German Environment Agency

24. November 2025

# AutoRess Factsheet 2: Fields of action for a GHG saving and resource efficient car

## Results from the project 'Resource efficient and circular electric cars' (AutoRess) – FKZ 3722 57 101 0

**Key findings**

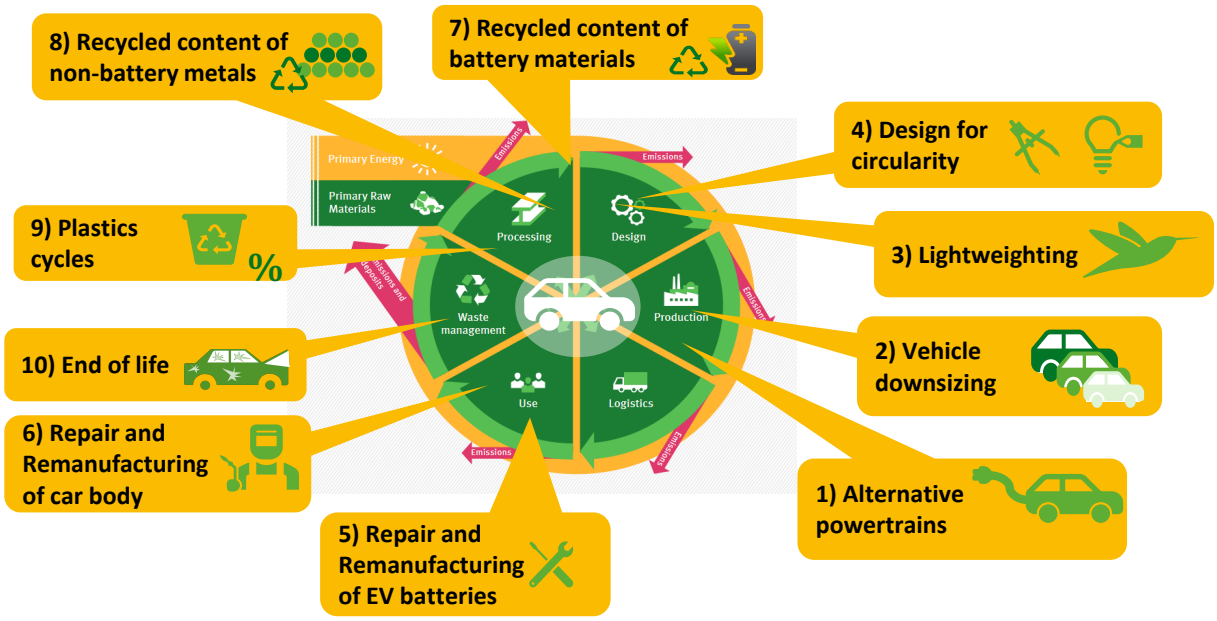
The aim of AutoRess is to derive suitable recommendations for action to reduce greenhouse gases and resource consumption of future cars over the entire life cycle. As a basis for effective measures, potentials for a wide range of technical and non-technical approaches were examined. These range from the size of new cars and batteries to longevity and better repairability, lightweight construction, the use of recycled materials in car production and increasing material recovery at the end of life.

Most approaches have significant ranges of savings potentials depending on their specific design and assumed implementation intensity. The highest GHG savings are possible through a significant reduction in overall material requirements (smaller and fewer new cars) and fewer fossil-based materials. There are also potential conflicts of interest between the reduction of selected critical materials (e. g. lithium, cobalt) and the reduction of GHG emissions. Measures for a GHG and resource saving car must therefore take such interactions into account

## 10 technical and non-technical topics were selected for in-depth analyses that can reduce greenhouse gases and material requirements throughout the vehicle's life cycle

The aim of the AutoRess project is to identify instruments which, on the one hand, reduce the consumption of primary raw materials and the associated environmental and social consequences and, on the other hand, bring additional GHG savings over the entire life cycle. To this end, technical and non-technical approaches were examined across all life cycle phases of vehicles on their effects on GHG emissions and material requirements. In a first step, key levers for reducing GHG emissions and limiting the use of raw materials along all life cycle phases of motor vehicles were identified. This systemic analysis included factors directly affecting the vehicle usage and production itself (GHG in all life-cycle stages, material requirements in vehicle production) as well as indirect influencing factors (particularly material supply in vehicle production, maintenance and vehicle disposal). A basic prioritization of the influencing factors was used as a starting point for the analysis of promising fields of action.

**Figure 1: Selected topics in AutoRess**




Source: Own figure Oeko-Institut / ifeu based on Müller et al 2020[1]

10 specific technical and non-technical topics along the car´s life cycle were defined and then analysed in depth. Each topic addresses a specific aspect of car transport that can be influenced by technological, social or political measures. The current status quo, development trends with current drivers and fields of action for additional drivers to reduce GHG emissions and material requirements were researched and discussed in expert workshops. A model of car transport in Germany was set up, including all stages of the vehicle life cycle, to derive comparable GHG and materials savings potentials up to 2045. There are various design options within the topics examined. In addition, the intensity of implementation has a decisive influence on the possible effects. For this reason, up to five variants were modelled for each topic in order to estimate the range of potential GHG and material effects.

### 1) Alternative powertrains

The electrification of passenger cars is a key lever for reducing greenhouse gas emissions in transport. With current legislation, only battery-electric passenger cars (BEV) will be newly registered in Germany from 2035 onwards. However, GHG savings in the use phase of electric cars are partly offset by additional emissions from vehicle production, particularly due to the batteries. In addition, increasing quantities of critical raw materials are needed for the batteries. Thus, this topic focuses on the impacts of battery-related key parameters:

1. Vehicle range and battery size: Based on an average 80 kWh usable battery capacity in trend, a potential increase to 100 kWh and decrease back to the 2021 size of 55 kWh are modelled.

Emerging battery technologies: In 3 variants, a potential switch to LFP, Na-ion or solid-state batteries from 2030 onwards is modelled.

[1] Müller,F.; Kohlmeyer, R.; Krüger, F.; Kosmol, J.; Krause, S.; Dorer, C.; Röhreich, M. (2020): 9 PRINCIPLES FOR A CIRCULAR ECONOMY; Umweltbundesamt; https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020_10_23_leitlinie_kreislaufwirtschaft_englisch_bf.pdf

### 2) Vehicle downsizing

In the past, there has been a clear trend towards larger and heavier cars. Future increases of vehicle sizes are expected. Downsizing towards smaller vehicles would bring clear ecological benefits both in operation and manufacture of passenger cars. Increasing vehicle sizes are driven less by technical necessities than by customer demand for comfort, features and larger vehicles. Downsizing is therefore primarily a question of purchasing behaviour. The aim of this topic is to assess the potential of a systematic shift in new registrations toward smaller vehicle segments.

Smaller vehicle segments are already available today, no fundamental technical redevelopment of new concepts is required. The potential analysis for downsizing in AutoRess focuses on a shift in the new car market towards smaller purchase segments. Two different size classes (EU mini car segment, kei cars as in Japan) and two different market shares (moderate and ambitious) are modelled.

### 3) Lightweighting

Lightweight construction is a technical option to reduce vehicle weight by using specifically lighter material compositions or through special design processes, while maintaining the vehicle size and equipment. It reduces specific GHG emissions during vehicle operation, but additional GHG emissions in vehicle production can offset or exceed these GHG savings. Furthermore, lightweight construction affects specific material requirements and can also have an impact on the recycled content in car production and on the possible recovery of materials in vehicle disposal.

In AutoRess, potentials of lightweight construction are analysed for established approaches as well as for selected prospective new drivers.

1. Conventional lightweighting: Steel components in body and chassis are replaced by aluminium
2. Gigacasting: large-format aluminium die-cast parts replace several body parts and materials
3. Cell-to-chassis design: Battery cells are integrated directly into the vehicle structure, eliminating the need for a battery housing. This can reduce battery weight by about a third, but potentially makes reuse and recycling more difficult.

Analysed variants also cover potential impacts on repairability and, thus, vehicle lifetime and on the dismantlability for reuse of batteries from decommissioned vehicles.

### 4) Design for circularity

The design of vehicles sets the fundamental basis for saving materials and greenhouse gases throughout the entire life cycle. In AutoRess, the focus was set on longevity and dismantlability.

1. The switch to electric mobility and increasing shares of renewable energies will foreseeably lead to strong GHG reductions in vehicle operation, at the same time increasing the importance of manufacturing. Increased durability of vehicles reduces the need for new vehicles and, thus, GHG emissions and material requirements in vehicle production. Upgradeability of hardware or software components enabling adaptation to new requirements allow the vehicle to meet the user's requirements for a longer time, thereby also extending its lifetime.
2. Increasing the dismantlability is a key factor for repairs during the usage phase. At the end of life, easy dismantling supports reuse of components (spare parts, second life of batteries). In addition, easy dismantling of different materials can make an important contribution to high-quality recovery of materials.

Model analyses include two variants related to an extended vehicle service life (+10% and +20%) to be introduced gradually from 2035. Two further variants model improvements in dismantlability, in particular through higher reuse and recycling rates for materials and batteries.

**5) Repair and remanufacturing of electric vehicle batteries**

The battery is one of the most expensive and environmentally relevant components of electric vehicles. Extending its service life and, consequently, the lifetime of the entire vehicle offers great potential to reduce waste, primary material requirements and related environmental impacts. In addition, functional batteries from end-of-life vehicles can be reused for other purposes, e.g. stationary energy storage. At the same time, materials from reused batteries can only be recovered for the production of new vehicles after a delay.

In order to model the effects of repair, reuse, and remanufacturing of electric vehicle batteries, the possible introduction of BEV models with high battery repairability and high reuse potential is considered. In addition, aspects such as collection rates, battery state of health (SoH), and vehicle age for end-of-life vehicles, as well as potential secondary uses in stationary storage applications, are varied in the modelling.

**6) Repair and remanufacturing of car body**

Repair and remanufacturing extend the service life of components and vehicles, reducing the need for new production and the associated environmental impacts. Unlike repair, remanufacturing describes an industrial, standardized process with high quality standards. Remanufactured units account for around half of the EU automotive aftermarket. With their functionality and warranty comparable to that of new parts, remanufactured parts could also be adopted in new vehicles.

AutoRess examines the potential impacts of foreseeable development trends on repair and remanufacturing of vehicle components. The ongoing digitalisation is adding complexity with a shift from mechanical to electro-mechanical and electronic components. With the shift to electric mobility, demand for traditional powertrain components will decline, thus, electric car specific components offer new, high-value opportunities for remanufacturers. Components that are independent of the powertrain will continue to evolve, though their design and wear patterns may change (e.g., due to regenerative braking). Based on these analyses, various shares for the recovery of spare parts in End-of-life prior to shredding are modelled, which can be reused or remanufactured, and the resulting savings potentials of materials for new components are analysed.

**7) Recycled content of battery materials**

Global demand for battery materials such as lithium, cobalt and graphite is rising sharply with the growth of electric mobility. Currently, secondary raw materials are hardly available. With the increasing availability of used batteries, recycled battery materials must make an important contribution to reducing the future demand for primary raw materials. The establishment of closed material cycles is a key challenge in this context due to globalized supply chains and the increasing importance of international trade flows involving recycled intermediate products. The take-back of end-of-life vehicles and the recycling of used batteries is also complex, as a significant proportion of vehicles leave the EU. Uncertainties regarding future battery technologies and second-life applications make it difficult to assess recycling capacity requirements.

EU Battery Regulation sets binding recycling quotas and minimum percentages for the use of secondary materials. In AutoRess, the achievability of these EU quotas and the effects of missing

them on GHG and primary material requirements are assessed. In addition, special attention was paid to effects of establishing graphite recycling on an industrial scale.

### 8) Recycled content of non-battery metals

Vehicle manufacturing is considered one of the most resource-intensive industries in Europe: it accounts for around 19 % of steel demand, 10 % of plastic consumption and a significant proportion of the demand for aluminium, copper and glass. The sector not only demands a substantial amount of raw materials, but also provides a significant flow of secondary raw materials through EoL-vehicles. Depending on the material, however, downcycling is established (e.g. steel in construction steel) and secondary materials are not fed back into the vehicle production process in a closed loop.

The aim of this topic is to systematically assess the current and future potential for secondary base metals in vehicle bodies. Different variants are analysed in terms of recycled content in new cars taking into account open-loop and closed-loop secondary metals, the latter via changes in the proportion of high-quality recycled materials from end-of-life vehicles. Discussion of potential measures take into account both technical feasibility and the risks of global displacement effects.

### 9) Plastics cycles

The proportion of plastic in a vehicle varies usually between 14 % and 18 %, but only a very small proportion of this is recycled content. The reasons for the low use of recycled materials lie in the high-quality requirements, lack of purity, and low recycling rates of end-of-life vehicles. Accordingly, greater use of recycled materials in a closed loop and better recycling of end-of-life vehicles offer great potential for conserving resources and reducing GHG emissions. Furthermore, carbon footprint of plastics can be reduced by several levers, e.g. chemical recycling, producing plastics from biomass and from captured carbon and maximising energy efficiency in production processes.

In AutoRess, a strong future increase of recycled plastics in new cars and an increase of reuse and recycling from decommissioned vehicles is modelled. Additionally, the potential of reaching GHG neutrality in the plastic sector by 2050 by using all levers is analysed.

### 10) End of Life

In the disposal of end-of-life vehicles, the legally prescribed overall recycling rate, material-specific recycling rates and their qualities as well as reducing the number of vehicles not going into regular disposal channels are particularly relevant fields of action. Important questions concern, for example, the effects of higher recovery rates for certain materials, or benefits and the effectiveness of material-specific targets for high-quality recycling. In addition, there is the question of the environmental benefits of targeted dismantling prior to shredding compared to improved post-shredding technologies. In AutoRess, three key measures are modelled:

1. Pre-shredder dismantling of components to enable reuse or higher-quality material recycling
2. Increasing material recycling of glass into new glass products
3. High-quality recycling of specific materials to enable closed-loop approaches in the car sector

## The specific design of the topics and included variations lead to a wide range of GHG & material effects

GHG and material impacts for all 10 topics were modelled and compared to a reference development without these measures. The specific design of the topics and included variations lead to a wider range of effects. This can be illustrated with selected examples.

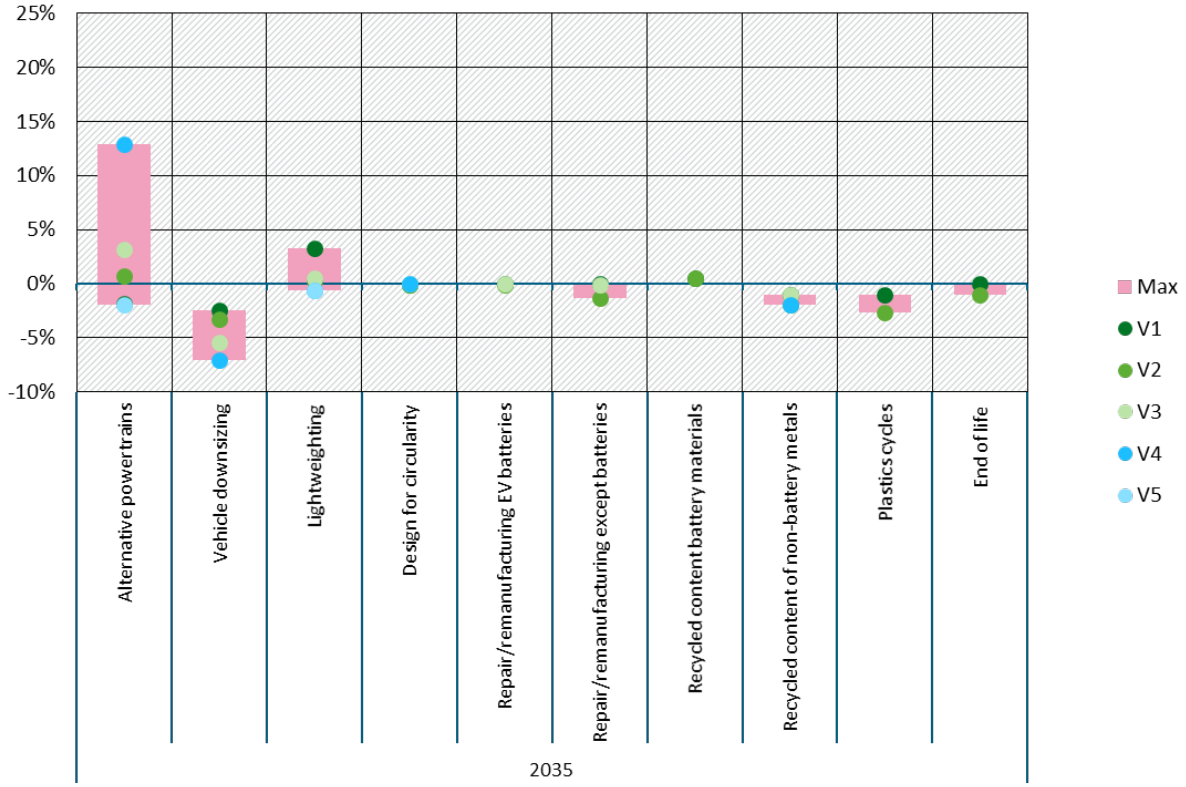
- Alternative battery technologies to save critical materials can slightly reduce, but also significantly increase GHG emissions.
- Lightweight construction increases total GHG emissions in most of the analysed variations. This is due to increased GHG emissions in car production, which are higher than the GHG savings in the use phase. Furthermore, lightweighting reduces the demand for (primary) steel. In case of a simple material exchange, the demand for the other material (e.g. aluminium) increases. However, other construction methods can lead to a reduction in overall material requirements.
- Downsizing makes cars both smaller and lighter; it reduces the material and energy demand in car manufacturing as well as during the use phase. The exact GHG savings of downsizing vary depending on the assumed reduction in vehicle sizes as well as on the new registration shares of small cars. An additional benefit of downsizing may be the reduced parking space requirements in cities.
- Upgradeable vehicle designs and better reparability have only little effect on the individual vehicle. But with extended vehicle lifetime fewer cars are produced per year and the total GHG emissions and material requirements for the new vehicle fleet could be significantly reduced.

Overall, the highest GHG savings in the topics investigated are achieved with a substantial reduction in overall material requirements (smaller and fewer new cars) and through the reduction of fossil-based vehicle materials. Primary material requirements can be reduced by reducing total material requirements or increasing the recycled content in the material used. While some topics affect the material requirements of new vehicles as a whole, other topics only have a targeted effect on selected material groups. There are also potential conflicts of interest between the reduction of selected critical materials (e. g. lithium, cobalt) and the reduction of GHG emissions. Measures for a GHG and resource saving car must therefore take such interactions into account.

A comparison of the individual topics only shows which options can have how much additional GHG impact on their own. By combining several topics, significantly greater additional GHG savings can be achieved in the long term, or increased GHG emissions associated with the saving of critical raw materials could be offset by GHG savings elsewhere.

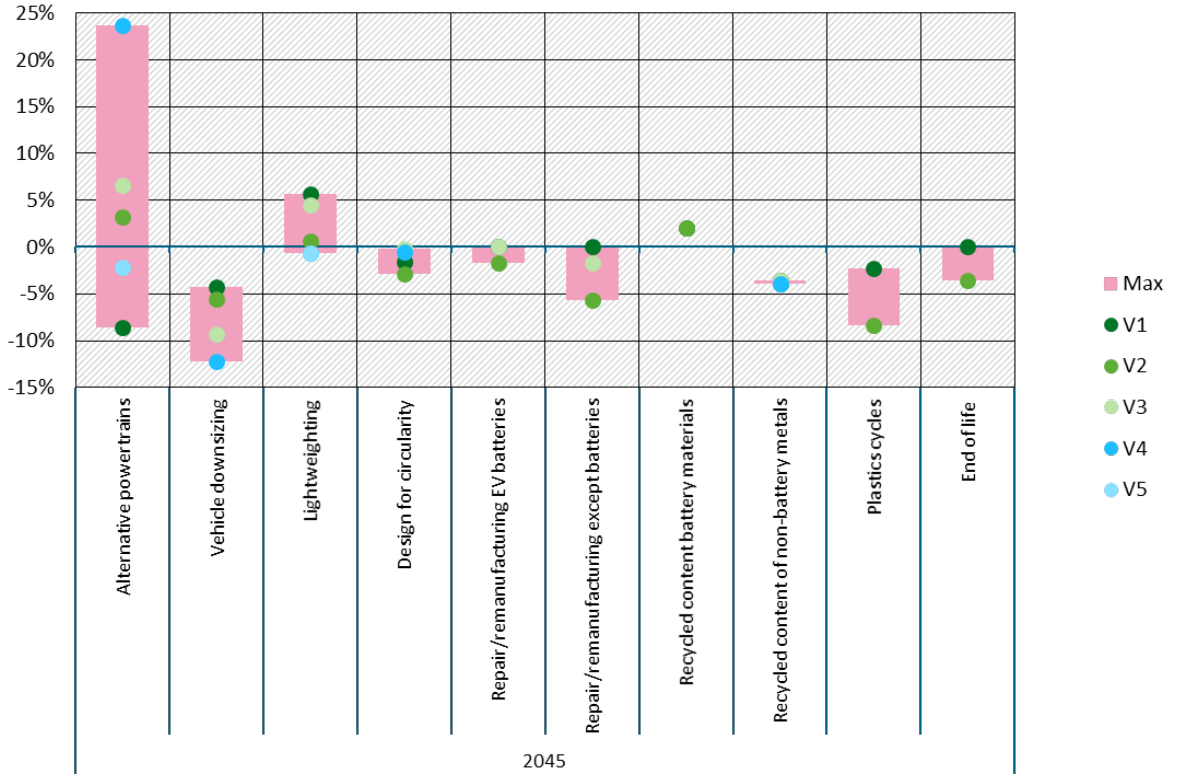

Detailed information on fields of action analysed in AutoRess and on the modelling of related GHG and material effects can be found in the final report in Chapter 3.

**Figure 2: GHG emission changes of car transport in Germany 2035 (all life stages) compared to the baseline of the respective scenario year**




Source: Own figure Oeko-Institut / ifeu

**Figure 3: GHG emission changes of car transport in Germany 2045 (all life stages) compared to the baseline of the respective scenario year**




Source: Own figure Oeko-Institut / ifeu

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