Circular Economy

Strengthening the Circular Economy

The increasing closed-loop circulation of materials helps to reduce the negative environmental impact of resource consumption and counteract the shortage of raw materials. This makes it a key sustainability topic for the Volkswagen Group. At the same time, this development offers us many opportunities: It necessitates innovation in the areas of material design, recycling technologies and business models – thus promoting the emergence of new ideas and technologies. The shift toward a circular economy comes with new legal requirements. The requirements relevant to the automotive industry include, for example, the new EU Batteries Regulation, which entered into force in 2023 and sets clear requirements for the circular economy. Additional requirements will be created by the new end-of-life vehicle legislation, a first draft of which was published by the European Commission in the reporting year. Another important driver of the circular economy is the ongoing decarbonization of the Volkswagen Group: The growing use of secondary materials and the establishment of closed loops of materials can help to significantly reduce our CO_2 emissions.

Group-Wide Working Structures and Steering Committees

Recognizing the importance of this topic, Volkswagen has anchored circular economy as a focus topic in Group initiative 6 of the NEW AUTO Group Strategy. Cross-divisional and cross-brand working structures have been developed at Group level for managing the topics to be developed. These build on the work of committees such as the Group Steering Committee for the Environment and Energy, the Group Steering Committee for Product Recycling and the Group Working Committee for Environment Product.

We want to intensify our efforts for a transition to a loop-oriented and resource-conserving way of doing business even further in the future. To achieve this, we rely on alliances and the implementation of joint projects with various partners, such as suppliers, plant manufacturers, the recycling sector and universities.

Our Contribution to a Circular Economy

As part of Group initiative 6, we pursue several lines of action in the area of circular economy. These include, for example, increased use of circular materials, secondary materials and renewable raw materials in our vehicles. In addition, we are working intensively on business models that simplify the recovery of raw materials from our products. For example, we are testing the dismantling of scrap vehicles, which returns valuable materials to circulation, or recycling precious metals from used catalytic converters and diesel particulate filters. Another approach is to preserve recyclable materials through reuse and repurposing – for example, in the recycling of high-voltage vehicle batteries in the pilot facility in Salzgitter.

The topic of circular economy is also a core element of the goTOzero Group environmental mission statement, on which we orient the strategic design of this action area. This mission statement sets the Volkswagen Group targets including, for example, further improving its resource efficiency and promoting reuse and recycling approaches in the areas of materials, energy and water. Other topics that contribute to a circular economy are embedded in the Zero Impact Factory program. It is guided by the vision of creating a factory that has no adverse environmental impact. The Volkswagen Group's environmental standards and policies specify the requirements for the development of our vehicles and their components. One specific example is the vehicle environmental standards, which now also includes guidelines on the topic of "recycling-friendly product development for plastic components."

→ Environmental Compliance Management

With a circular way of doing business in mind, we aim to minimize our consumption of resources, to live up to extended producer responsibility and to reduce energy consumption. The vehicles already have a long service life: The average age of an end-of-life vehicle is 14 to 20 years according to national authorities in Europe. For the first steps regarding circular economy, we have concentrated on the aspects of

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batteries, steel, aluminum and plastics. The results obtained from this are used to further develop the overall circular economy strategy and for devising new business models. In geopolitically difficult times, the topic of circular economy is also about strengthening the Group's resilience and minimizing dependencies. We will achieve this in particular by closing our own material loops.

Our approach to waste disposal in production aims to reduce the quantity of waste we produce and to reuse unavoidable waste to create high-quality materials – i.e., to close loops. The focus is on:

- Avoiding waste creation by optimizing production and auxiliary processes and increasing material utilization levels (material efficiency)
- Prioritizing the reuse of waste and reducing the quantity of waste that needs to be disposed of

In order to optimize our management of waste, we are increasingly using digital waste management systems. They make it easier to control waste management processes and facilitate state control of the disposal of hazardous waste.

In order to monitor waste management and recycling processes, regular cross-site, cross-brand and cross-company waste disposal audits take place in Germany and the rest of Europe. In this way, we determine whether waste disposal service providers are disposing of the waste in accordance with their contractual and legal obligations. In addition, there are regular discussions between the auditors. The aim is to ensure that they have a common understanding of the quality requirements associated with waste disposal services, to carry out audits of consistently high quality and to allow other original equipment manufacturers and suppliers to take advantage of the findings.

In addition to waste, another focus is on the resource of water. You can find further information in the Environmental Compliance Management chapter.

→ Environmental Compliance Management

Measures along the Entire Life Cycle

The most important measures that we want to take to implement the circular-economy strategy include further clarifying targets and indicators and also realizing circular business models. This applies to the most important components and materials, such as batteries, steel, aluminum or plastics. In addition to the existing KPIs (DCI, reduction of the environmental impact of production), the Board of Management adopted a KPI set for the topic of circular economy in the reporting year. It includes a description of the use of circular materials at vehicle level and a breakdown by different vehicle projects. The KPI set will also be used in battery production and show the progress in this area. The KPIs will be reported in the future.

To make our contribution to a circular way of doing business, we are stepping up efforts to use material loops in our production processes. When selecting raw materials, we opt for recycled ones obtained from production waste (pre-consumer recycled materials) or end-of-life products (post-consumer recycled materials). In addition, when developing new vehicles, we pay attention to the recyclability of the required materials and avoiding pollutants. Under the current European Directive on end-of-life vehicles, passenger cars and light commercial vehicles must be 85% recyclable and 95% recoverable at end of life. All our vehicles registered in Europe comply with these standards.

Our Procurement Division has established a Group-wide system for recovering waste materials that can generate income – for example, paper, plastics, wood, electronic components or metal. Under the umbrella of the Zero Impact Factory initiative, we are intensifying our efforts to avoid plastic waste with the Zero Plastic Waste project. This includes the project for recycling plastic waste in diesel tank production, which is described below.

Vehicle Development Measures

As also set out in the Group standard on the topic of recycling, we include the circularity of our vehicles in our thinking as early as the development stage. For example, all fluids can later be removed from the end-of-life vehicle and parts to be removed are disassembled. Other measures include:

- The use of recycled materials is prioritized for many components if they meet the same quality standards as the primary materials and are available in sufficient quantity over the service life.

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- All components made of plastic are labeled in accordance with international ISO standards so as to be able to later identify them and separate them by type.
- The vehicle environmental standard includes design recommendations that enable materials to be better separated from each other after the end of the vehicle's life.

Use of Renewable Raw Materials

To reduce our resource consumption, we rely on raw materials from renewable sources when manufacturing our vehicles. Wherever possible, our Group brands use, for example, the natural fibers flax, cotton, wood and cellulose. Such materials can be used if they comply with all the technical requirements and perform better than conventional materials over the life cycle. In addition, our sustainability standards apply to our suppliers. More information can be found in the Supply Chain and Human Rights chapter and in the Responsible Raw Materials Report.

→ Supply Chain and Human Rights

→ www.volkswagen-group.com > Responsible Raw Materials Report

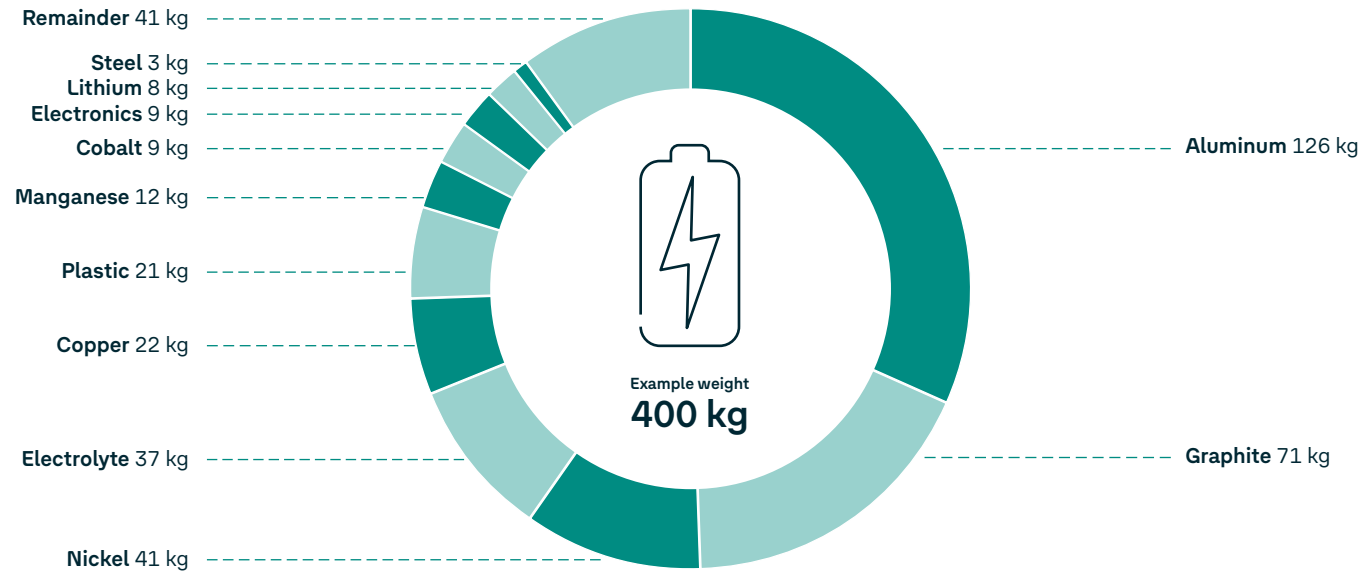
Use of Recycled Materials in Vehicles

Using the highest possible proportion of recycled materials is very important for us. The Volkswagen Group's environmental standards also state that recycled materials or materials with a recycled content should be used preferentially in place of other materials where technically possible. In the ID. family, headliners, fabrics, carpets, seats, door trim panels and decorative inlays, for example, are made from recycled materials. Some of the seat textiles for all lines are made of up to 100% recycled PET – which was frequently previously PET bottles. In the Golf 8, 28% of the textiles and 6% of the thermoplastics are made from recycled materials.

In-House Expertise in Battery Recycling

Electric drives are an important step toward low-emission mobility and thus help to protect the climate. At the same time, their production results in different components entering circulation than in the production of conventional vehicles – for example, high-voltage batteries. The raw materials these contain are valuable and it is important for them to remain in circulation for many reasons. For example, the mining and use of these raw materials is associated with emissions and other adverse environmental impacts. If we use battery raw materials multiple times instead, this significantly reduces these impacts and helps us to reduce our carbon footprint. Moreover, making use of materials multiple times also helps to save costs. Volkswagen AG is already working on a recycling concept for batteries. In addition, Volkswagen AG is exploring strategic partnerships with numerous players in the battery value chain to comprehensively close the loop for the Group.

Making New from Old – This Is How Many Valuable Materials a High-Voltage Battery Contains



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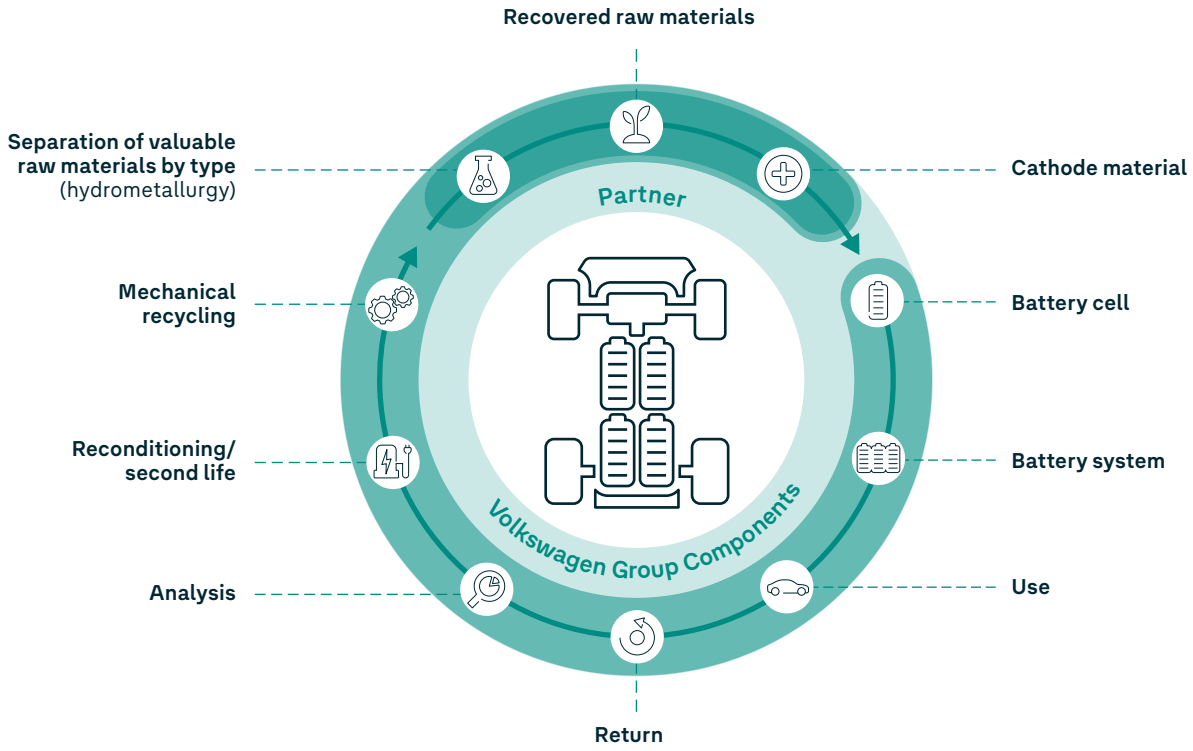
Volkswagen AG opened the Group's first pilot facility for recycling high-voltage vehicle batteries at the Salzgitter site at the start of 2021. The objective is industrialized recovery of valuable raw materials such as lithium, nickel, manganese and cobalt in a closed loop and also of aluminum, copper and plastic. Moreover, in connection with this we develop various concepts for discharging and dismantling batteries and carry out investigations into the further recyclability of battery materials. Batteries are only recycled in the pilot facility if they can no longer be used in other ways – for example, in reconditioned form in mobile energy storage systems such as flexible fast-charging stations or charging robots. The facility has been initially designed to recycle up to 3,600 battery systems per year in pilot operation.

The innovative and CO_2-saving recycling process does not require energy-intensive melting in a blast furnace. The used battery systems are delivered, deep discharged, and dismantled. The individual parts are ground into granules in the shredder and then dried. In addition to aluminum, copper and plastics, the process mainly yields valuable "black powder" containing lithium, nickel, manganese, cobalt and graphite, which are important raw materials for batteries. The separation and processing of the individual substances by hydrometallurgical processes – using water and chemical agents – is subsequently carried out by specialized partners. As a consequence, essential components of old battery cells can be used to produce new cathode material. The material recovered can be used to support battery cell production at Volkswagen in the future.

After Use Is before Use – The Loop for Battery Raw Materials



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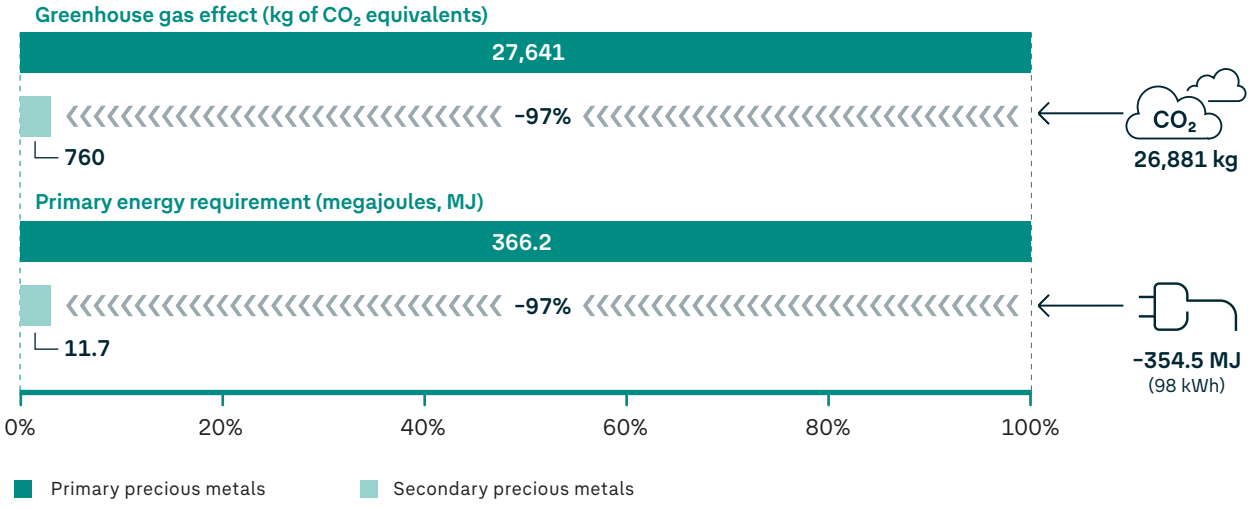
Remanufacturing of Tools
In 2023, 77,090 tools were processed at the center of excellence for tools at the Salzgitter site to make them suitable to return to use. This means that the production tools at Volkswagen are reconditioned.

Remanufacturing of Vehicle Parts
Our focus on high quality with a low need for repair is aimed at ensuring a long service life for our vehicles during the use phase and is therefore an important contribution to resource efficiency. Should a part fail, Group After Sales and its brands offer the opportunity to participate in the Exchange Parts program for selected products. A central component of the exchange program is the return of so-called used parts from participating importers and national companies with the aim of industrial remanufacturing and possible reuse in other Group vehicles. Used parts that cannot be remanufactured immediately are replaced with a brand-new part.

Recycling of Precious Metals from Used Catalytic Converters and Particulate Filters
As part of the Exchange Parts program, used catalytic converters and particulate filters are taken back in order to recover the precious metals platinum, palladium and rhodium they contain through defined processes. In addition, catalytic converters from engine test benches and production batches flow into the recycling process and are then available to the company as secondary material, thus closing material cycles and reducing the environmental impact compared to primary material.

The environmental impact of secondary precious metals was evaluated in a life cycle assessment carried out by the Fraunhofer Institute IST on a pilot plant. As a result, a reduction in primary energy requirements and a reduction in greenhouse gas emissions of around 97% compared to primary raw materials can be achieved through recovery. This could result in a reduction in greenhouse gas emissions (electrical energy based on Sphera database electricity mix 2021) of almost 27 tons per kilogram of secondary precious metal compared to primary precious metals. The life cycle assessment was externally audited by TÜV Nord in accordance with ISO 14040.

Environmental Impact of Recycling Precious Metals



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Sustainable Parts at Audi: Sustainable Alternatives to the Genuine Part

Audi aims to position itself as a sustainable premium brand. To this end, the Group has also repositioned itself in after sales in order to be able to offer its customers sustainable solutions when a repair is needed. Thus, in addition to the spare parts and parts repair, which customers are already aware of, in the future used parts will also be available to customers. Used vehicles are dismantled in Ingolstadt for this purpose. The high-quality used replacement parts represent a low-CO_2 and inexpensive alternative to new parts and are used in vehicles aged five years or more. The replacement part portfolio includes body and paintwork repair parts such as lights, fenders and doors but also complete engines and transmissions – always with a two-year guarantee. Audi original used parts ("sustainable parts") will gradually be available in EU markets from 2024.

Aluminum Closed Loop

A closed loop for aluminum was achieved for the first time beyond Company boundaries in the Audi Neckarsulm plant in 2017 with the Aluminum Closed Loop Project. The waste from aluminum sheet-metal parts from the press shop is delivered directly back to the suppliers, who can recycle the scrap and use it to produce new material that Audi then uses again in the press shop. Compared with using primary aluminum, recycling aluminum waste can save up to 95% of the energy used in manufacturing. In this way, Audi avoids CO_2 emissions and reduces the quantity of primary raw materials needed. In addition to the plant in Neckarsulm, the Audi plants in Ingolstadt and Győr and the multi-brand plant in Bratislava have now also joined the Aluminum Closed Loop process. The process itself and the resultant net CO_2 savings of more than 850,000 metric tons of CO_2 since 2017 have been verified by independent third parties.

→ **More than**

850,000 metric tons of CO_2

have been saved in net terms since 2017 through the Aluminum Closed Loop

Recycling Production Waste

Waste with recyclable content generated in production is also being increasingly systematically included in our closed-loop processes. For example, in the Volkswagen Group Components foundry, all aluminum chips generated at the Kassel site are returned to the casting process. Around 20 metric tons of aluminum chips are produced here each day and melted down in the plant. According to forecasts, this alternative to regular aluminum production reduces the energy requirements by around 3,250 MWh per year and reduces CO_2 emissions by more than 1,400 metric tons per year. Once the technical preparations for retrofitting have been completed, the foundry wants to melt down a further 40 metric tons of material from other European Volkswagen plants per day. In the long term, the quantity is set to rise to up to 80 metric tons of chips per day. It is currently around 200 metric tons per month. Copper from the site operated by Volkswagen Group Components in Salzgitter was also melted down in the foundry in September 2023.

At the Volkswagen plant in Wolfsburg, plastic waste produced in the process of manufacturing gasoline tanks (co-extrusion) is prepared and used again for the production of diesel tanks (mono-extrusion). As a result, around 1,600 metric tons of material that would otherwise be disposed of can be used in plastic tanks in this way each year. This can save the plant 2,500 metric tons of CO_2 and €2 million in costs of materials each year.

Research and Development

The Volkswagen Group is actively involved in publicly funded research projects on recycling technologies to optimize the recycling processes even further. These research projects are carried out in collaboration with partners, universities and research institutions throughout Germany and aim to improve and automate individual process steps. This relates, for example, to dismantling batteries or recycling raw materials multiple times.

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One example of this is the research consortium HVBatCycle. The consortium, which was created in 2023, is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and is set to operate for three years. Under the leadership of the Volkswagen Group, the research team wants to prove that the most valuable components of traction batteries can be recovered and reused several times in succession through recycling. The aim is to permanently recover valuable materials in this way, thus contributing to more sustainability and greater security of supply. In addition to Volkswagen, the consortium comprises TANIOBIS GmbH, J. Schmalz GmbH, Viscom AG and researchers from RWTH Aachen University, TU Braunschweig and the Fraunhofer Institute for Surface Engineering and Thin Films.

Open Hybrid LabFactory

The Open Hybrid LabFactory (OHLF) has also dedicated itself to the research of automotive material loops. Funded by the German Federal Ministry of Education and Research (BMBF), the research campus provides a platform for dialog between science and industry in order to accelerate research activities and their implementation in mass production. The OHLF's work is divided into four fields of research: design for circular economy, processes for reverse production, circular material concepts and overall system analyses and design. Experience shows that collaboration between industry and science – including from the areas of design, production technology, materials science and sustainability – provides ideal conditions for developing circular economy solutions.

Circular Economy KPI	Unit	2023	2022	Notes and comments
CO_2 avoided since 2017 through the Aluminum Closed Loop Project	in metric tons of CO_2	854,005	633,881	