

**Report  
on the critical verification of the approach toward the**

**Determination of the percentage of secondary  
material used in the Golf VI**

**Client:**

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**Experts:**

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**Examination basis:**

3 diploma theses:

[1] Möhle, Henrik Robert. "Detaillierte Erhebung zum Sekundärmaterialeinsatz bei den Metallwerkstoffen des Golf VI" (Detailed examination of percentages of secondary metal materials used in the Golf VI). 14 June 2008.

[2] Jeanvré, Sebastian. "Ermittlung der durchschnittlichen Rezyklatmenge der im Fahrzeug verwendeten Kunststoffe, Reifen und Gläser" (Determination of average *recyclate quantities of plastics, tyres and glass in a vehicle*). 14 July 2008.

[3] Krüger, Wiebke: "Bestimmung des Rezyklatanteils und Aufzeigen von Entsorgungswegen der Betriebsflüssigkeiten des Golf VI" (*Determination of the percentage of recyclates and identification of the disposal paths of service fluids of the Golf VI*). 30 June 2008.

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## 1. General Information

### 1.1. Topic and objective

Volkswagen AG, department EGFT/6 – Vehicle Recycling, submits three diploma theses outlining an approach toward the determination of the percentages of recycled materials used in the Golf VI. Thesis [1] analyses all metals, [2] analyses all plastics, tyres and glass, and [3] analyses the service fluids used at factory filling.

The analyses are based on the following vehicle type: Golf VI "Trendline", 2 doors, 1.6-l common-rail diesel engine, 77 kW, 5-speed manual transmission, automatic A/C, without sunroof, 1,274 kg actual total vehicle weight (w/o fuel), of which secondary materials account for approx. 42% (see table 1).

Material	Secondary material in [g]	Secondary material percentage [%] of total vehicle weight
Metals (steel-wheel version)	500,926	39.33%
Plastics	14,340	1.13%
Glass	8,967	0.70%
Tyres	400	0.03%
Service fluids	1,733	0.34%
<b>TOTAL</b>	<b>526,366</b>	<b>41.53%</b>

Tab.1 Percentages determined by Volkswagen of recycled metals, plastics, glass, tyres and service fluids of the Golf VI as per [1], [2] and [3]

Volkswagen AG, EGFT/6 – Vehicle Recycling, commissioned the TÜV NORD CERT Umweltgutachter GmbH as an independent external reviewer to perform a critical verification of the approach toward the determination of the percentages of secondary materials.

At TÜV NORD CERT, the review was performed by environmental evaluators Dr. J. Hanel, Dipl.-Ing. F. Schneichel (responsible) and environmental management auditor MSc. A. Blarr. All aforementioned auditors are certified in accordance with the German environmental auditing legislation.

The objective of the critical verification was to determine the reliability, transparency, relevance and representative character of the methods applied in these three theses regarding:

- the determination of materials percentages of one vehicle type with a defined equipment level,
- the concept applied for the determination of the secondary material, and
- the calculation and estimation of the percentage of secondary material used.

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### 1.2. Procedure

With due consideration of general quality criteria (i.e. transparency, reproducibility, quality of software and data, identification of data sources), the critical analysis was performed in two steps:

- Analysis of the submitted diploma theses for consistency of calculation method, material data sets used and plausibility of results
- Follow-up research of the major exemplary items from the vehicle's bill of material.

The procedure involved a review of files, internal databases and other representative documents as well as various specific calculation procedures done by a computer system.

## 2. Results of the critical verification

### 2.1. Starting point of the verification

EU legislation requires automotive manufacturers not only to collect vehicles at the end of their lifecycle and to provide proof of corresponding recycling percentages, but also to increase the use of secondary materials. The implementation of the EU directives into national law of the EU member states is ongoing. As one of the first countries, France demands automotive manufacturers to submit yearly reports on their current status of secondary materials used in new types. This requires the development of new methods, i.e. suppliers providing relevant information in the planning phase already.

Generally, the presented approach to the calculation of percentages of metals, plastics, glass, tyres and service fluids is suitable for that matter.

### 2.2. Definition of secondary material

The calculation of secondary material percentages is based on the definition of the term recyclate provided in the 'VW Umweltnorm Fahrzeug VW 91102' (edition 02/07):

*Recyclates are materials replacing primary materials and can be designated as secondary materials. Accordingly, recycled materials of the following three categories are classified as recyclates:*

1. *Recycling of material returned from production*

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2. *Recycling of material during its use*
3. *Recycling of scrap material*

In the area of service fluids, only such fluids must be designated as recyclates that have already been used and that have been restored for repeated use (Krüger, 2008).

By implementing material returned from production, i.e. materials originating from rework, regrinding or scrap created in a technical process and that can be reused within the same process, the term "recyclate" extends beyond the definition set forth in DIN EN ISO 14021.

### 2.3. Determination of secondary material use

The definition of secondary material presented in [1], [2], and [3] is mainly oriented on the weight proportions of the individual materials with their known, calculated or estimated percentage of secondary material of the total vehicle weight. For this purpose, all parts of the vehicle are classified and sorted for further evaluation by material, specific material properties and suppliers using the general database of the automotive industry, IMDS (International Material Data System), and the VW-internal database MISS (Material Information Sheet System) to the greatest possible extent that was technically feasible.

In theory, at least, the corresponding materials of VDA categories 1 to 5 (Verband der Automobilindustrie e.V. – Automotive Manufacturer's Association) can be extracted quite easily from the IMDS database. This database contains material information sheets provided by the suppliers, and also declarations of origin which are mandatory for materials with a weight greater than 25 g. However, the system is not suitable for queries on secondary material percentages in vehicles without further adjustments. For example, the weight provided by the IMDS relates to the complete component and not exclusively to the part containing secondary materials. Also, double counts are possible, and the correctness of information entered into the database is not verified. Consequently, a so-called "checked parts list" in which the redundant designations had been corrected was created manually using a primary number configuration (PR) of the Golf VI and the VW-internal data system "MISS". Now, this detailed bill of material describes the selected vehicle type completely; however, individual parts (assemblies) cannot be viewed independently.

IMDS and MISS were used to find contact details of suppliers. However, problems occur with components which may consist of parts from multiple sub-supplier. Here, the software ESON (Entwicklungsstückliste Online - development parts list online) was used.

In the next step and by random sampling, suppliers were queried and the market situation was analysed to determine the actual percentages of secondary materials in

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metals, plastics, tyres, glass and service fluids. Then, the actual percentage of secondary materials used in a complete vehicle was calculated (table 1), resulting in 42% of the overall vehicle weight.

### **2.3.1. Determination of percentage of secondary materials in metals**

About 75% of the Golf VI equipped with the selected features is made of metals from VDA categories 1 to 4: steel, aluminium, lead, copper, cast iron and zinc. Subject of investigation was the type of vehicle described above, both with steel and aluminium rims.

According to information gained in surveys from the suppliers of the heaviest components (total: 500 kg), the body parts produced at the Volkswagen press shops contain an average of 20% of secondary materials [1].

For all other components, the composition of the individual materials was compared against the secondary materials typically contained in components available on the market. These proportions were allocated to the quantities actually incorporated in the Golf VI. This was mostly achieved by interpretation (average value) of sound data provided by the corresponding automotive manufacturer's associations.

The steel used by German suppliers for automotive production is either made in blast furnaces or in electric arc furnaces. The two methods differ greatly in terms of secondary material usage. For blast furnace steel, which is e.g. used for panels, [1] assumes a cooling scrap percentage of 17.5 – 30%. For the purpose of this verification, a value of 18% is used as a calculation basis, representing the average value of the past seven years (2001 – 2007) of all German steel mills. Further information was provided upon request by Salzgitter Flachstahl, Saerstahl AG, Thyssen-Krupp Stahl AG and Arcelor Mittal. The average annual percentage of cooling scrap for 2008 was determined to be approx. 20%. For electric arc furnace steel, which is used i.e. for bolts, beams and wires, a scrap percentage of 100% is assumed for calculations. This assumption is based on the mass balances of the electro steel production of the past years and information provided by Peiner Träger GmbH, Germany.

The percentage of aluminium alloys used as secondary material in a specific vehicle is difficult to estimate because the names of the alloys do not allow a definite allocation of primary or secondary materials. The German Verband der Aluminiumrecycling-Industrie e.V. (Association of the aluminium recycling industry) provided [1] with figures from the German aluminium production, stating a percentage of 50% for secondary materials. A differentiation can be made between cast alloys and wrought alloys in the use of aluminium. Due to the production process it can be assumed that at least cast aluminium parts for automotive applications are made of 100% secondary materials.

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Figures provided by an association were also used to determine the percentage of lead (metals statistics 2001-2006 of the WVM - Wirtschaftsvereinigung Metalle (metal trade association)). The same approach was taken to determine the average of 29% of zinc as secondary material in German zinc production. The secondary material percentage of parts containing copper is also derived from an analysis of the raw-material market. According to the evaluation of the metal statistics of 2001 to 2006, an average of 54% of secondary material is used in the German copper production. For cast iron it is assumed that only very little primary material is used (95% secondary material).

### **2.3.2. Determination of percentage of secondary materials in plastics, tyres and glass**

The plastics used for the Golf VI can be categorized as thermoplastics, elastomers and duroplastics falling into the VDA categories of polymer materials (VDA group 5) and process polymers (VDA group 6). It can be assumed that approx. 20% of the overall vehicle is made of such materials.

Secondary material is e.g. used for wheelhouse liners, underbody covers and insulating and noise-dampening mats for which a percentage of 30 - 60% is assumed [2]. However, not all plastics are suitable as secondary material. Thermoplastics are considered as not fully recyclable, because their stability, touch and feel are affected by the melting process. Additives and dyes may also have a harmful effect on recyclability. Generally, it must be assumed that no secondary material is used in the areas of the vehicle that are visible to the customer.

An initial problem when investigating the percentage of secondary plastic materials used in the Golf VI was the fact that contrary to metals, there is no international material number code for plastics. Due to inconsistent description, no suitable dataset could be created from MISS. Consequently, information about the material composition was requested from the suppliers of the heaviest plastic parts. Parts incorporated in assemblies and plastic compounds were especially problematic [2]. No statement can be made as to which extent valid values were actually successfully investigated. Based on a "checked bill of material" (see above) and statements of the suppliers, a secondary materials percentage of 2.8% is estimated for PE and PP [2].

The use of secondary materials in tyres was also investigated, using summer tyre 205/55 R 16 91 W ContiPremiumContact with a weight of 9.3 kg (10 kg assumed per tyre for easier calculation) as sample. Tyres comprise two components: the cord threads of the carcass and the steel belt enclosing and stabilising the carcass that is made of several layers of rubber-coated steel wires. Since these are made of electro steel, a secondary material percentage of 100% is assumed (see above). The percentage of steel of the total weight of the tyre is 12.5% on average. According to the manufacturer, each tyre contains a percentage of regenerated elastomers of approx. 1% of the total tyre weight.

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All glass parts of the Golf VI are provided by one supplier. Waste from glass production is returned into the production process at defined points. The so-called regenerative tank furnace processes approx. 20 to 40% of broken glass material. Accordingly, [2] calculates that 30% of the glass used for the Golf VI is made of such recycled material.

### **2.3.3. Determination of percentage of secondary materials in service fluids**

Approx. 2 - 5% of the vehicle weight is attributed to the service fluids [3] falling into VDA category 9 "Operating and auxiliary materials". Service fluids are generally divided into water-based substances such as coolant, washer fluid and battery acid, and oil-based substances such as engine oils, transmission fluids and shock-absorber oils. Preservation media and greases were not investigated. In [3], the term recyclate (see above) is restricted in scope and only includes substances that are relevant when exchanging service fluids within the vehicle's service life or when the vehicle is disassembled in the end-of-life process.

"Checked bills of material" were also applied when investigating the service fluids. In addition to IMDS and MISS, the VW-internal system VeROn (Vehicle recovery online) was also used.

All fluid volumes [ml] relate to the total weight of the vehicle [g]. The conversion into grams is based on material density. Additional information was obtained from component developers about the service fluids with the highest volumes such as engine oil and coolant which were also adopted into the "checked bill of material".

At authorized VW workshops, service fluids are collected in cooperation with CCR Logistics Systems AG who organise pick-up, storage and recovery. Recycled oil-based service fluids are currently not used by VW. It is assumed that the sulphuric acid of the battery is made of secondary material. This results in a percentage of recyclate materials from VDA category 9 of approximately 0.3% of the total vehicle weight [3].

## **2.4. Data sources**

The determination of the percentage of secondary materials is oriented mainly on the portion of the total vehicle weight of individual materials with a known, calculated or estimated percentage of secondary materials.

The starting point is always a "checked bill of material" (containing 4,875 metal items alone) providing a detailed representation of the overall vehicle. Since a faultless representation could currently not be created using the MISS and IMDS databases, the datasets derived from these databases were manually checked for redundant entries. This approach is reproducible and can be realized without excessive

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technological and financial efforts. MISS and IMDS currently provide the most comprehensive material collections.

The information about the individual parts and parts list used in IMDS is evaluated in the course of the initial sample evaluation.

The material categories provided by the VDA are helpful for the evaluation of the quantities of individual materials independent of complex assemblies. This facilitates the representation of the quantities of the individual materials used in a vehicle.

Suppliers are not obliged to provide additional information about secondary material use for parts. In theory, the table "Recyclate" allows a differentiation between production waste and scrap material. Until this becomes mandatory an alternative method must be applied to estimate the percentage of secondary materials used. MISS always states a contact person for each part. During the research for the present paper, the percentage of secondary materials was queried at the suppliers of the heaviest parts (metals). The results were compared with the data provided by the VDA (average values of material production of the years 2001 – 2007). VDA values are generally accepted and the approach to the calculation is reproducible. The comparison was made manually, but can now be done by random checks using an Excel-based program which uses macros to detect material names and allocates defined secondary material percentages to them.

The further development of this Excel application is recommended because not all material names had been recorded using the macros by the on-site appointment of November 10<sup>th</sup>, 2008.

### **2.5. Plausibility and completeness check**

The authors' analysis is based on random checks in the areas of glass, metals and plastics. In the process, the correctness of the average values which could not be derived from published material information was checked for selected major sample parts:

- Secondary material percentage in float-glass production
- Secondary material percentage in plastic fuel tanks
- Secondary material percentage in cast aluminium parts



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The plausibility of the calculations and the results were also tested using the following parts as examples:

- Crankcase, part no. 03L103021L, material TL 009
- Bell housing, part no. 0A4301107H, material ALSi9Cu3(Fe)

To ensure traceability of percentage values (secondary material percentages referenced to specific materials) to source data, the calculations as well as the documentation were reproduced and investigated. This was performed in Wolfsburg on October 20th 2008 with attendance of Mr Schoppe, Dr Schmid, Mr Möhle, Dr Hanel, Mr Schneichel and Ms Blarr, and on November 10th 2008 with attendance of Dr Schmid, Mr Schlei, Mr Möhle and Ms Blarr.

It can be concluded that the procedure for the data generation process and the approach to the calculation are transparent, reproducible and plausible.

### 2.6. Error estimates

Metals are the largest share of the Golf VI materials. For this area a comparative calculation using the following determinants was performed to provide a sensitivity analysis:

- a) The calculation is based on the data on secondary material percentage for individual materials provided by associations and suppliers.
- b) The figures for secondary material use in electro steel and cast aluminium parts were provided by the VW-Zentrallabor Werkstofftechnik (VW central laboratory for material science), other data were provided by suppliers and associations.
- c) The calculation considers only electro steel, blast furnace steel and cast iron. All other metal materials are not considered (reliability test).

All three calculation methods were reproduced on site on November 10<sup>th</sup>, 2008 using a computer. Assuming a vehicle weight of approx. 1,274 kg, the comparison of the results from a) to c) only yields a deviation of 1.5% of the quantity of secondary materials.

## 3. Results of the critical analysis

This critical verification of the method for the determination of secondary material used in the Golf VI can be summarised as follows:

- The methods outlined in the theses for the determination of secondary materials percentages comply with all requirements of reliability, transparency, relevance and representative character.

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- The calculations performed to determine the material percentages of a vehicle with defined equipment features are based on the material information maintained in the IMDS/MISS databases.
- The secondary material percentages were calculated using the information provided by the industry associations responsible for the specific materials. This information was adjusted with the IMDS/MISS data and was verified by targeted investigation at the major suppliers.
- The data used are adequate, suitable and qualified for the objective of the calculations.
- The calculations presented in the theses are consistent, adequate, transparent and plausible.

An analysis report was issued for the critical evaluation performed as presented above (see attachment).

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