LIFE CYCLE ASSESSMENT

In accordance with ISO 14025:2006
for MAN TGX 18.470 4×2 BLS GM
from MAN Truck & Bus SE

GENERAL INFORMATION

Programme Information

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Verified on	07 November 2024	

Please Note: The content of this Life Cycle Assessment refers to an reference vehicle. All data, values etc. in this Life Cycle Assessment are typical data, values etc.. Hence, we duly make you aware that the content as well as the data, values etc. of this Life Cycle Assessment may vary regarding every concrete vehicle and its application.

COMPANY INFORMATION

Description of the organization

MAN Truck & Bus is a member of the TRATON GROUP and one of Europe's leading commercial vehicle manufacturers. MAN is currently undergoing a transformation to become a provider of environmentally friendly and more sustainable transportation and mobility solutions. The company operates manufacturing facilities in three EU countries.

Name and location of production site

This study assesses the cradle-to-grave of a MAN Diesel Truck type TGX 18.470 4×2 BLS GM in EU. The MAN in-house manufacturing steps take place at the following sites:

Figure 1: MAN truck production site overview

PRODUCT INFORMATION

Product identification and description

The MAN TGX redefines the standards in the commercial vehicle industry. Equipped with efficient and powerful engines, it offers an impressive combination of power and reliability. The ergonomically designed driver's workplace and modern equipment ensure maximum comfort, while extensive safety functions and advanced assistance systems provide outstanding safety. With the MAN TGX, you can handle your transportation tasks efficiently, safely and comfortably. The MAN TGX is an ideal truck for demanding transportation tasks. Thanks to individual design options, the vehicle adapts exactly to your needs. Innovative assistance systems help to increase safety and support the driver in his work. Thanks to its efficient drive technology, the MAN TGX impresses with low fuel consumption and high reliability, and MAN Services will get you back on the road quickly. To evaluate the environmental impacts of the MAN Diesel Truck type TGX 18.470 4×2 BLS GM, a specific vehicle configuration is determined to represent a typical selection of equipment options. The technical features of this typical vehicle are detailed in the following.

Geographical scope

The geographical scope of this LCA is EU.

Table 1: Technical description of the vehicle

Group	Concept	Value
General	Abbreviation used within this report	TGX/Truck
	Description	MAN TGX 18.470 4×2 BLS GM
	Truck Type	06K
	Denomination	06K-0084
	Model year	2022
	Max. permitted gross combination weight (national registration)*	40 t
	Gross combination weight used for consumption simulation based on VECTO (vehicle in running order+ trailer weight + payload) (8 t + 7.5 t + 19.3 t)*	34.8 t
	Calculated weight in running order (EU type approval regulation) (Vehicle mass acc.to (EU) 2021/535)*	8 t
Cabin	Cabin type	TGX  2240 mm  2280 mm
Engine	Denomination/Engine type	D2676 LFAI 
	Fuel/Energy	Diesel
	Nominal power/torque	346 kW (470 hp)/2400 Nm
	Emissions compliance	Euro 6e
Gearbox	Type	MAN TipMatic 12 TX 2620 TD (D2X)
Axles	Axles	2
	Axle configuration	4 × 2 (Front axle with independent wheel steering)
	Suspension type, front/rear	BL: leaf/air
	Tyres	Front axle: 315/70R22.5 Rear axle: 315w70R22.5
Air conditioning	Cabin air conditioning type	Climatronic, Diesel auxiliary air-conditioning system (electrically operated)

TGX-Trucknology Generation class X, heavy weight class vehicle of the new vehicle generation with extra wide cabin. BLS-Brake light switch/GM-Sleeper cab (cab type with sleeping provision).

* rounded values, different interpretations are possible within the vehicle specifications, which may lead to different results.

LCA INFORMATION

Functional unit and reference flow

The function of the truck is to transport goods over long-haul distances and within regional areas.

The chosen functional unit to quantify the environmental impact is defined as the transport of an typical payload of 11 tonnes over a distance of 1,300,000 km, considering representative operating cycles and covering the complete life cycle of one vehicle.

Time representativeness

Primary data is collected for the years 2021. The utilized LCA for Experts databases edition CUP 2022.2 have reference year 2018 or 2020 (depending on the dataset) and this data is valid until 2024.

Database(s) and LCA software used

The life cycle assessment of the vehicle is carried out by modelling in LCA for Experts software. Secondary data is selected from VW LEAD[1] Database 2022.2, which is based on Sphera's LCA for Experts databases edition CUP 2022.2 (LCA_for_Experts.com).

Allocation

The CO_2 emissions of some locations that are not purely lorry or bus locations are allocated proportionately to the lorries and finally to the tractor unit in accordance with a unit and mass weighting of the commercial vehicles produced. The same weighting method is used to allocate the greenhouse gas emissions generated by transport (incoming freight and distribution for lorries and buses). In LCA for Experts instead of Gabi, the allocations described in the associated documentation are applied.

1 LEAD database is the Volkswagen Group internal database composed of GaBi datasets and Volkswagen Group internally developed models (e. g. battery cell production, tire production)

System boundaries

The following figure depicts the system boundary of this assessment and provides an overview over the included single life cycle stages. The life cycle stages are summarized into three models. The life cycle assessment considers the impacts over the whole life cycle of the assessed product system from raw material aggregation to end-of-life and therefore represents a cradle-to-grave perspective.

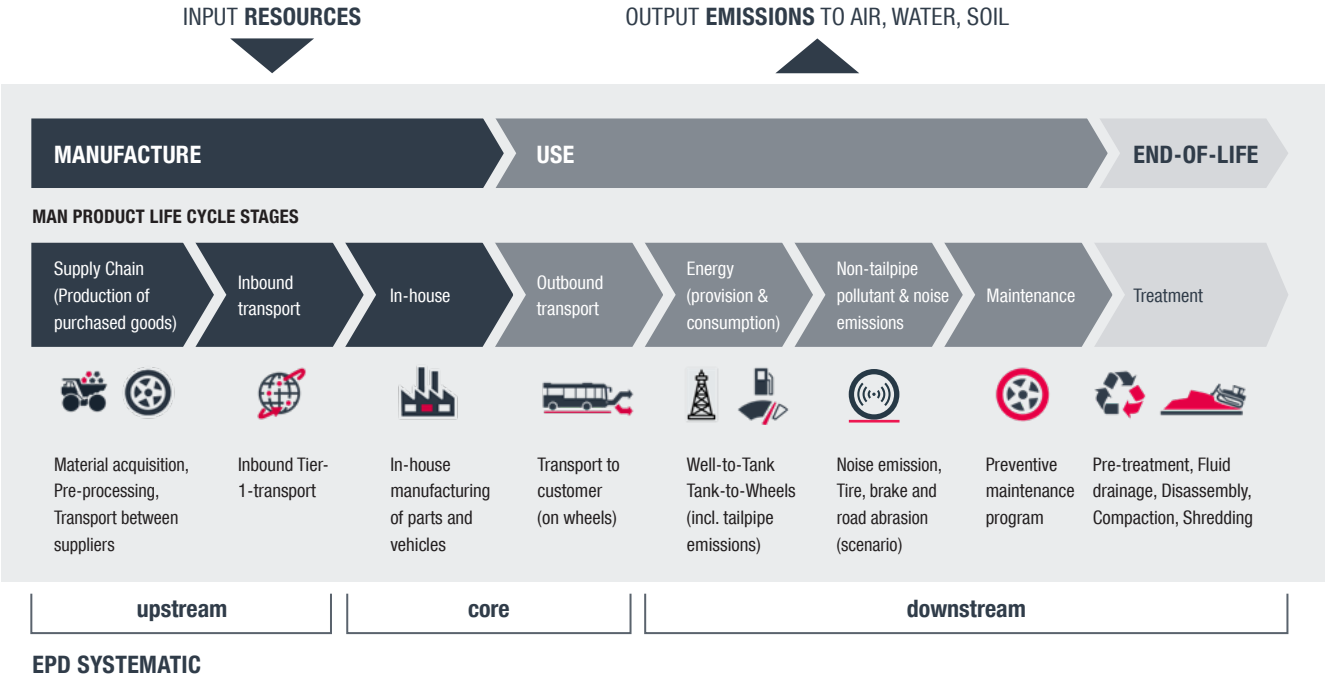


Figure 2: System boundary

Upstream module

For the **supply chain model**, material data is aggregated in 2021. The year 2021 is a representative year in terms of operations. Year 2022 was not as representative due to two significant factors: supply chain issues and the Ukraine crisis. VW group internal datasets, as well as external LCA for Experts database datasets are assigned to the incorporated materials. All serial production **inbound logistics** processes relevant for truck production are included based on existing corporate logistics information and assigned to this specific vehicle via a top-down approach based on a mass criterion. Inbound transport from direct suppliers of MAN is included in this assessment.

Core module

The **In-house production model** is based on environmental management data from 2021 (energy, water, process gas, waste, wastewater, emissions to air), as well as additional paint shop specific data for 2020. The information is allocated to the relevant components and truck production via a top-down approach based on a mass criterion. The transport of the produced vehicles to customers is made on autotransporter, particularly in EU, which is the scope of this LCA. Therefore, the **outbound logistic** is modelled designed as truck transport similar to the inbound logistics model.

Downstream module

The **use stage model** includes energy consumption, tailpipe emissions and preventive maintenance parts. A simulation approach is chosen to determine the energy consumption values by an MAN in-house simulation tool. During the lifetime, parts like tyres, starter batteries, brake pads, engine oils, gearbox- and axle oils, different filters, etc. are changed as part of the maintenance. Maintenance changes with different customer operations and may vary widely, and not all parts are environmentally significant from a vehicle life cycle perspective. To not provide irrelevant assumptions and due to insignificant environmental impact, decision is taken to only include specific maintenance parts in the maintenance phase.

The **end-of-life model** follows the ISO 22826:2002 requirements. A cut-off approach is defined and credits as well as burdens from energy or material recovery are excluded.

Limitations

Comparability - It is important to bear in mind that product LCAs for vehicles are complex calculations that require many specific methodological as well as data related decisions by the practitioner, which affect the impact assessment results of an LCA. Differences in use case profiles, data aggregation methods (top-down/bottom-up), data quality, databases etc. may lead to differences in the outcome. When comparing the order of magnitude of results from this study and truck LCAs from other OEMs, this needs to be taken into account. The underlying scope and assumptions would first need to be understood and aligned in order to allow a fair comparison of the environmental product performance although all standards are followed. **A fair comparison of the direct results from different studies** without taking the differences in consideration **is not possible**.

Representativeness - This LCA is conducted for a typical vehicle configuration using established assumptions for use case and end-of-life that form an reference scenario. In reality, different vehicle configurations and use cases and end-of-life scenarios may occur and would lead to deviating results. This shall be considered when using the results of this study.

Content declaration

Material distribution [kg]

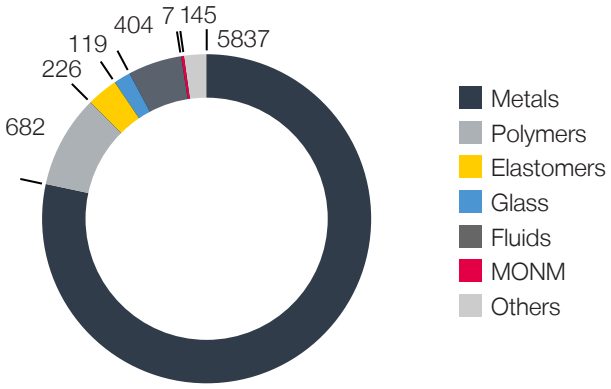
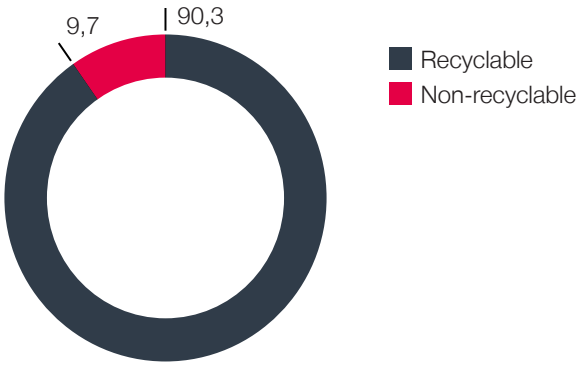


Figure 3: Content declaration according to DIN ISO 22628

Based on this content declaration, the vehicle's recyclability and recoverability rates are calculate as defined in the ISO 22628:2002 standard – "Road vehicles – Recyclability and recoverability – Calculation method". The results are shown in the following figure.

End-of-Life treatment:
Recyclability rate [%]



End-of-Life treatment:
Recoverability rate [%]

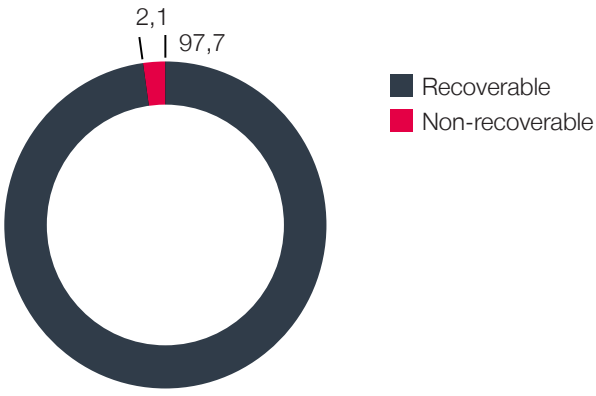


Figure 4: Recycling and recoverability rates according to DIN ISO 22628

ENVIRONMENTAL PERFORMANCE INDICATORS

The evaluated impact categories in the LCA are the following.

Global Warming Potential (GWP)
The global warming potential (GWP) describes the emission of greenhouse gases, which lead to an increase of the heat absorption of solar radiation within the atmosphere and thus can contribute to an increase of global average temperatures. The reference substance for the global warming potential is carbon dioxide. All other greenhouse gases (e. g., CH_4, N_2O, SF_6) are calculated in relation to carbon dioxide (CO_2 equivalents).

- **Indirect land use change (ILUC)**
  ILUC stands for Indirect Land Use Change. It describes the unintended consequences of land use changes that occur due to the production of biofuels like ethanol or biodiesel. When more land is used to grow crops for biofuels, less land is available for growing food. To meet the demand for food, new agricultural land must be created, often by converting natural areas such as forests or grasslands into farmland. This conversion releases additional greenhouse gases because forests and other natural areas store carbon. When these areas are cleared, the stored carbon is released. Therefore, ILUC is an important factor in assessing the environmental friendliness of biofuels, as it affects the overall balance of greenhouse gas emissions.

Acidification Potential (AP)
The acidification potential (AP) describes the impact of the emission of acidifying substances like e. g., SO_2 or NO_x. These substances have a variety of impacts on soils, waters, ecosystems, biological organisms, and materials (e. g., buildings). Examples are the dying forest syndrome and the dying of fish.

Eutrophication potential (EP)
The eutrophication potential (EP) describes an excessive discharge of nutrients into waters and soils, leading to an undesired shift in the composition of species. Additionally, eutrophication in waters results in oxygen depletion and thus oxygen starvation.

- **Freshwater**
  Freshwater eutrophication occurs due to the discharge of nutrient into soil or into freshwater bodies and the subsequent rise or increased availability in nutrient levels namely of phosphorus and nitrogen. The reference substance for the eutrophication potential in freshwater is phosphorus (P). All other relevant EP-influencing substances are calculated in relation to phosphorus (P equivalents).

- **Eutrophication potential (EP) Marine**
  Marine eutrophication can be defined as a response of the marine ecosystem to an increased availability of limiting nutrients in marine waters. The reference substance for the marine eutrophication potential is nitrogen (N). All other relevant EP-influencing substances are calculated in relation to nitrogen (N equivalents).

- **Eutrophication potential (EP) Aquatic terrestrial**
  The reference substance for the aquatic terrestrial eutrophication potential is also nitrogen (N). All relevant nitrogen containing substances such as nitrogen oxides, nitrate and ammonia, which influence the terrestrial EP, are calculated in relation to mole of N equivalents.

Photochemical ozone creation potential (POCP)
The photochemical ozone creation potential (POCP), also known as photochemical ozone formation potential (POFP), describes the formation of photo oxidants like ozone, peroxyacyl nitrates, and other substances that can evolve from hydrocarbons, carbon monoxide (CO) and nitrogen oxides (NO_x) under the influence of sunlight. Photo oxidants can impair human health and the function of ecosystems as well as damage plants.

Ozone depletion potential (ODP)
The parameter ozone depletion potential comprises damages on the stratospheric ozone layer caused by degradation of ozone molecules by chemicals such as refrigerants. Ozone depletion can lead to an increased UV radiation reaching the earth surface, which results in higher UV exposure for living organisms with detrimental effects.

Abiotic depletion potential – Elements (ADP elements)
The abiotic resource depletion potential (ADP) regarding elements describes the depletion of minerals. It therefore represents the depletion of non-renewable mineral resources and deprivation for future generations if these are not kept in the material cycle. The effect of this consumption on the depletion is estimated according to their availability stock at a global scale. Abiotic depletion is measured in kilograms of Antimony (Sb) equivalents.

Abiotic depletion potential – Fossil fuels (ADP fossil fuels)
The abiotic resource depletion potential (ADP) regarding fossil fuels describes the depletion of non-living (abiotic) and non-renewable energy resources. It therefore represents the depletion of non-renewable energy resources and its deprivation for future generations. All influencing elements are calculated as MJ (net calorific value).

Water Scarcity Footprint (WSF) / Water Deprivation Potential (WDP)
Water scarcity refers to a low volume of available water in a region. The water scarcity footprint aims at determining the criticality of the water usage associated with the evaluated product system. This is done by weighting the water consumption with region-specific water scarcity indexes. The water scarcity footprint is measured in m^3 water equivalents (m^3 H_2O eq.).

Particular Matter formation
This indicator measures the adverse impacts on human health caused by emissions of Particulate Matter (PM) and its precursors (e. g. NO_x, SO_2). Usually, the smaller the particles, the more dangerous they are, as they can go deeper into the lungs. The potential impact of it is measured as the change in mortality due to PM emissions, expressed as disease incidence per kg of PM2.5 emitted.

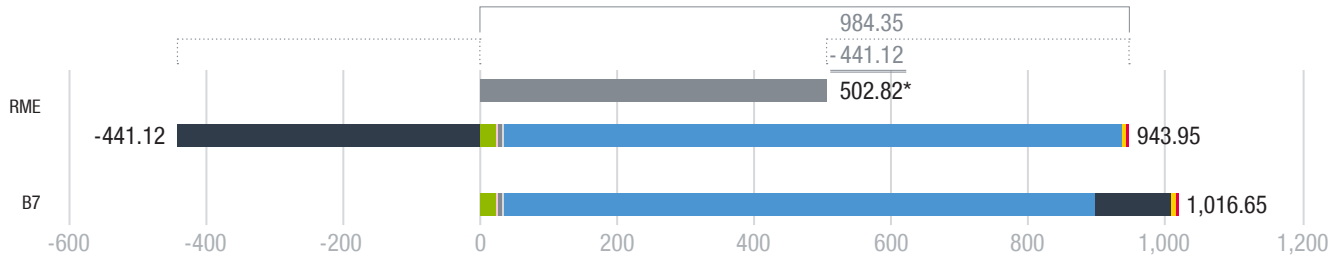
Land Use
Use and transformation of land for agriculture, roads, housing, mining or other purposes. The impacts can vary and include loss of species, of the organic matter content of soil, or loss of the soil itself (erosion). This is a composite indicator measuring impacts on four soil properties (biotic production, erosion resistance, groundwater regeneration and mechanical filtration), expressed in (crop eq.).

Human toxicity, non-cancer
This indicator refers to potential impacts, via the environment, on human health caused by absorbing substances from the air, water, and soil. Direct effects of products on human health are currently not measured. The unit of measurement is Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.

ENVIRONMENTAL PERFORMANCE RESULTS

In the following, absolute results over the life cycle per vehicle are presented in order to reflect the footprint per vehicle from cradle-to-grave as an outcome of this LCA.

Total Global Warming Potential (GWP) [t CO_2 eq.]
incl. GWP from land use change and biogenic sources



* Indicates total resulting value for RME summarizing positive and negative values.

RME (Rapeseed Methyl Ester): A biofuel produced by transesterifying rapeseed oil with methanol. It is a type of biodiesel used as an alternative to fossil diesel.

B7: A diesel fuel blend that contains up to **7 % biodiesel** (usually RME) mixed with 93 % fossil diesel. This blend is widely used in the EU.

Total Global Warming Potential (GWP)

	B7	RME
Supply chain	23.98	23.98
Inbound logistics	0.62	0.62
In-house	3.81	3.81
Outbound logistics	0.15	0.15
Use - TTW	868.96	908.58
Use - WTT	112.33	-441.12
Use - Maintenance	6.22	6.22
EoL	0.59	0.59
Total	**1,016.65**	**502.82**

Figure 5: Absolute total GWP results per vehicle for different fuel types

The greenhouse gas emissions determined with the LCA database/software used do not include ILUC data. Therefore, we would like to present here a possible range of ILUC effects, which, however, have considerable uncertainties. Unfortunately, another cause for uncertainty is also due to the age of the ILUC emission factors, which we have available for our study. Despite these uncertainties, the results provide a more complete picture of the greenhouse gas impact. This should help to avoid incorrect interpretation on the basis of a shortened greenhouse gas balance without ILUC. In the following the emission factors from the EU Renewable Energy Directive III (RED III) and the JRC study were used.

Global Warming Potential (GWP) incl. ILUC [t CO_2 eq.]

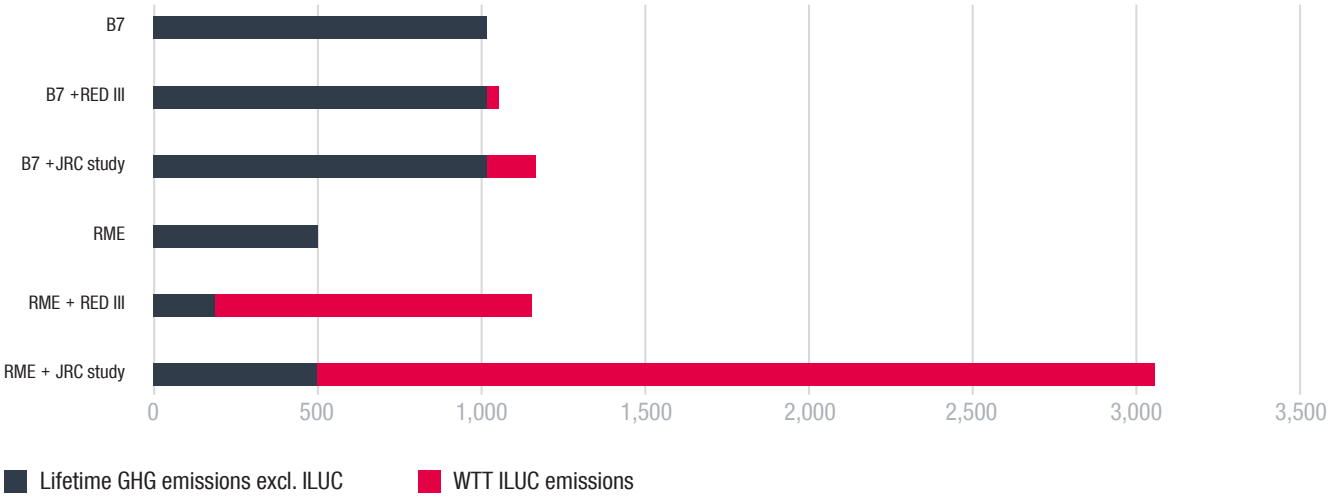
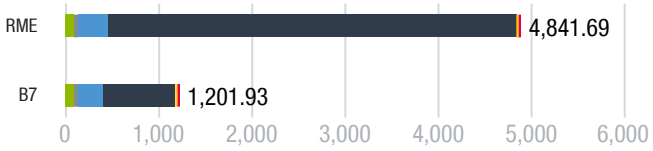


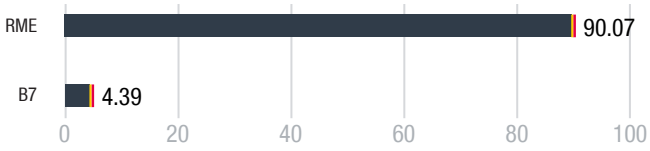
Figure 6: Global warming potential ILUC results per vehicle

In Addition to the results it needs to be mentioned that the cultivation of biofuels has further environmental impacts. These, in turn, can have further negative effects on climate change, which cannot be adequately reflected in the balance sheet.

Acidification potential (AP) [Mole of H^+ eq.]



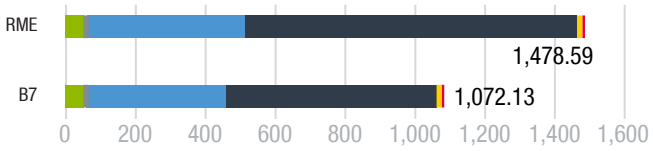
Eutrophication potential (EP) freshwater [kg P eq.]



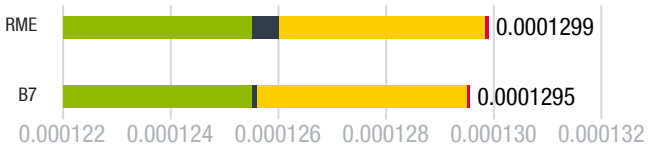
Eutrophication potential (EP) marine [kg N eq.]

Eutrophication potential (EP) aquatic terrestrial [kg N eq.]

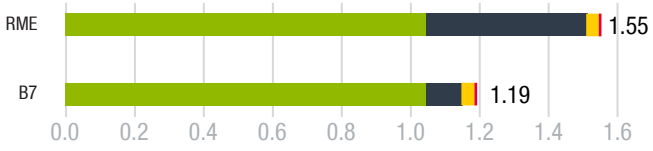
Photochemical ozone formation, human health [kg NMVOC eq.]



Ozone depletion potential (ODP) [kg CFC 11 eq.]

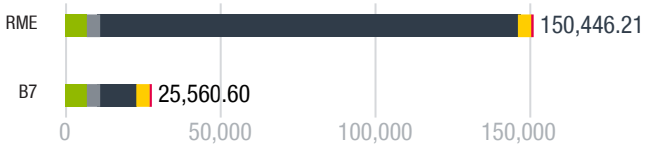


Abiotic depletion potential (ADP elements) [kg Sb eq.]

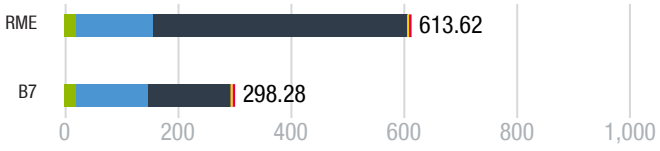


Abiotic depletion potential (ADP) for fossil resources [MJ]

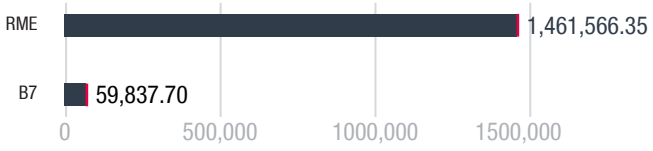
Water Scarcity footprint (WSF) [m3 world eq. deprived]



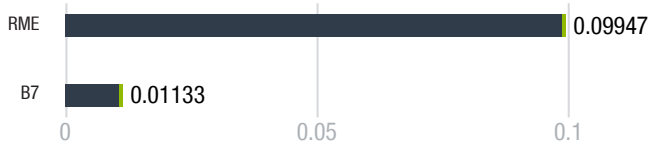
Particulate Matter Formation [kg PM2.5 eq.]



Land Use [Annual crop eq. × y]



Human toxicity, non-cancer [CTUh]



Supply chain | Inbound logistics | In-house | Outbound logistics | Use - TTW | Use - WTT | Use - Maintenance | EoL

List of Abbreviations

ADP	Abiotic depletion potential
AP	Acidification Potential
BASt	Bundesanstalt für Straßenwesen
BEV	Battery Electric Vehicle
B7	Diesel fuel with up to 7 % biodiesel
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DIN	German Industrial Standard
EN	European Standard
EoL	End-of-Life
EP	Eutrophication Potential
EPD	Environmental Product Declaration
eq.	Equivalents
FU	Functional unit
GaBi	LCA software with Databasis from Spehra Solutions GmbH
GWP	Global warming potential
H_2O	Water
ISO	International Organization for Standardization
KBA	Kraftfahrtbundesamt
kW	Kilowatt
kWh	Kilowatt hours
LCA	Life Cycle Assessment
LEAD	Volkswagen Group developed LCI database
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrous oxides
N_2O	Nitrous oxide
PCR	Product Category Rules
POCP	Photochemical ozone creation potential
RME	Rapeseed Methyl Ester, biofuel
SORT	Standardized on-road test cycles
SO_2	Sulfur dioxide
SF_6	Sulfur hexafluoride
tonne	Metric tonne (1,000 kg)
TTW	Tank to wheel
VOC	Volatile organic compounds
WSF	Water Scarcity Footprint
WTT	Well to tank

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