDI (77 kW)[2] Delivery Van with its almost equally powerful successor, the new 1.6 TDI (75 kW)[3] and the especially economical 1.6 TDI BlueMotion Technology (75 kW)[4]. The Caddy Life with 1.9-litre TDI engine (77 kW)[5] was compared with a similar successor model, the Caddy Startline 1.6 TDI (75 kW)[6], as well as the 1.6 TDI BlueMotion Technology[7] (75 kW).

Function and functional unit of the vehicle systems assessed

The functional unit used for the Life Cycle Assessment is the transport of goods (cargo space 3.7 m^3) in the Delivery Van or passengers (up to 5 persons) in the Caddy Startline 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).

[1] The successor models represent the Caddy range which was available when this report was finalised.
[2] 6.2 l/100km (NEDC) 164 g CO_2/km
[3] 5.6 l/100km (NEDC) 147 g CO_2/km
[4] 4.9 l/100km (NEDC) 129 CO_2/km
[5] 6.2 l/100km (NEDC) 164 g CO_2/km
[6] 5.7 l/100km (NEDC) 149 g CO_2/km
[7] 5,1 l/100km (NEDC) 134 g CO_2/km

Table 1: Technical data of the vehicles compared

	Caddy Delivery Van 1.9 TDI	Caddy Delivery Van 1.6 TDI	Caddy Delivery Van 1.6 TDI BlueMotion Technology	Caddy Life 1.9 TDI	Caddy Startline 1.6 TDI	Caddy Startline 1.6 TDI BlueMotion Technology
Engine capacity [cm^3]	1896	1598	1598	1896	1598	1598
Output [kW]	77	75	75	77	75	75
Gearbox	5-speed manual	5-speed manual	5-speed manual	5-speed manual	5-speed manual	5-speed manual
Fuel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Emission standard	Euro 4	Euro 5	Euro 5	Euro 4	Euro 5	Euro 5
Maximum speed [km/h]	170	168	170	170	168	170
Acceleration 0-100 km/h [s]	13.0	12.2	12.2	13.3	12.9	12.9
Max. torque [Nm] at rpm	250/ 1900	250/ 1500-2500	250/ 1500-2500	250/ 1900	250/ 1500-2500	250/ 1500-2500
Unladen weight [kg][8]	1372	1375	1375	1470	1475	1475

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 fl ows 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 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 and Levin, 2000].

[8] Unladen weight in accordance with DIN 70020 without driver or luggage, with fuel tank 90% full.

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. 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.

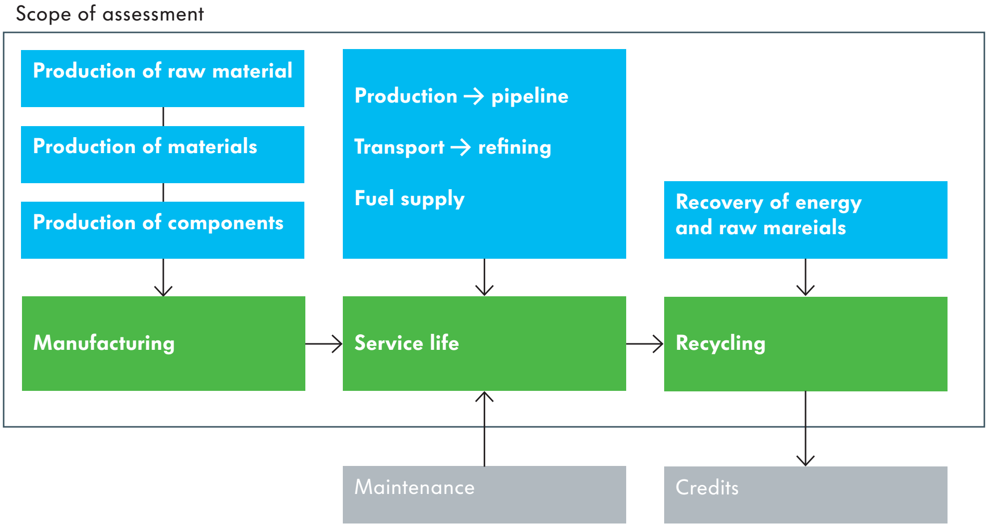

Fig. 1: Scope of the Life Cycle Assessment

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[9] 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. 2005a]. The environmental impacts determined in the Life Cycle Assessments are measured in different units. For instance, the global warming potential is measured in CO_2 equivalents and the acidification potential in SO_2 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_2 equivalents (see Table 2).

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

Environmental category		Unit
Eutrophication potential	15906	PO_4 equivalents
Ozone depletion potential	31	R11 equivalents
Photochemical ozone creation potential	7228	C_2H_4 equivalents
Global warming potential	4440050	CO_2 equivalents
Acidification potential	21553	SO_2 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.

[9] A more detailed description of these environmental impact categories is given on the internet at www.umweltpraedikate.de.

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 (see Chapter 1).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.

For the regulated emissions CO_2, NO_X 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 (Diesel vehicles)

		Euro 4		Euro 5	
Vehicle group / class		N1 II	M	N1 II	M
Limits [mg/km]	Carbon dioxide emissions (CO)	0.63	0.50	0.63	0.50
	Nitrogen oxide emissions (NO_X)	0.33	0.25	0.235	0.18
	Hydrocarbon emissions (THC) + NO_X	0.39	0.30	0.295	0.23
	Particulate emissions	0.04	0.025	0.005	0.005

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_2 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.[10]

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

[10] 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

	Caddy Delivery Van 1.9 TDI	Caddy Delivery Van 1.6 TDI	Caddy Delivery Van 1.6 TDI BlueMotion Technology	Caddy Life 1.9 TDI	Caddy Startline 1.6 TDI	Caddy Startline 1.6 TDI BlueMotion Technology
Fuel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Fuel consumption urban/highway/combined) [l/100 km]**	7.5/5.5/6.2	6.5/5.1/5.6	5.7/4.5/4.9	7.5/5.5/6.2	6.6/5.2/5.7	5.9/4.7/5.1
Emission standard	Euro 4	Euro 5	Euro 5	Euro 4	Euro 5	Euro 5
Carbon dioxide emissions, combined [g/km]	164	147	129	164	149	134
CO [mg/km]	0.046	0.241	0.160	0.046	0.241	0.160
NO_X [mg/km]	0.218	0.118	0.154	0.218	0.118	0.154
NO_X + HC [mg/km]	0.238	0.158	0.185	0.238	0.158	0.185
Particulate emissions [mg/km]	0.001	0.00021	0.00016	0.001	0.00021	0.00016

* Total average consumption in the NEDC

In sum, all information relevant to the aims of this study was collected and modelled with a sufficient degree of completeness.[11] 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.

[11] 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

Aim of the Life Cycle Assessment
• Comparison of the environmental profiles of predecessor and successor versions of selected Caddy models with diesel engines
Scope of assessment
Function of systems • Delivery Van: transport of goods (cargo space 3.7 m³) • Startline: transport of passengers (5-seater)
Functional unit • Transport of goods (cargo space 3.7 m³) in a Delivery Van or passengers (up to 5 persons) in a Caddy Startline over a total distance of 150,000 kilometres in the New European Driving Cycle (NEDC), with comparable utilisation characteristics (e.g. performance)
Comparability • Comparable performance figures • Vehicles with standard equipment and fittings
System boundaries • The system boundaries include the entire life cycle of the vehicles (manufacture, service life and recycling phase).
Cut-off criteria • The assessment does not include maintenance or repairs • No environmental impact credits are awarded for secondary raw materials produced • Cut-off criteria applied in GaBi data records, as described in the software documentation (www.gabi-software.com) • Explicit cut-off criteria, such as weight or relevance limits, are not applied
Allocation • Allocations used in GaBi data, as described in the software documentation (www.gabi-software.com) • No further allocations are used

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

- Material compositions in accordance with VDA (German Association of the Automotive Industry) Standard 231-106
- Life Cycle Inventory results include emissions of CO_2, CO, SO_2, NO_X, NMVOC, CH_4 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

Software

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

Evaluation

- Evaluation of Life Cycle Inventory and impact assessment results, subdivided into life cycle phases and individual processes
- Comparison 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 and does not include any environmental impact credits for secondary raw materials produced.

Delivery Van

Fig. 2 clearly shows that the emissions of the predecessor model, the 1.9 TDI Delivery Van, such as carbon dioxide (CO_2), carbon monoxide (CO) and nitrogen oxides (NO_X), are mainly generated during the service life of the vehicle. In contrast, both methane (CH_4) 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 emissions (SO_2). CO_2 emissions over the entire life cycle of the 1.9 TDI [75 kW] Delivery Van (predecessor model) reach approx. 33.7 metric tons. The total energy demand amounts to about 466 GJ.

Life Cycle Inventory Data

Caddy Delivery Van 1.9 TDI [77 kW] (predecessor)

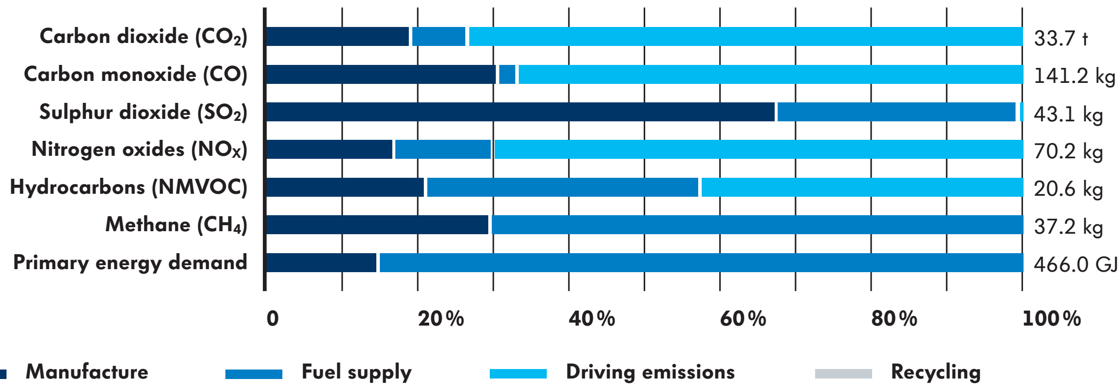

Fig. 2: Life Cycle Inventory Data for Caddy Delivery Van 1.9 TDI [77 kW] (predecessor)

In qualitative terms, the life cycle inventories for the new Caddy models with 1.6-litre TDI engine only differ slightly from those of the predecessor model (see Fig. 3 and 4). However, the lower energy demand and emissions of the new model compared with its predecessor are clearly evident. Thus, the energy requirement for the 1.6 TDI is reduced from 466 GJ to slightly less than 426 GJ and CO_2 emissions are only 30.7 metric tons, three metric tons less than for the predecessor model. The situation is even better with regard to the 1.6 TDI BlueMotion Technology Delivery Van model. Over its entire life cycle, it has a primary energy demand of 380 GJ and causes only 27.8 metric tons of CO_2 emissions.

Life Cycle Inventory Data
Caddy Delivery Van 1,6 TDI [75 kW]

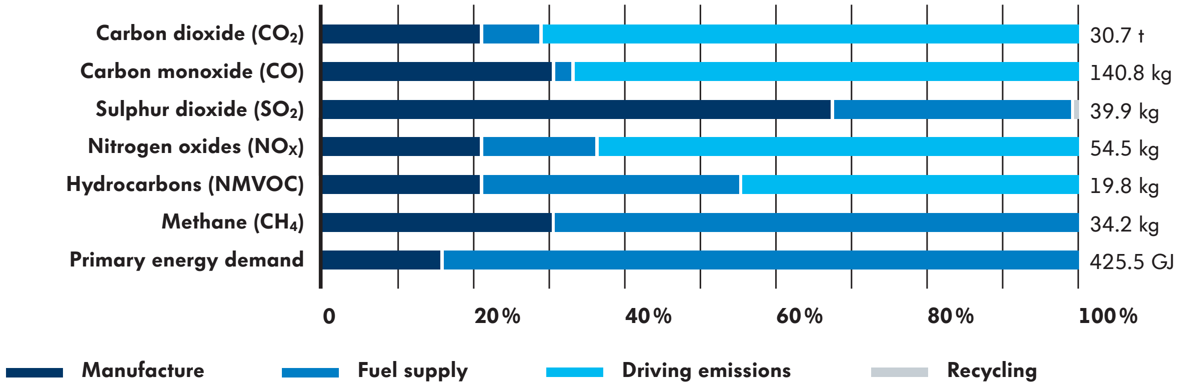

Fig. 3: Life Cycle Inventory Data of Caddy Delivery Van with 1.6 TDI [75 kW]

Life Cycle Inventory Data
Caddy Delivery Van 1,6 TDI BlueMotion Technology [75 kW]

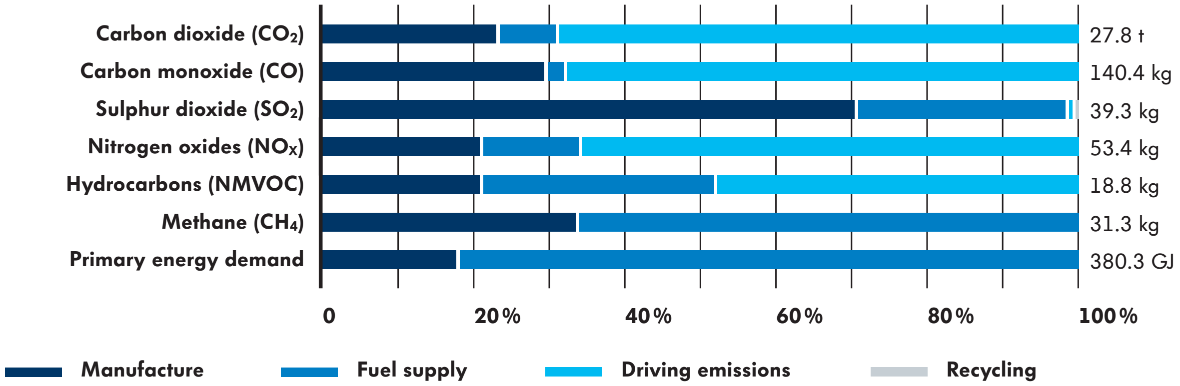

Fig. 4: Life Cycle Inventory Data of Caddy Delivery Van with 1.6 TDI and BlueMotion Technology [75 kW]

Startline

Figures 5, 6 and 7 show the results of the Life Cycle Inventories for the three Caddy models mainly designed for passenger transport which were compared. Over its entire life cycle, the predecessor model causes total CO_2 emissions of the order of 34 metric tons and has primary energy requirements of approx. 471 GJ (see Fig. 5).

Life Cycle Inventory Data
Caddy Life 1,9 TDI [77 kW] (predecessor)

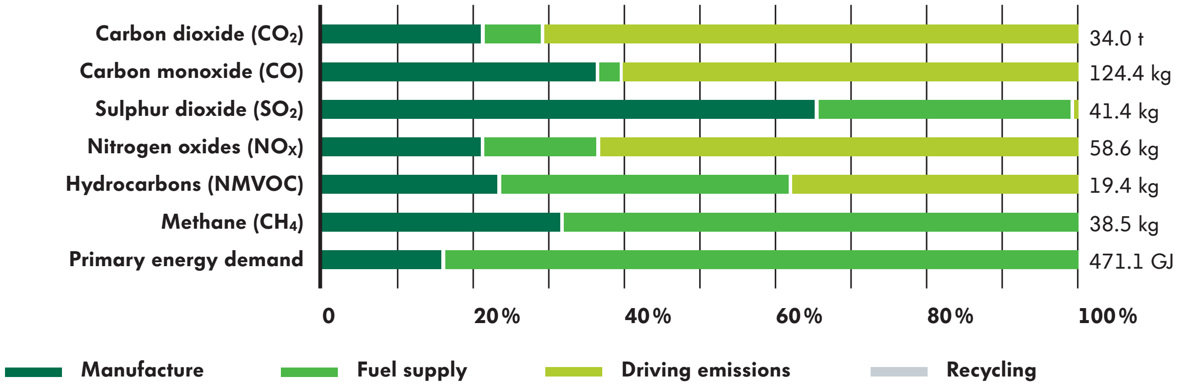

Fig. 5: Life Cycle Inventory Data of Caddy Life with 1.9 TDI [77 kW] (predecessor)

The successor model (Startline) with 1.6-litre TDI engine causes some 2.6 metric tons less CO_2 emissions and has considerably lower primary energy requirements, at 437 GJ (see Fig. 6). This is the direct result of its lower fuel consumption compared with the predecessor model. The significant impact of the utilisation phase on the overall results, especially as regards fuel supply and driving emissions, means that the significantly lower fuel consumption also leads to a reduction in all the other life cycle impact categories.

Life Cycle Inventory Data
Caddy Startline 1,6 TDI [75 kW]

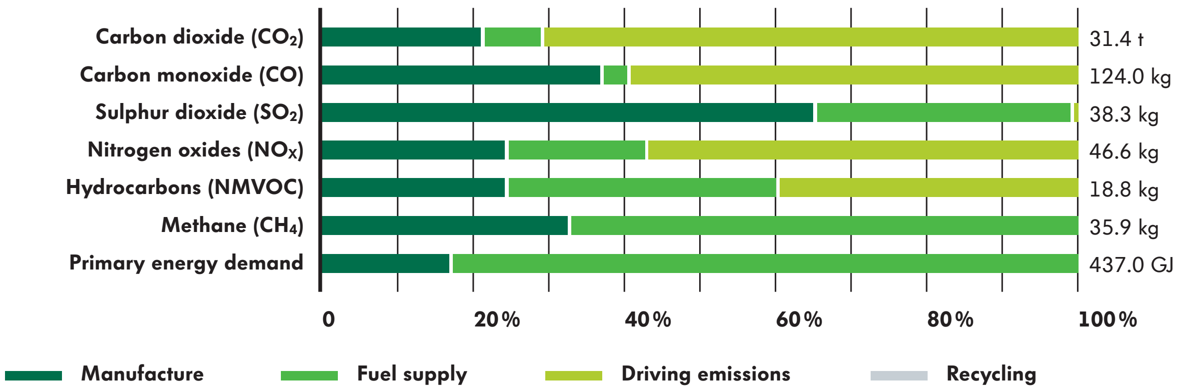

Fig. 6: Life Cycle Inventory data – Caddy Startline 1.6 TDI [75 kW]

The Caddy Startline 1.6 TDI BlueMotion Technology even outperforms even these very good results. Energy requirements are slightly below 400 GJ and CO_2 emissions, at 28.9 metric tons, are even more clearly below the values of the predecessor model (see Fig. 7).

Life Cycle Inventory Data
Caddy Startline 1.6 TDI BlueMotion Technology [75 kW]

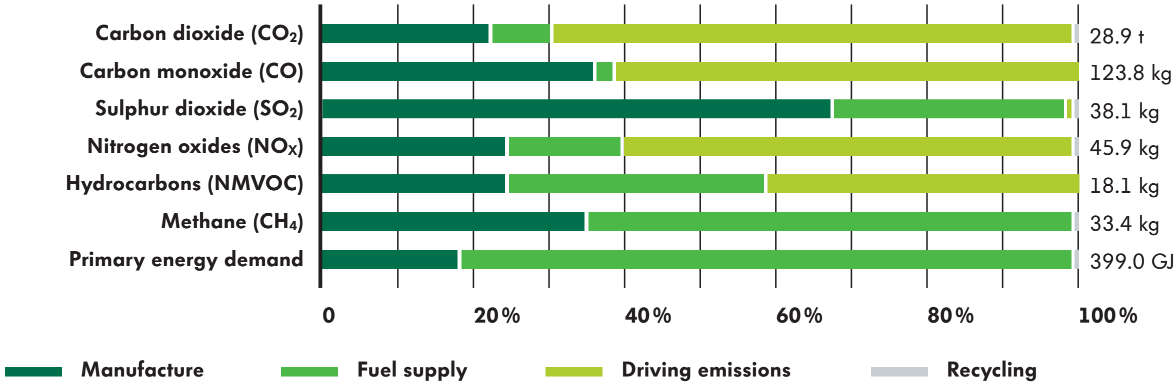

Fig. 7: Life Cycle Inventory data of Caddy Startline 1.6 TDI with BlueMotion Technology [75 kW]

Comparison of Life Cycle Impacts

On the basis of the Life Cycle Inventory data, Life Cycle Impact Assessments are drawn up for the environmental impact categories described. The interactions of all the emissions recorded are considered and potential environmental impacts are determined based on scientific models.[12]

Delivery Van

Fig. 8 clearly shows that the successor models achieve improvements compared with their predecessors in all the environmental impact categories considered. With reference to overall environmental impacts in the European Union, the graph indicates that the vehicles considered here make their largest contributions to overall environmental impacts in the categories of global warming potential (greenhouse effect) acidification and photochemical ozone creation (summer smog). Contributions to the categories eutrophication and ozone depletion potential are low by comparison. Consequently, the notes below focus on the first three environmental impact categories.

[12] You will find information on the environmental impact categories used here on the Internet at www.umweltpraedikat.de.

Comparative environmental impacts
absolute

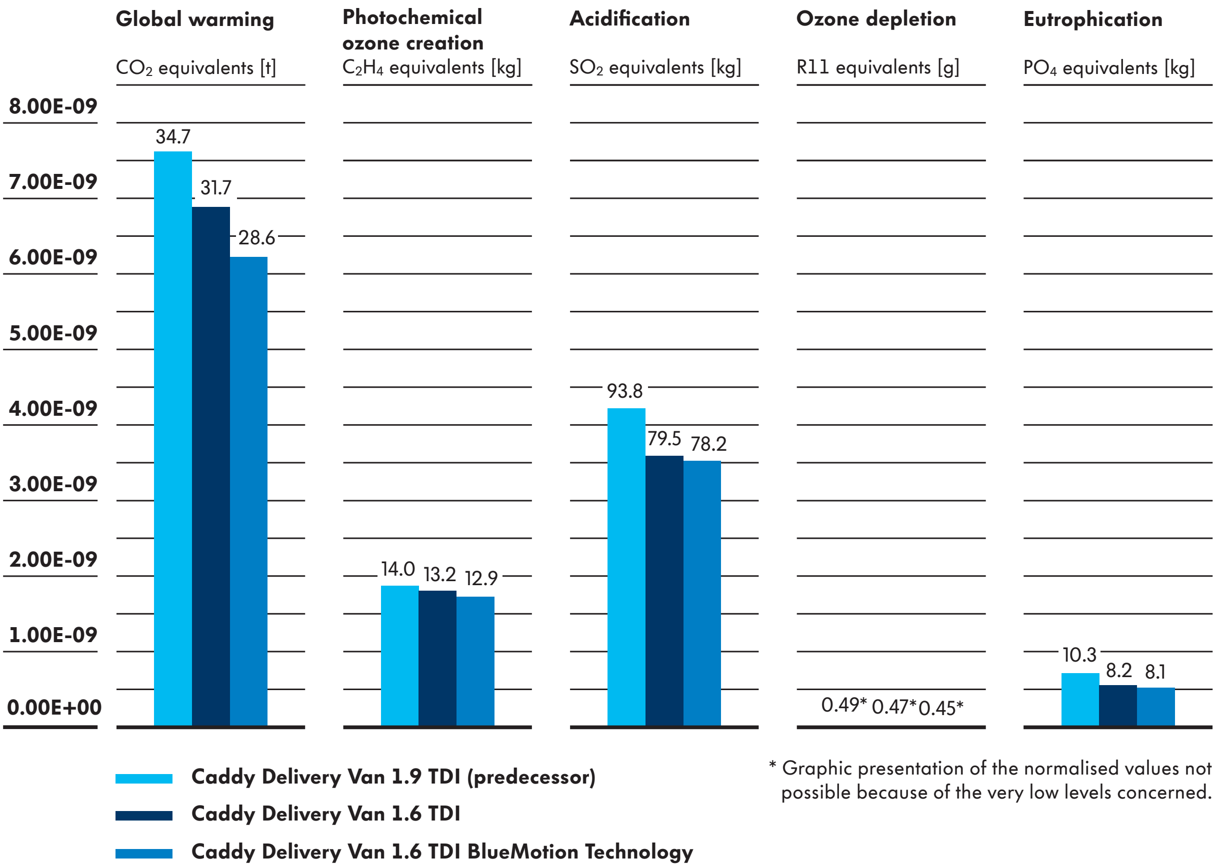

Fig. 8: Environmental impacts of Caddy Delivery Van 1.9 TDI (predecessor), 1.6 TDI and 1.6 TDI BlueMotion Technology (absolute)

Fig. 9 shows that the environmental impacts of the two successor models in the three categories considered are lower than those of the predecessor model – the Caddy Delivery Van 1.9 TDI. The reduction of nine percent in greenhouse gas emissions over the vehicle life cycle in the case of the Delivery Van 1.6 TDI corresponds to a saving of three metric tons of CO_2 equivalents. With the 1.6 TDI BlueMotion Technology, the saving is slightly more than six metric tons of CO_2 equivalents (or 18 percent) thanks to the additional use of fuel saving BlueMotionTechnologies (e.g. engine start-stop system).

Fig. 9 also shows how these reductions are achieved. The absolute environmental impacts are allocated to the individual life cycle phases. As the Life Cycle Inventories already showed, 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.

Comparative environmental profiles
normalised

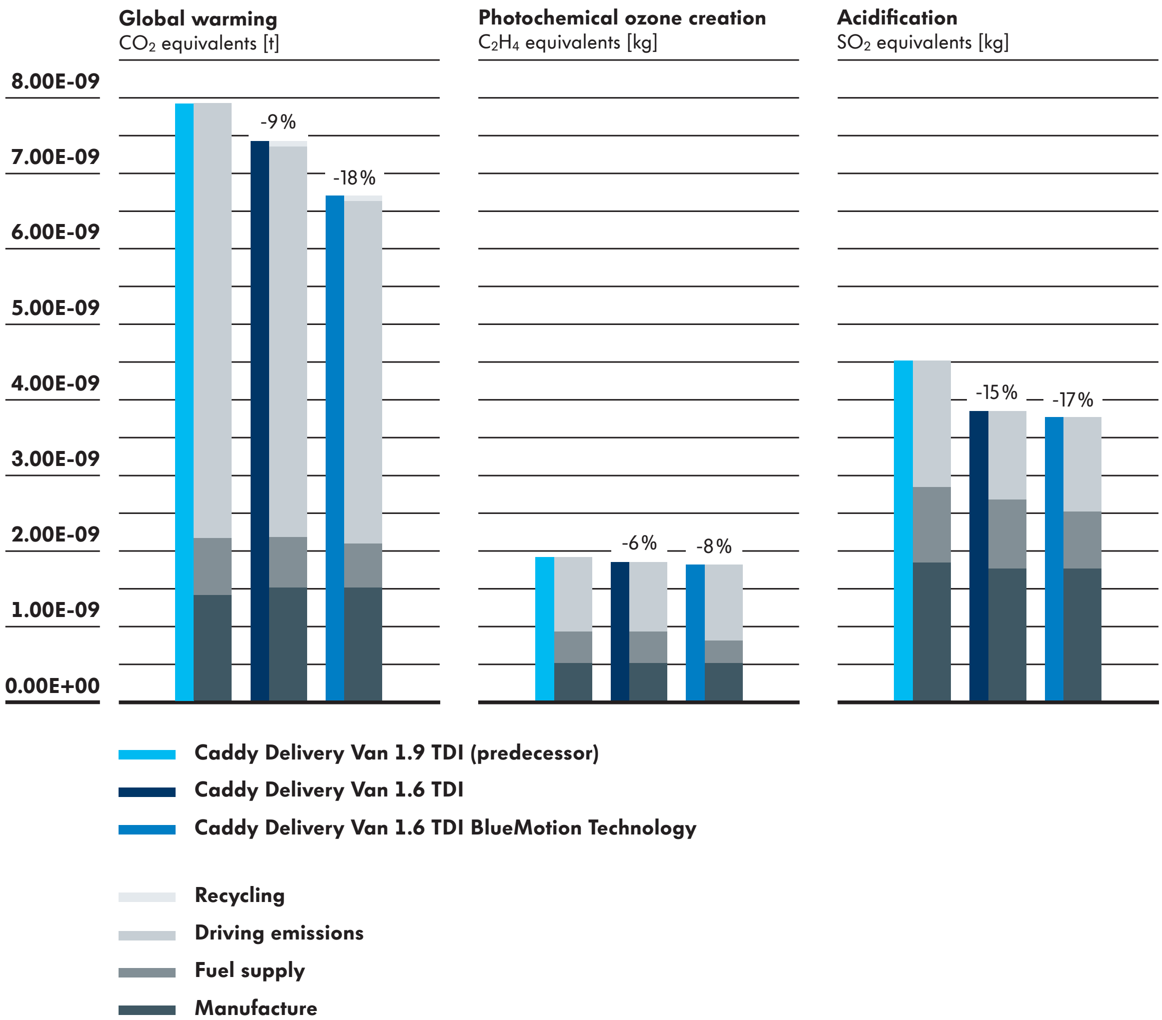

Fig. 9 Environmental impacts of the predecessor Delivery Van and the new 1.6 TDI and 1.6 TDI BlueMotion Technology (relative)

Fig. 10 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).

On the other hand, acidification and photochemical ozone creation are distributed more evenly over all the phases of the life cycle. The significant reductions in these impacts are chiefly due to compliance with the more stringent exhaust emission standard of the current models.

Comparison of environmental impacts over the full life cycle
normalised

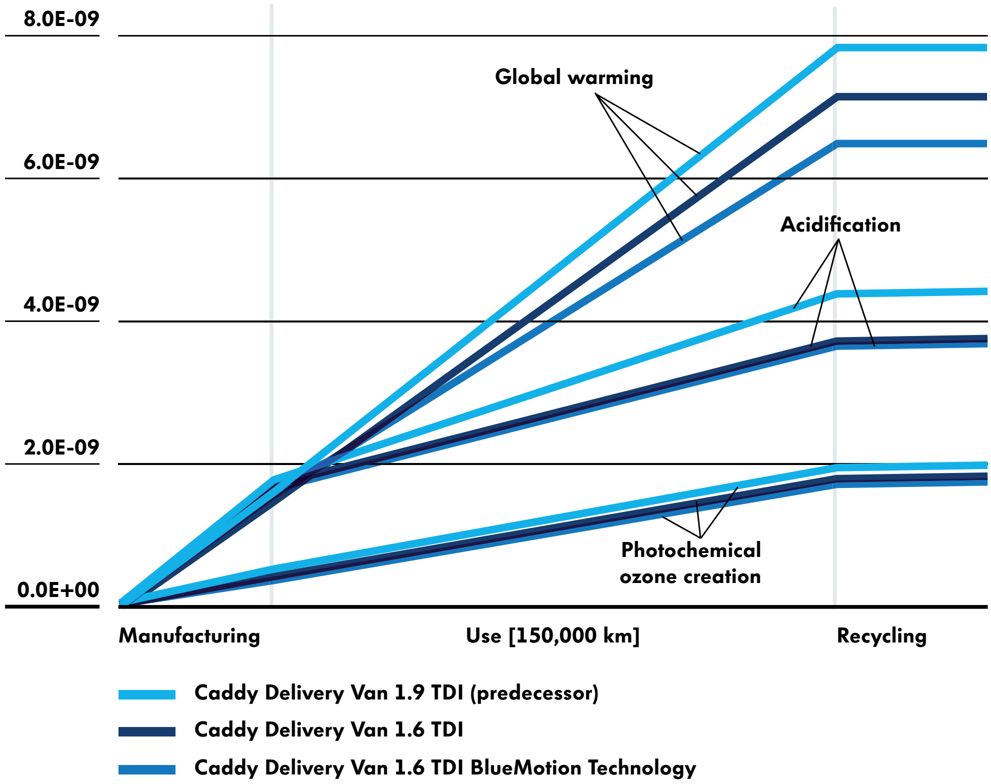

Fig. 10: Comparison of environmental impacts over the full life cycle – Delivery Van

Startline

A comparison of the Caddy models designed mainly for passenger transport also shows that the two successor models achieve improvements compared with their predecessors in all the environmental impact categories considered (see Fig. 11). In this case too, the vehicles considered here make their largest contributions to overall environmental impacts in the categories of global warming potential (greenhouse effect) acidification potential and photochemical ozone creation potential (summer smog).

As already described for the Delivery Van, the global warming potential caused by the successor models over their entire life cycle is significantly lower than that caused by the predecessor model. With the assumed mileage of 150,000 kilometres, total emissions of CO_2 equivalents are reduced by 2.7 metric tons per vehicle. The saving with the Caddy Startline 1.6 TDI BlueMotion Technology is even greater, at more than five metric tons of CO_2 equivalents.

Comparative environmental profiles
normalised

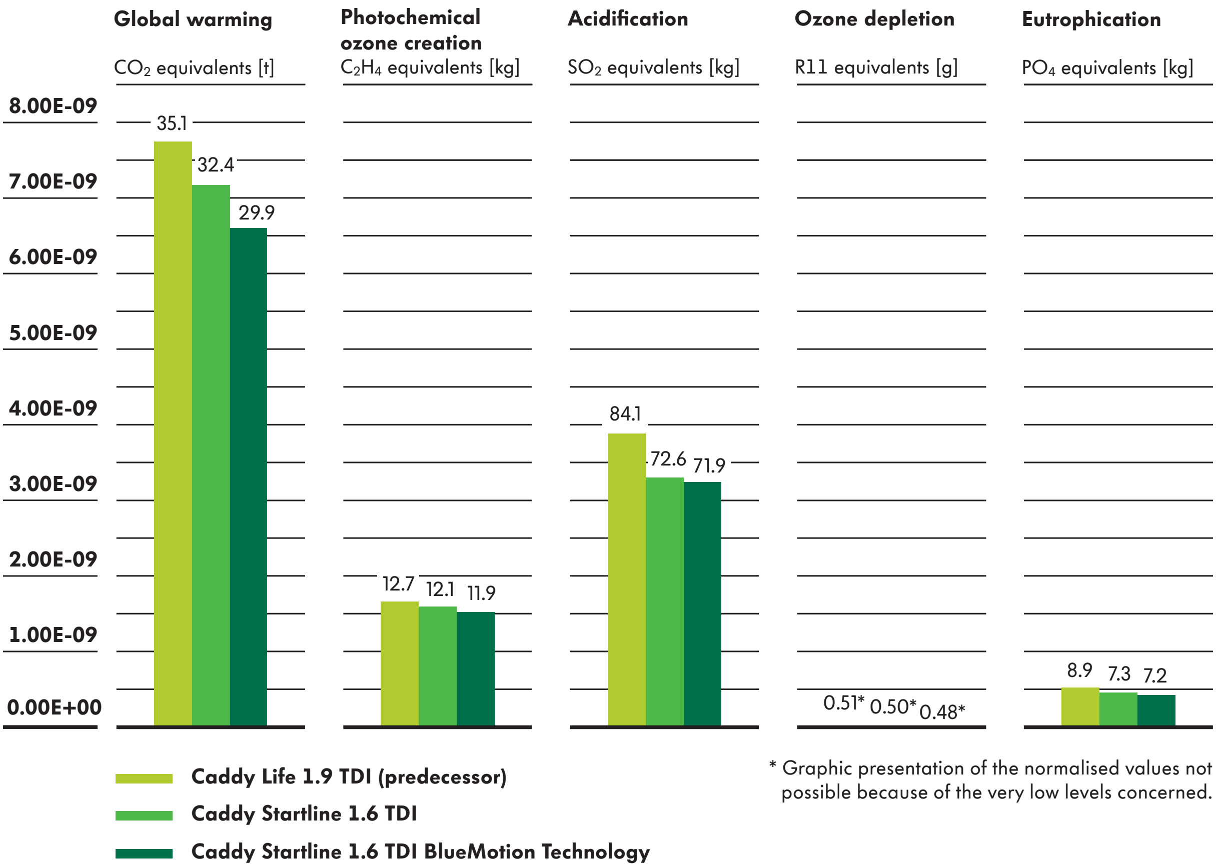

Fig. 11: Environmental impacts of Caddy Life 1.9 TDI (predecessor), Startline 1.6 TDI and Startline 1.6 TDI BlueMotion Technology (absolute)

Fig. 12 presents the changes in environmental impacts from the predecessor, the Caddy Life 1.9 TDI, to the two successor models in relation to each other. In the case of the Caddy with 1.6-litre TDI engine, impacts in the categories of photochemical ozone creation potential and acidification potential have fallen by five percent and 14 percent respectively. Global warming potential over the entire vehicle life cycle has been reduced by eight percent. The reduction in environmental impact with the Caddy Startline 1.6 TDI BlueMotion Technology is even more pronounced. Photochemical ozone creation potential is reduced by seven percent and acidification potential by 14 percent. As regards global warming potential, the reduction of 5.2 metric tons of CO_2 equivalents corresponds to a saving of 15 percent.

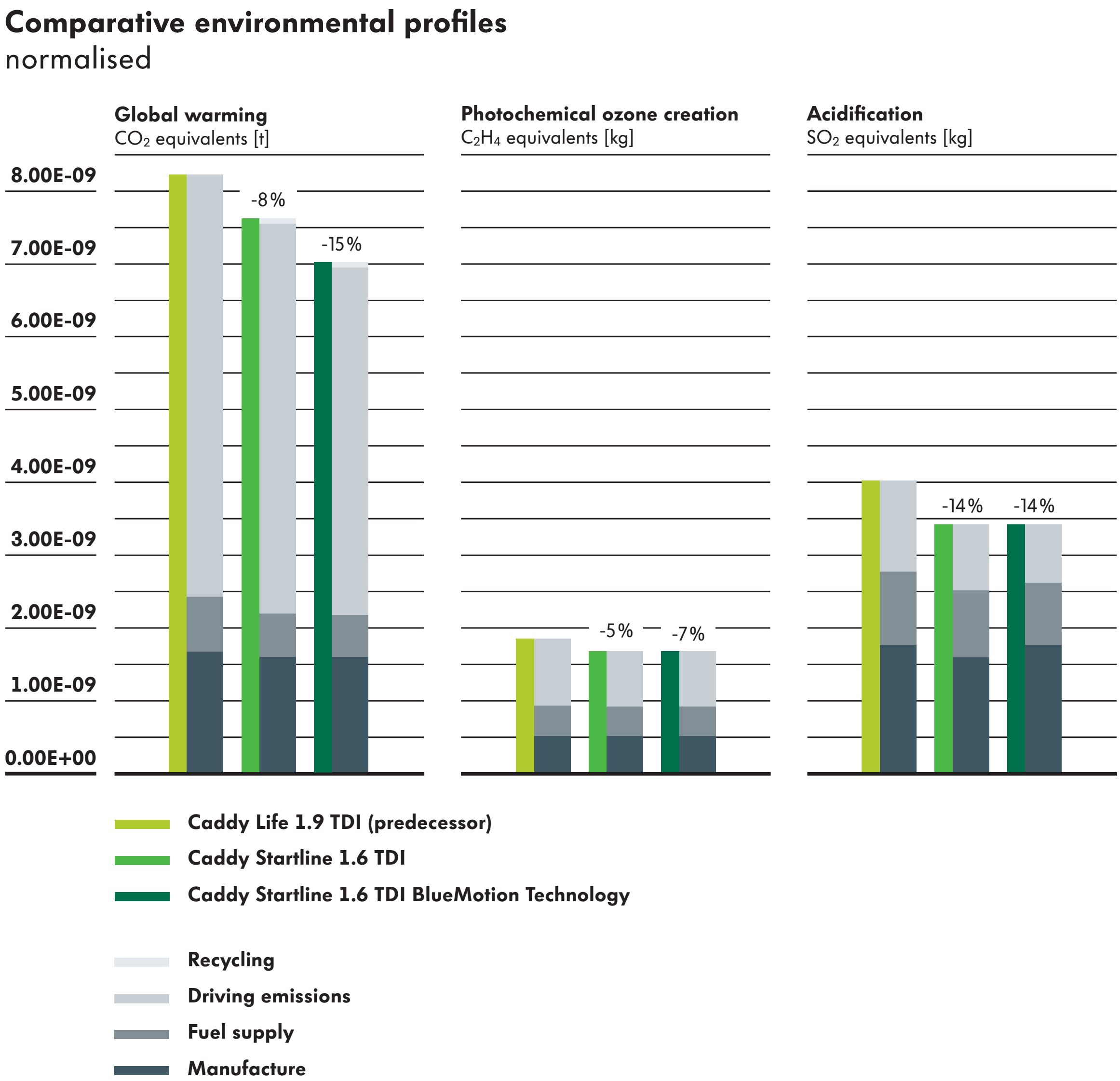

Fig. 12: Environmental impacts of the Caddy Life 1.9 TDI (predecessor), Startline 1.6 TDI and Startline 1.6 TDI BlueMotion Technology (relative)

Fig. 12 also shows how these reductions are achieved. As with the Delivery Van, most of the improvements are the result of the lower fuel consumption of the current model. It can clearly be seen that the driving emissions and the contribution to emissions associated with the fuel supply process are both lower in the case of the current model. In the manufacturing phase, there are only minor deviations between the vehicles compared.

Comparison of environmental impacts over the full life cycle
normalised

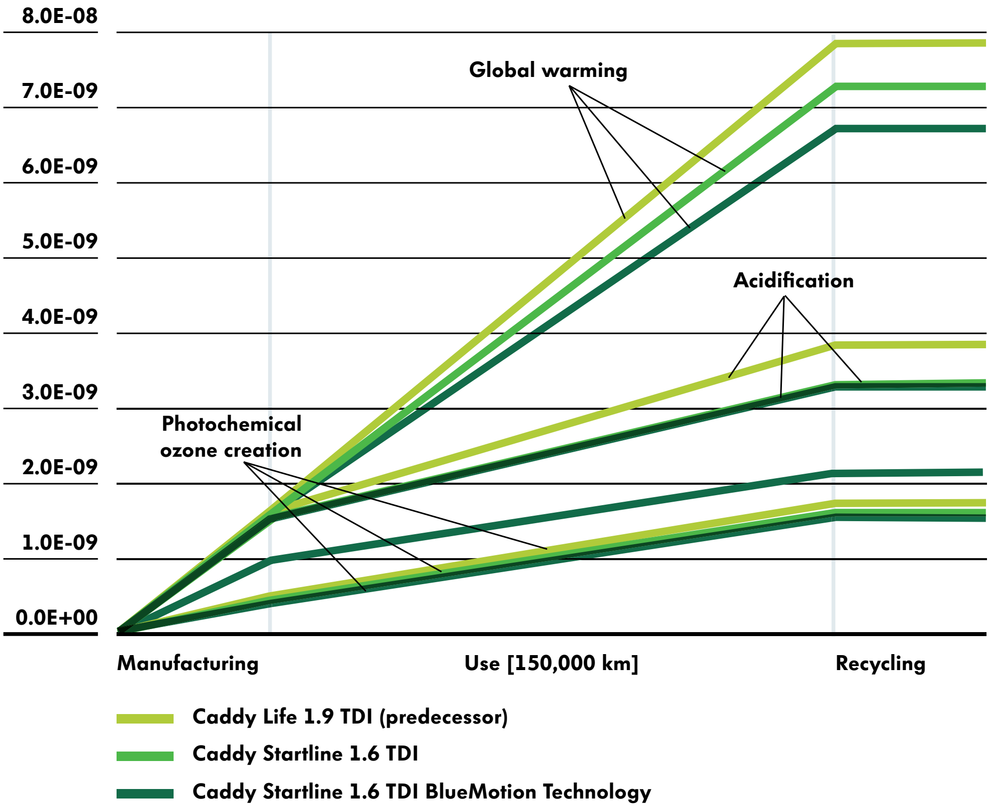

Fig. 13: Comparison of environmental impacts over the full life cycle – Startline

The service life of the Startline models is just as predominant in terms of global warming potential as in the case of the Delivery Van (see Fig. 13). The lower values for the Caddy Startline 1.6 TDI and the 1.6l TDI BlueMotion Technology 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 the fuel supply process for the current model, as well as to its compliance with a more stringent exhaust emission standard.

Certification

The statements made in the Transporter Environmental Commendation are supported by the Life Cycle Assessment of the Transporter. 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 TÜV NORD

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

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

Volkswagen AG
Berliner Ring 2
38346 Wolfsburg
Germany

Range of application

Environmental Commendation Caddy (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**

Audit Report No. 3506 7932

Certification office of the TÜV NORD CERT GmbH

Essen, dated 2010-10-18

Dr. Winfried Hirtz
Environmental verifier

Daniel Kielhorn
Experte

TÜV NORD CERT GmbH Langemarckstrasse 20 45141 Essen 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_4	Methane
CML	Centrum voor Milieukunde Leiden (Centre for Environmental Sciences, Netherlands)
CO	Carbon monoxide
CO_2	Carbon dioxide
DIN	Deutsche Industrienorm (German Industrial Standard)
DPF	Diesel particulate filter
DSG®	Dual-clutch gearbox
EDW	Einwohnerdurchschnittswert (average impact per inhabitant)
EN	European standard
EP	Eutrophication potential
EU 15	The 15 member states of the European Union before the eastward enlargement of the EU in 2004
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_2O	Nitrous oxide
NEDC	New European Driving Cycle
NH_3	Ammonia
Nm	Newton metre
NMVOC	Non-methane volatile organic compounds (hydrocarbons without methane)
NO_X	Nitrogen oxides
ODP	Ozone depletion potential
PAN	Peroxyacetylnitrate
PO_4	Phosphate
POCP	Photochemical ozone creation potential
ppm	Parts per million
PVC	Polyvinyl chloride
R11	Trichlorofluoromethane (CCl3F)
SET	Simultaneous engineering team
SF_6	Sulphur hexafluoride
SO2	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, 18.10.2010
TNC Umweltgutachter-H

Report

Critical Review of Life Cycle Assessment

Caddy - Environmental Commendation, Model Year 2011

Report No.:	8000 385 519
Client:	Volkswagen AG 38436 Wolfsburg
Author of Life Cycle Assessment:	Volkswagen AG K-EFUP Dr. Koffler
External reviewers :	Dr. Winfried Hirtz Daniel Kielhorn
Length of report:	9 pages

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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 " Caddy - 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 Cert GmbH by Dr.-Ing. Winfried Hirtz, Environmental Verifiers licensed under the Environmental Audit Act and Daniel Kielhorn, environmental expert for CDM.

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 upstream 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 model, the overall vehicle assessment of various box wagons, e.g. 1,6 TDI (file 2KO-O-O) were considered. Special data files were front window, vulcanisation and battery. 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 Caddy 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 a VW Caddy 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_2 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 Caddy, 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 utilisation phase is designed for 150,000 km. This is plausible based on the utilisation characteristics and the design of the engines and the catalysator. The absolute values relate to these suppositions. Influences due to different load weights have not been taken into consideration and may change the assessment in the specific case. 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.

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 auditors 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). 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 CO2 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 nutrification 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 Caddy 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 "Caddy - 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.

Dr. Winfried Hirtz Environmental Verifier DE-V-0151	Daniel Kielhorn expert

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November 2010