

The new Audi TT Coupé

Life Cycle Assessment



Vorsprung durch Technik **Audi** 



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Foreword

Dear readers,

mobility has always been associated with having an impact on the environment. However, legislators and customers tend to focus solely on the emissions that are measured at the car's exhaust pipe. Yet this is far from adequate if we want to take a long-term view. Audi therefore examines the entire chain of products and processes that constitute mobility. We want to set positive examples for the responsible use of finite resources. Our goal is to reduce the environmental impact of each model compared with its predecessor. We therefore prepare detailed life cycle assessments for every new model series.

In this way, Audi is able to demonstrate how a vehicle's effects on the environment have changed as compared with the previous model when assessed over the vehicle's entire life cycle, from production through use all the way to recycling.

Certified life cycle assessments of this kind are 'hard currency', because they reveal the size of the 'CO₂ backpack' that the vehicle has to carry when it leaves the factory and takes to the road – as well as how efficient the car is. Because of the holistic perspective taken, there are many factors that influence the results of the life cycle assessment. The greatest influence on combustion engine vehicles, like the Audi TT Coupé, has the use phase. There occur about 80 percent of total emissions. Audi is therefore devoting massive effort to increasing the efficiency of all its vehicle drivetrains. The TDI and TFSI engines, and the efficiency modules still offer great potential in this respect. In addition, we are introducing alternative drivetrains for road vehicles and playing a leading role in the development of alternative fuels.

We also regard the overall topic of environmentally acceptable lightweight construction as one of our most important tasks for the future. True to the motto: “the right quantity of the right material in the right place for optimum functions”, we pursue our goal to make every new model lighter than its predecessor. This means pioneering lightweight construction concepts both for existing drivetrain concepts using combustion engines and new forms of propulsion for electromobility. We are conscious of the fact that we can only adopt new technologies and materials in series production if their environmental characteristics also satisfy our high standards.

The life cycle assessment for the current Audi A6 and the current Audi A3 have confirmed that Audi is on the right track. We have now succeeded in considerably reducing the new Audi TT Coupé’s total emissions as well. The proof is to be found on the following pages.

Prof. Dr.-Ing. Ulrich Hackenberg
Member of the Board of Management of AUDI AG
Technical Development



Life cycle assessment – what’s involved

The life cycle assessment analyses the effects of a product on the environment during its entire existence, from production through its period of use and its end-of-life recycling. It is a quantitative evaluation of ecological aspects such as the emission of greenhouse gases (including carbon dioxide [CO₂]), energy consumption and acidification or ‘summer smog’. Audi compiles its life cycle assessments according to the procedure laid down in the international ISO 14040 series of standards.

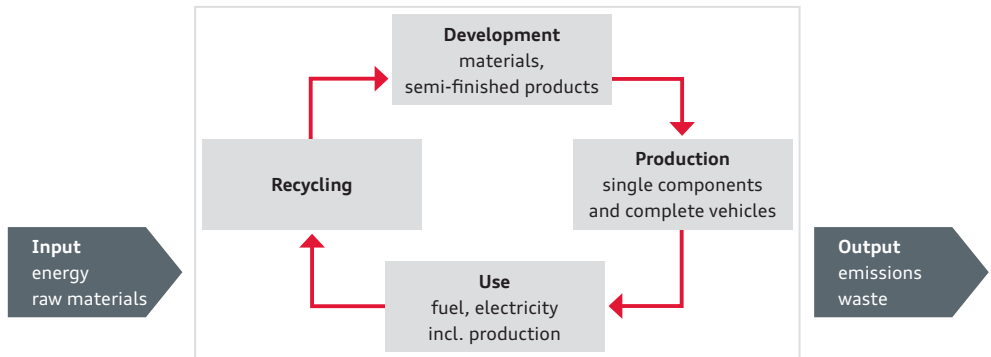
Life cycle assessment of vehicles as a major contribution to more sustainable treatment of the environment



Dimensions of assessment:

- ▶ **Development phase:** materials and semi-finished product manufacturing chains
- ▶ **Production phase:** components and complete vehicles
- ▶ **Use phase:** fuel/ electricity (including production)
- ▶ **Recycling phase:** process chains to recover valuable materials

Stages in motor vehicle life cycle assessment



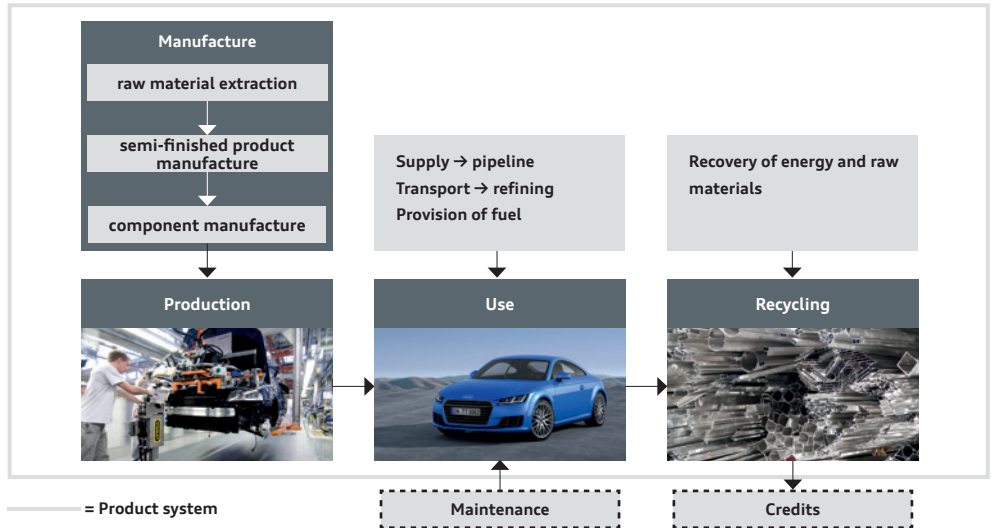
Life cycle assessment – the boundaries

Before a life cycle assessment is compiled, its boundaries must be defined by deciding which processes should be examined. The available means, the time framework and data availability all have to be taken into account. Audi has laid down broad limits for its complete vehicle life cycle assessments.

The examination starts with the manner in which raw materials are obtained, and how individual components are manufactured. Even during the first new model development stages, the engineering teams have to make decisions that have a major impact on in-house production and the entire supply chain.

Audi's experts assume for assessment purposes that vehicles will cover a distance of 200,000 kilometres. They not only take into account the emissions caused when the vehicle is being driven, but also those that occur when the fuel is produced. At the end of the vehicle's life cycle, the energy needed for recycling is also included in the assessment.

System boundaries of total vehicle LCA

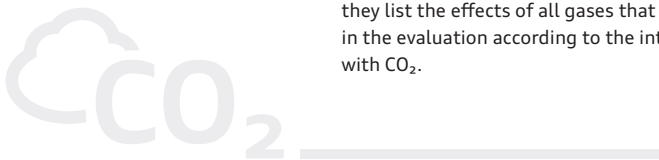


Life cycle assessment – effect categories

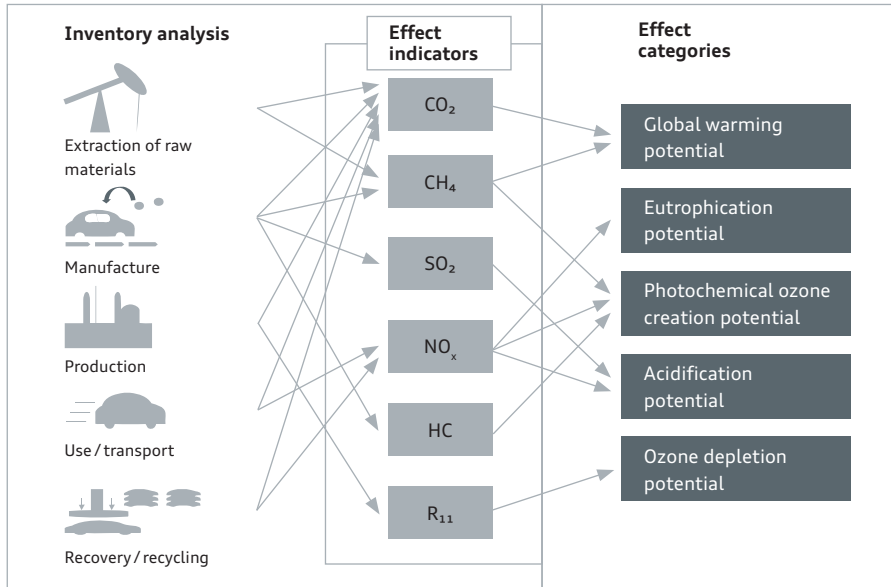
The main emphasis in life cycle assessments is currently the evaluation of greenhouse gases. But Audi is also carefully monitoring other environmental effects as well: eutrophication of water and soil, creation of summer smog, acidification of eco-systems and the damage to the ozone layer.

In accordance with the procedure laid down in the ISO 14040 standard, the results from data collection (inventory analysis) are converted into effect indicators, which are then grouped together in effect categories.

The effect categories describe the major ecological problem areas. When Audi's specialists assess the greenhouse effect as an important indicator, they list the effects of all gases that affect the climate. These are included in the evaluation according to the intensity of their effect as compared with CO₂.



Effect of substances on the environment



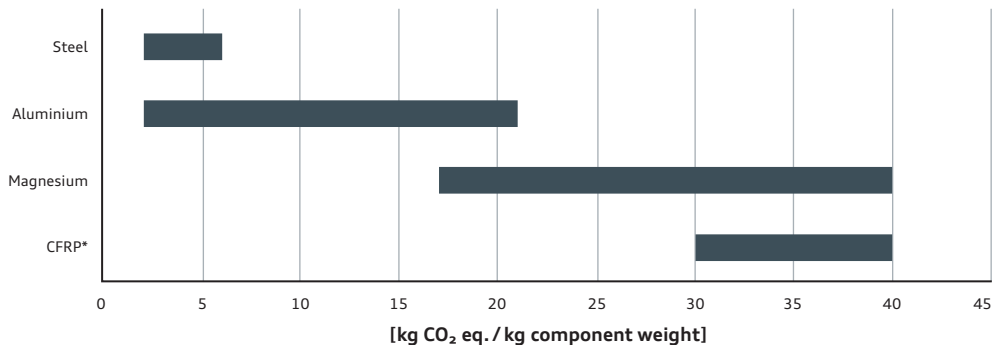
Lightweight construction – choice of materials

The choice of materials has a decisive effect on the CO₂ emissions that occur in component manufacturing. The range is wide, in view of the many different manufacturing and recycling methods involved. Due to the production process and the nature of the energy source, primary aluminium gives rise to higher emissions than occur in the production of primary steel. If on the other hand recycled aluminium can be used, the effort and expense are at a lower level, comparable with recycled steel. At Audi the recycling process starts in the production phase, when trimmings from the presses are collected and returned for recovery.



Production recycling makes a significant reduction in CO₂ emissions possible.

Greenhouse gas emissions for various materials



■ = Process-dependent scatter

*Carbon fibre reinforced polymer

- ▶ The scatter bandwidths for the various materials result from the different manufacturing and recycling processes that can be used.

Lightweight construction – component concepts

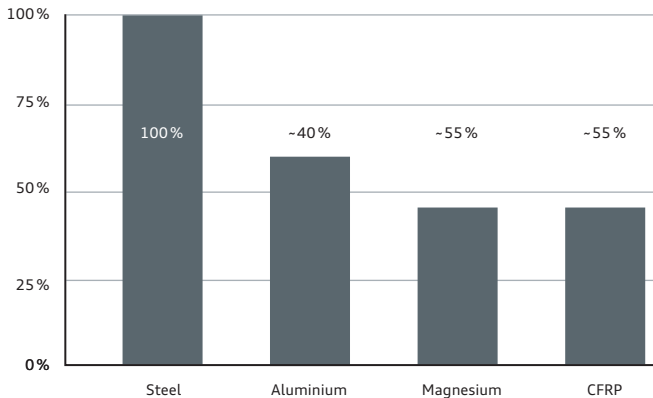
If a vehicle's use phase is considered in isolation, then lightweight materials are extremely attractive. The chart shows the potential weight saving for components with identical functions if a modern lightweight material is used instead of conventional steel.

Aluminium is about two-thirds lighter than steel, but metal of slightly heavier gauge has to be used for a vehicle body. An aluminium body built according to the Audi Space Frame (ASF) principle weighs about 40 percent less than a comparable steel body.

Magnesium is about a third lighter than aluminium. At the moment it is mainly used in the form of castings.

Carbon fibre reinforced polymer (CFRP) – a composite material containing about 50 percent woven carbon fibre in a resin matrix – is even lighter than magnesium, but offers a similar overall weight saving. Its production is still extremely intensive in terms of energy consumption.

Lightweight potential of components (identical functions)



Weight-saving potential, depending on material and manufacturing processes (compared with steel):

- ~40 % for aluminium
- ~55 % for magnesium
- ~55 % for CFRP

Audi TT Coupé – the life cycle assessment



Audi has compiled a detailed life cycle assessment for the new Audi TT Coupé. The bestselling model of the previous model series, the Audi TT Coupé 2.0 TFSI quattro 155 kW S tronic, was compared with its counterpart in the new model series, the Audi TT Coupé 2.0 TFSI quattro 169 kW S tronic.

Thanks to an intelligent choice of materials and enhanced lightweight construction measures, the new model is 45 kg lighter than its predecessor.

What effect the changes in weight – and also in the material mix and engine efficiency – have on the life cycle assessment is described and explained in more detail on the following pages.

* Fuel consumption acc. to NEFZ test cycle:

Audi TT Coupé 2.0 TFSI quattro 155 kW S tronic (MY 2014): fuel consumption: urban: 9,9 l/100km; country: 5,7 l/100km; combined: 7,2 l/100km; CO₂ emissions combined: 169 g/km; energy efficiency category E

Audi TT Coupé 2.0 TFSI quattro 169 kW S tronic (MY 2015): fuel consumption: urban: 8,4 – 8,3 l/100km; country: 5,5 – 5,4 l/100km; combined: 6,5 – 6,4 l/100km; CO₂ emissions combined: 151-149 g/km; energy efficiency category D



Audi TT Coupé – the body

Lightweight construction is one of Audi's greatest areas of expertise. Even the second-generation Audi TT featured an Audi Space Frame body (ASF) made of aluminium and steel. Audi consistently developed this principle for the new Audi TT – along the lines of “the right quantity of the right material in the right place for optimum functions”.

The Coupé's underbody structure has optimised axle loads and is made of modern, high-strength and ultra high-strength steel alloys. In sections of the passenger cell that are subject to high structural stress, form-hardened steel panels are used that are ultra strong and at the same time light – these constitute 17 % of the body's weight. The side sills and roof frame are made of extruded aluminium profiles, which are integrated into the structure using cast aluminium nodes. This construction principle creates a very rigid and safe bodyshell. The aluminium side sections and roof complete the structure. The bonnet, doors and tailgate are also made of this light metal.

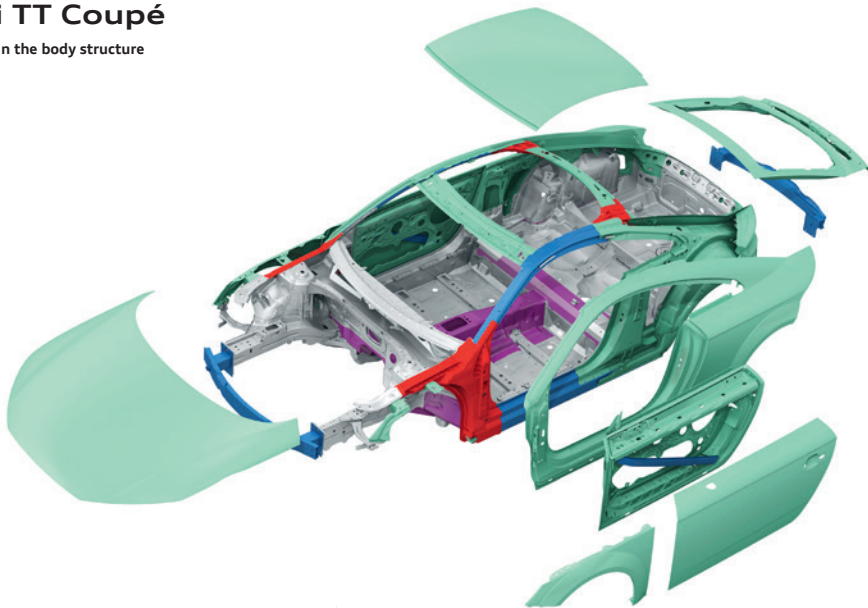
All in all, Audi engineers have succeeded in significantly reducing the unladen weight of the TT for the second time in a row. For the first model change in 2006, up to 90 kilograms were saved, while the new TT featuring the 2.0 TFSI engine weighs just 1230 kilograms. That makes it around 50 kilograms lighter than its predecessor.


The low overall weight is proof of Audi's expertise in lightweight design. This has a particularly positive effect on acceleration, handling, consumption and, last but not least, on the life cycle assessment.

Audi TT Coupé

Materials in the body structure

03/14



 Ultra-high strength steels (hot-formed)

 Conventional steels

 Aluminium section

 Aluminium sheet

 Aluminium castings

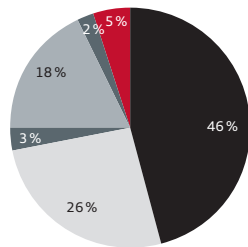
Audi TT Coupé – the materials

The materials that are used have a major influence on the results of the life cycle assessment. For example, more energy is consumed when producing light metals such as aluminum and magnesium than for steel; this has the effect of increasing greenhouse gas emissions during their production phase.

The inventory of materials was determined for the models under examination and summarized according to VDA classification 231-106.

The material composition of the Audi TT Coupé's predecessor model is shown in the diagram opposite. Steel and iron materials account for the largest proportion here, almost 50 per cent of the vehicle's total weight. Light metals, primarily aluminium, make up the second largest proportion, at 26%. This relatively high percentage of light metals illustrates the use of ASF technology, as already mentioned.

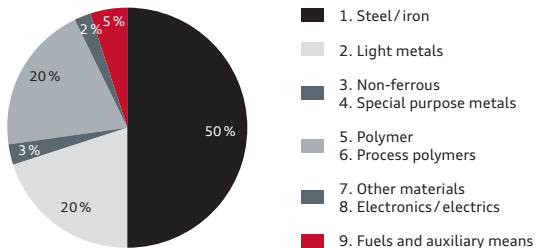
**Audi TT Coupé 2.0 TFSI quattro
(MY 2014)**



In comparison, a distinct change can be seen in the case of the Audi TT Coupé 2.0 TFSI quattro 169 kW S tronic (MY2015). Replacing aluminium with steel in the body has reduced the percentage of light metals by 6 %. The percentage of steel and iron materials has increased accordingly by 4 %. The remaining 2 % has been replaced by polymer.

This illustration clearly shows the change in body materials described above.

Audi TT Coupé 2.0 TFSI quattro (MY 2015)



Audi TT Coupé – the results of the life cycle assessment

Over its entire life cycle, the new Audi TT Coupé causes 5.5 fewer tonnes of greenhouse gas emissions than its predecessor, which represents a reduction of around 11 %.

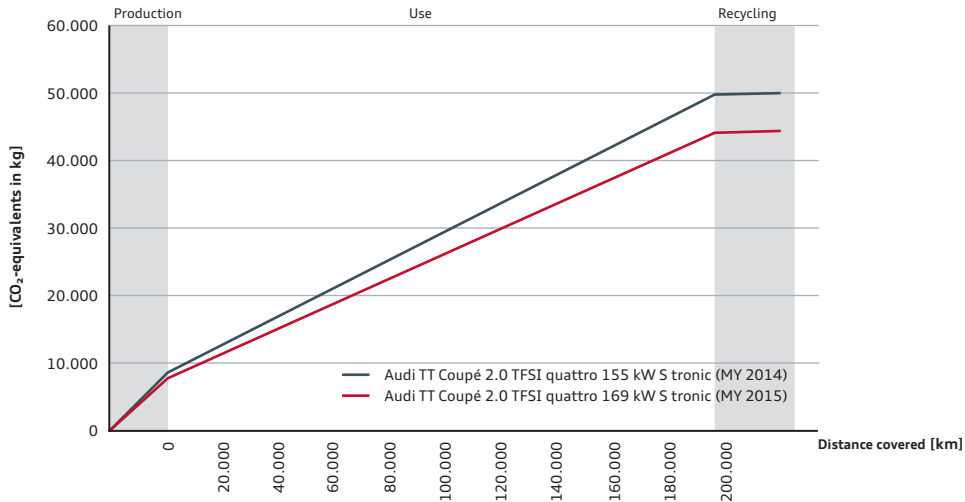
Thanks to the intelligent choice of materials and the reduction in weight, Audi engineers succeeded in lowering greenhouse gas emissions even during production – despite lightweight construction measures. The predecessor of the Audi TT Coupé generated around 8.4 tons of greenhouse gas emissions in the production phase, whereas it was possible to reduce greenhouse gas emissions during the production of the new Audi TT Coupé by around 9 % to just under 7.6 tonnes. Over its entire life cycle, the Audi TT Coupé (MY 2014) generates some 50 tonnes of greenhouse gas emissions, the Audi TT Coupé (MY2015) around 44.5 tonnes.

In other categories too, it was possible to reduce the new Audi TT Coupé's impact on the environment. For example, the acidification potential was also reduced by 11 %, eutrophication potential by 9 % and photochemical ozone (summer smog) creation potential by 5 %. Only in terms of ozone depletion potential is there an increase of 19 %, which in absolute terms is in the hundred-thousandths range. This corresponds to the volume of ozone-depleting substances generated during the production of 3 kg of PET bottles.

Reduction in almost all the assessed effect categories:

Greenhouse gas potential	-11 %
Eutrophication potential	-9 %
Ozone depletion potential	+19 %
Photochemical ozone creation potential	-5 %
Acidification potential	-11 %

Greenhouse gas emission values for the entire life cycle of the Audi TT Coupé



Greenhouse gases were reduced even in the production phase of the new Audi TT Coupé.

Conclusion

The public today tends to judge vehicles to a large extent by their fuel consumption. Here too, Audi looks one step ahead. Its life cycle assessments analyze effects on the environment for the vehicle's entire lifetime. The use of sustainable materials and manufacturing processes can greatly reduce these effects.

The life cycle assessment prepared by Audi for the new Audi TT Coupé shows that the new model has improved in almost all of the relevant environmental categories. Thanks to the intelligent choice of materials, Audi engineers have succeeded in not only reducing the weight of the vehicle even further, but also in reducing the environmental impact as early as the production phase in almost all of the categories analysed.

These results demonstrate that Audi is on the right track towards sustainable and resource-conserving mobility.



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