Methodological Convention 3.2 for the Assessment of Environmental Costs

Value Factors

Version 10/2024

German Environment Agency

Umwelt Bundesamt

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Based on the findings of the research projects "Methodological Convention 3.0 - Further Development and Extension of the Methodological Convention for Estimating Environmental Costs", work by David Anthoff (Anthoff 2024) as well as the research project “Methodological Convention 4.0 - Principles for Updating and Extending the Methodological Convention for Estimating Environmental Costs - Part 1”.

Imprint

Publisher
German Environment Agency (UBA)
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
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Internet: www.umweltbundesamt.de

Cover Image Photo Credits:
photocrew - Fotolia.de

Publications as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, October 2024

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Introductory Remarks

The value factors presented in the following chapters are based on the results of different research projects. Chapters 1 and 2 on the emission of greenhouse gases and air pollutants are based on work by David Anthoff (Anthoff 2024) as well as the research project "Methodological Convention 4.0 - Principles for Updating and Extending the Methodological Convention for Estimating Environmental Costs - Part 1". The remaining chapters are based on the research project "Methodological Convention 3.0 - Development and Extension of the Methodological Convention for Estimating Environmental Costs" and are largely adopted from the Handbook on Environmental Value Factors "Methodological Convention 3.1", but incorporate the new value factors on the environmental impact of greenhouse gases and air pollutant emissions. Detailed information on the data and methods used in the Methodological Convention 3.1 can be found in the research reports prepared as part of the research project.[1] These are available upon request (Bjoern.Buenger@uba.de, Nadia.Eser@uba.de, Astrid.Matthey@uba.de).

All value factors of the handbook "Methodological Convention" pursue the goal of assessing the impacts or damages that society incurs due to environmental pollution, expressed in monetary terms. This goal is best met by the damage cost approach, which is therefore used to estimate the value factors of the Methodological Convention. The value factors are average values for emissions in Germany, which can, however, also have an effect abroad. This particularly applies to damages caused by greenhouse gas emissions. Emissions of classical air pollutants and noise cause damages of varying geographical range depending on the emission context. If the environmental impacts are to be estimated for specific local circumstances, the value factors should be adjusted to the respective circumstances where possible. Average values can only provide an approximation. To apply the value factors outside Germany, they should be adjusted to the respective income level, and local conditions like population density, background emissions etc. as appropriate.

All value factors presented in this document are adjusted to the price level of 2024. All other data (e.g. emission factors, capacity utilization rates) continue to refer to the 2016 database used for the Handbooks Methodological Convention 3.0 and 3.1. In particular, no adjustments have been made to the emission factors of vehicles and power plants, the composition of the vehicle fleet, etc. A comprehensive revision of these components will become available with the publication of the Handbook on Environmental Value Factors 4.0 in 2025.

For an application of the value factors to activities or emissions after 2024, a price adjustment is required. For this purpose, we recommend adjusting the value factors with the consumer price index of the National Statistical Office.

[1] Bieler/Sutter (2018), Bieler/Sutter (2019), Bijleveld/de Bruyn/Sutter (2019), Doll/Sutter (2018), Schäppi et al. (2019).

1 Emission of Greenhouse Gases

1.1 Value Factors for Carbon Dioxide and other Greenhouse Gas Emissions

We recommend using a value factor of 880 $€_{2024}$ / t CO_2-eq when weighting the welfare of current and future generations equally (0% pure rate of time preference) and a value factor of 300 $€_{2024}$ / t CO_2-eq when placing a higher weight on the welfare of current compared to future generations (1% pure rate of time preference).[2] In addition, we recommend a sensitivity analysis with the respective other value.

These recommendations follow the social cost of carbon (SCC) or damage cost approach and are based on the Greenhouse Gas Impact Value Estimator (GIVE) model. The original GIVE model (Rennert et al. 2022) was adapted as follows for this handbook (for details see 1.2 Methodological Background):

- Use of equity weighting to account for damages in different world regions[3];
- Use of the Value of a statistical life (VSL) based on Amann et al. (2020a) to ensure consistency with the value factors on air pollutant emissions presented in Chapter 2;
- Use of the consumer price index of the German Federal Statistical Office to adjust prices from the base year of the GIVE model 2005 to 2024[4] ;
- Use of OECD purchasing power parities for currency conversion from USD into EUR[5] .

In addition to affecting the SCC value factors, the use of equity weighting and a lower VSL also lead to a shift in the most relevant impact categories: In the adapted GIVE model, damages in the agricultural sector are the main driver of climate damage costs (59%), followed by mortality (32%), energy consumption (7%) and sea level rise (2%). The lower VSL reduces the impact of the mortality effects on the overall SCC while the use of equity weighting entails a larger share of agricultural damages within the overall SCC.

[2] See chapter 1.2 Methodological background for further information on the pure rate of time preference and discounting.

[3] Prest et al. (2024), Anthoff (2024)

[4] Destatis (2024). When stating $€_{2024}$ or price level of 2024 this means that the price development, i.e. the inflation up until the end of 2023 has been taken into account.

[5] OECD (2024)

For emissions in years beyond 2024 the GIVE model, adjusted for the above-mentioned parameters, yields the following recommendations:

Table 1: UBA recommendation on climate costs in €$_{2024}$ / t GHG

Year	Climate costs in €$_{2024}$ / t GHG					
	CO_2		CH_4		N_2O	
	0% PRTP	1% PRTP	0% PRTP	1% PRTP	0% PRTP	1% PRTP
2024	880	300	7,840	4,825	250,470	104,275
2025	890	305	8,090	5,040	254,125	106,570
2026	900	315	8,335	5,255	257,785	108,865
2027	910	320	8,585	5,465	261,440	111,155
2028	920	325	8,830	5,680	265,100	113,450
2029	930	330	9,080	5,895	268,755	115,740
2030	940	335	9,325	6,105	272,410	118,035
	…	…	…	…	…	…
2050	1,080	435	15,340	11,070	327,775	155,365

Source: Adapted GIVE model (Anthoff 2024) and own calculations.

- To obtain value factors for years for which no figures are given in Table 1, we recommend linear interpolation between the indicated value factors.
- For a price adjustment of the value factors, we recommend using the consumer price index[6] .
- The greenhouse gas potential (Global Warming Potential (GWP), time horizon 100 years) can be used to transfer the value factors of carbon dioxide to other greenhouse gases not mentioned in the above table [7].
- In order to transfer the value factors to greenhouse gas (GHG) emissions in the aviation sector, it has to be accounted for the fact that combustion processes develop a higher damage potential at high altitudes[8]. If no precise value for the emission weighting factor for individual flights is available we recommend using an average emission weighting factor of 3.

6 For Germany, see https://www-genesis.destatis.de/genesis/online?operation=result&code=61111-0001&deep=true#abreadcrumb

7 Cf. IPCC AR5 (2014) http://cdiac.ornl.gov/pns/current_ghg.html

8 UBA (2023)

1.2 Methodological Background

Cost concept - Damage cost vs. abatement cost approach

Throughout this handbook, the aim is to estimate the level of damages or impacts incurred by society as a result of various environmental effects. Accordingly, the damage cost approach is used throughout. In other contexts, the mitigation or abatement cost approach may be more suitable, e.g. if the goal is to estimate the cost of measures necessary to reach a politically stipulated goal regarding the level of environmental impacts.

In the context of climate change, we assess the impacts or damages that occur worldwide as a consequence of greenhouse gas emissions. This cost concept is usually referred to as social cost of carbon (SCC).

GIVE model

Climate costs in previous versions of this handbook were based on the SCC estimates of the FUND model by Anthoff (2007). In the current version we use SCC estimates of the successor model GIVE, which was introduced in 2022.

The GIVE model is an open source integrated assessment model used to compute SCC. In a first step, projections regarding the economic and demographic development serve as predictors of a future CO_2-eq emissions pathway. Secondly, the projected CO_2-eq emissions pathway is fed into a climate module[9], which can then be used to model CO_2-eq concentrations, temperature increases and sea level rise[10]. Finally, the modelled impacts of climate change on different sectors are monetized, aggregated and converted into a present value by means of discounting.

In contrast to older models, GIVE accounts for uncertainties of individual components as well as across the overall modelling process, enabling a consistent assessment of the impacts associated with marginal CO_2-eq emissions. Furthermore, the GIVE model builds on a better understanding and integration of uncertainty and other components relevant for estimating climate damage costs as well as improved projections of economic and demographic developments.

The damage module deployed in GIVE comprises four impact categories: agriculture, health (through heat related mortality), building energy consumption and sea level rise. Climate damage costs in the impact categories health, energy consumption and sea level rise are available at the country-level, whereas the social costs of CO_2-eq in the agricultural sector are available only at the regional level (16 world regions). In the central estimate in Rennert et al. (2022), which does not implement equity-weighting, the increased heat related mortality due to climate change contributes 49% to the total social costs of CO_2-eq, while agricultural damages make up for 45% percent, followed by a contribution of energy consumption of around 5% and damages from sea level rise that only amount to 1% of the overall climate damage costs. The neglectable impact of rising sea levels on the climate damage costs is mainly due to the fact that significant damages from sea level rise occur further in the future, thereby implying that the effects of discounting are strongest for this impact category. The small contribution of sea level rise to overall climate damage costs is also rooted in the model used for this impact category (Coastal Impact and Adaptation Model (CIAM)). The model optimizes the adaptation strategy, thereby presumably entailing only small costs that may not be in line with the actual, real world costs of adapting to rising sea levels (Rennert et al 2022).

[9] Finite Amplitude Impulse Response (FaIR) model, see Smith et al. (2018)

[10] Building blocks for Relevant Ice and Climate Knowledge (BRICK), see Wong et al. (2017)

By aggregating the climate damage costs over four impact categories, GIVE covers a range of climate change effects. However, it is crucial to note that a large number of impact categories and effects are not or not fully considered, such as tipping points, migration, conflict, biodiversity, extreme weather events or labour productivity. The integration of these and other impacts into the model framework is likely to substantially increase the climate damage cost estimates, see, e.g., recent work by Kotz et al. (2024) and Bilal and Känzig (2024). Furthermore, even the impact categories that are considered do not cover the whole range of climate damages occurring in the respective sectors, e.g. health impacts only comprise heat-related mortality increases but do not consider morbidity effects and, as detailed above, the costs of adapting to rising sea levels are likely to be much higher than predicted using CIAM. Keeping in mind that a multitude of the impacts brought about by climate change are not or not comprehensively considered in GIVE, the climate damage costs presented in this chapter must be viewed as very conservative estimates which are likely to gravely underestimate the actual damage caused by the emission of CO_2-eq. Basing estimates on the precautionary principle must be expected to increase damage costs by at least an order of magnitude.

Discounting and the pure rate of time preference

The time at which the costs and benefits of today's decisions materialize has an important impact in economic analyses. Therefore, to compare future costs and benefits, they are discounted to the present day using a discount rate. In business decisions it is common to use a market interest rate, representing the opportunity cost of capital, to discount future costs and benefits.

In contrast, for the economic valuation of most environmental impacts there is a consensus that a lower discount rate must be applied, as many of the impacts valued only materialize in the distant future, e.g. health damages with long-term effects or impacts of greenhouse gas emissions that remain in the atmosphere for decades or centuries. For such extensive periods of time, the market interest rate is not the appropriate concept, because it does not, for example, take future generation's preferences into account. In addition, since the monetization of environmental impacts is based on a marginal utility concept, the discount rate has to account for limitations in the link between the marginal utility of those affected and financial markets as well as for changes in the marginal utility of different types of capital.

When dealing with effects that materialize over extensive time periods, the chosen discount rate has an immense impact on the results of the economic valuation, as can be seen in the table below comparing a discount rate of 1% and 3%. When applying a discount rate of 1%, 74% of the damages occurring in 30 years are taken into account, whereas when applying a discount rate of 3%, only 41% of the damages occurring in 30 years are considered.

Table 2: Consideration of future damages as a function of the discount rate

	10 years	20 years	30 years	50 years	100 years
1% discount rate	91%	82%	74%	61%	37%
3% discount rate	74%	55%	41%	23%	5%

Source: own calculation.

In the GIVE model we use the social discount rate developed by Frank Ramsey (Ramsey 1928). It combines two elements: i) consumption growth and its effect on the marginal utility of consumers, and ii) the pure rate of time preference (PRTP), which describes how future costs and benefits are weighted in comparison to costs and benefits materializing today. A PRTP of 0%

implies that future and present costs and benefits are weighted equally, whereas a positive PRTR tips the scales towards a stronger consideration of today's costs and benefits in comparison to those occurring in the future. A positive PRTP can thus be interpreted as prioritizing the needs of current generations over those of future generations, and consequently presents a value judgement.

In GIVE, the consumption growth rate is a dependent variable and hence varies throughout the Monte Carlo runs. Therefore, it is not possible to specify the exact discount rate used for the climate costs presented in this chapter. However, the rate of pure time preference is kept constant over the Monte Carlo runs, and results are presented for a PRTP of 0% and 1%.

Equity weighting

The UBA has advocated using equity weighting since the first edition of this handbook "Methodological Convention 1.0" in 2007, to take equal account of the welfare effects on all humans. With equity weighting, the damages caused by greenhouse gases emitted in Germany but occurring in different parts of the world are weighted with the respective ratio of average incomes (see box *Equity Weighting*). We thus value the damage costs caused by one tonne (metric ton) of CO_2-eq as if they were incurred (entirely) in Germany, or rather as if the whole world had the same income level as Germany. Differences in income within Germany are not considered, i.e. the damage is valued as if climate impacts affect poor and rich people equally.

It would not be necessary to use equity weighting when calculating climate costs, if the affected parties were to actually be compensated immediately by the parties causing the damage. However, this is not a realistic assumption, neither for interregional nor for intertemporal compensation. Equity weighting is therefore required to ensure that the social costs of carbon value the impacts of emissions on the quality of life of the affected people (the "utility" or "welfare" in economic terms) rather than only nominal income losses.

Background and Application of Equity Weighting

The effects of climate change are global, they occur irrespective of where greenhouse gases are emitted. Accordingly, every tonne of greenhouse gas which is emitted in Germany results in damages all around the world.

However, due to the different economic wealth in various regions of the world, comparable damages correspond to different nominal monetary values. If, for example, residential buildings are destroyed by severe weather events, their material value is on average higher in richer countries than in poorer countries. However, the people in poorer countries are at least as much affected in terms of their quality of life (their "utility" in economic terms) as people in richer countries, often even more so, due to the lack of insurance and government aid. It is true that it is also nominally cheaper to restore the damage incurred (e.g. repairing buildings and the infrastructure) in poorer countries. But the resulting loss of utility per monetary unit that is used for the repairs – and hence cannot be used for other purposes – is also greater. These differences in wealth can be accounted for in the assessment of global climate damage by using equity weighting. Using German equity weights thus means that we estimate costs as if all damages caused by one tonne of CO_2-eq were incurred entirely in Germany, or rather as if the whole world had the same income level as Germany.

With equity weighting, the nominal monetary values of the damages are weighted by the average income of the country in which they occur. If climate change causes assumed damage of €1 in a country which has an average income of €100 per capita, the damage amounts to 1/100 of the per capita income. However, if the same damage occurs in a country with an average income of €5,000, this damage would only represent 1/5,000 of the per capita income. Thus, in relation to income, the damage in the richer country is less severe. Equity weighting means weighting the damage in accordance with the average income. If the per capita income in a poor country is 50 times less, the nominal damage costs are weighted 50 times higher.

1.3 Exemplary value factors for greenhouse gas emissions as a result of land use change

The type of land use and changes between different land uses are a crucial determinant for the ecosystem services a certain area provides. A hectare of forest, for example, provides a number of ecosystem services, which greatly differ from the extent and type of ecosystem services provided by, e.g. a hectare of arable land or a hectare of settlement area. One dimension by which land use types differ, is the sequestration or emission of greenhouse gases. The amount of GHG sequestered or emitted on an area of a certain land use type per year is determined by a variety of factors, such as the soil characteristics or the biomass above and below ground.

The below tables illustrate the costs and benefits that arise from changes in biomass following land use changes. Table 3 illustrates the GHG related costs and benefits of land use change per hectare and year for the year of conversion in the biomass above and below ground, when using a value factor of 300€$_{2024}$/t CO_2-eq (1% PRTP). Table 4 illustrates the costs and benefits for the same land use changes, however when using a value factor of 880€ $_{2024}$ /t CO_2-eq, i.e. with 0% PRTP. They refer to the year of conversion; in comparison with subsequent years, deviations may occur due to growth processes.

Please note that these value factors only capture a fraction of the overall costs and benefits from land use change and that the additional consideration of soil related sequestration or emission of GHG may in some cases reverse the biomass related impacts of land use change. The values presented in the tables below should therefore be viewed as an exemplary illustration that does not pursue the objective of comprehensively depicting all GHG related impacts of land use change. To obtain a more recent and more comprehensive overview of the changes in GHG sequestration due to land use change, other factors, such as soil characteristics, must be taken into account. Please see the UBA report “Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2022” for information on further land use change related impacts on GHG sequestration (UBA 2022).

The tables provided in the UBA (2022) report mostly refer to tonnes of carbon per hectare and year. To be able to use the value factors for greenhouse gas emissions provided in Chapter 1.1, the values referring to tonnes of carbon must be converted to CO2, by multiplying them with a conversion factor of 3.667. In cases where other GHG are referred to, the GWP100 can be used to compute the respective value factors. Subsequently, the value factors in Chapter 1.1 can be used to compute the GHG related costs and benefits of land use change.

Table 3: **a) Costs (negative sign) and benefits (positive sign) rounded per hectare and year [$€_{2024}$ ha^{-1} a^{-1}] in the year of conversion in above and below ground biomass after land use change for the year 2017 at a value factor of 300$€_{2024}$/t CO_2-eq.**

	Forest	Field	Grassland in the narrower sense	Woody plants	Terrestrial wetlands	Water-bodies	Settle-ments
	Assessment of mean carbon stocks in above- and belowground biomass						
[$€_{2024}$ ha^{-1}]	60,300	7,400	7,500	47,600	20,900	0	13,800
	Costs for a change in biomass [€ ha^{-1} a^{-1}]						
Forest		-52,900	-52,800	-12,700	-39,400	-60,300	-46,600
Field	3,800		100	40,200	13,500	-7,400	6,400
Grassland in the narrower sense	3,600	-100		40,100	13,400	-7,500	6,300
Woody plants	2,100	-40,200	-40,100		-26,700	-47,600	-33,900
Terrestrial wetlands	3,800	-13,500	-13,400	26,700		-20,900	-7,100
Waterbodies	4,000	7,400	7,500	47,600	20,900		13,800
Settlements	3,700	-6,400	-6,300	33,900	7,100	-13,800	

Source: Own calculations based on UBA (2019a) and Anthoff (2024). Grassland in the narrow sense includes meadows and pastures.

Table 4: b) Costs (negative sign) and benefits (positive sign) rounded per hectare and year [$€_{2024}$ ha^{-1} a^{-1}] in the year of conversion in above- and below-ground biomass after land use change for the year 2017 at a value factor of 880$€_{2024}$/t CO_2-eq.

	Forest	Field	Grassland in the narrower sense	Woody plants	Terrestrial wetlands	Water-bodies	Settle-ments
	Assessment of mean carbon stocks in above- and belowground biomass						
[$€_{2024}$ ha^{-1}]	176,000	21,600	21,900	139,000	61,000	0	40,200
	Costs for a change in biomass [€ ha^{-1} a^{-1}]						
Forest		-154,500	-154,100	-37,000	-115,100	-176,000	-135,800
Field	11,100		400	117,400	39,400	-21,600	18,600
Grassland in the narrower sense	10,400	-400		117,100	39,000	-21,900	18,300
Woody plants	6,200	-117,400	-117,100		-78,000	-139,000	-98,800
Terrestrial wetlands	11,200	-39,400	-39,000	78,000		-61,000	-20,700
Waterbodies	11,700	21,600	21,900	139,000	61,000		40,200
Settlements	10,900	-18,600	-18,300	98,800	20,700	-40,200	

Source: Own calculations based on UBA (2019a) and Anthoff (2024). Grassland in the narrow sense includes meadows and pastures.

2 Emission of air pollutants

2.1 Average value factors for air pollutant emissions

For the air quality and exposure modelling we use the EcoSenseWeb model developed for the EU project NEEDS (New Energy Externalities for Sustainability), Version v1.3 (Preiss et al. 2008), that has already been used in previous versions of this handbook (Methodological Conventions 2.0, 3.0 and 3.1). EcoSenseWeb is an integrated atmospheric dispersion and exposure assessment model to calculate external costs of air pollution focused on human health impacts (University of Stuttgart 2024). It is based on the European Monitoring and Evaluation Programme (EMEP) model. Due to decreasing emission levels in Germany, the EcoSenseWeb emission scenario for the year 2020 is used for this update of the handbook Methodological Convention, as opposed to the 2010 emission scenario that has been used for previous versions. While more recent findings for modelling the atmospheric dispersion of emissions within the EMEP model are available, these are not taken account of in the currently available version of EcoSenseWeb and can therefore not be used to estimate the value factors. Besides health impacts, the value factors for the emission of air pollutants also incorporate biodiversity losses, crop failures as well as building material damages. Where possible, crop failures were assessed on the basis of the response functions in Mills et al. (2007). For the remaining air pollutants as well as for building material and biodiversity impacts, the value factors were derived from updated NEEDS data.

Table 5: Average environmental cost of air pollution from emissions from unknown source (in $€_{2024}$ / t emission)

$€_{2024}$/t emission	Value factors for emissions in Germany				
	Health damage	Biodiversity loss	Crop damage	Material damage	Total
Germany total					
$PM_{2.5}$	145,000	0	0	0	**145,000**
PM_{coarse}	1,900	0	0	0	**1,900**
PM_{10}	102,000	0	0	0	**102,000**
NO_X	40,700	2,900	1,600	200	**45,400**
SO_2	39,000	1,100	-100	900	**40,900**
NMVOC	600	0	1,500	0	**2,100**
NH_3	34,400	11,700	-100	0	**46,000**

Assumption: PM_{10} consists of 70% $PM_{2.5}$ and 30% PM_{coarse}. For NO_x and SO_2, the costs represent the damage caused by secondary particulate matter formation.
Source: Van der Kamp et al. (2024), own calculations.

Table 5 shows the average environmental costs per emitted tonne of the respective pollutant[11] for emissions from "unknown sources"[12] in Germany. These average values can be used for a

11 The most important air pollutants in this context are particulate matter (PM), nitrogen oxides (NOx), sulphur dioxide (SO2), non-methane volatile organic compounds (NMVOC) and ammonia (NH3).

12 Unknown source (unknown height of release) means that there is no specification regarding the stack height of the respective emission source plant. Consequently, these are average values. The damage costs increase with decreasing height of the emission

rough estimate of the damage costs caused by air pollutants if no specific information on the emission source is available.

2.2 Differentiated value factors for air pollutant emissions from different sources

The adverse impacts of air pollutants on human health tend to increase as the height of the emissions source decreases and the population density around the emission source increases. Therefore, the value factors per tonne of emissions vary as a function of these factors. This differentiation is primarily relevant for the value factors for particulate matter, while the value factors for the other air pollutants show little variation with regard to the release height and location. For most applications it is thus sufficient to use average value factors. However, if site-specific valuations are needed or the share of particulate matter emissions is relatively high, the application of differentiated value factors can generate additional insights.

Table 6 shows the value factors from the emission of air pollutants through power generation as well as industrial and small-scale combustion plants for Germany. The monetized health effects are differentiated by release height (power stations (>100m), industrial power generation (20-100m) and small-scale combustion plants (0-20m)) as well as location of the emission source (metropolitan areas (city) and urban areas (town)).

source, i.e. emissions from low emission sources (plants with low stack heights) lead to higher damage costs than those from higher emission sources.

Table 6: Value factors for the emission of air pollutants from power stations, combustion processes in industry and small scale combustion plants and (in €$_{2024}$ / t emission)

	Health damage											**Material damage**	**Crop damage**	**Biodi-versity loss**
	Power stations	**Combustion processes in industry**					**Small scale combustion facilities**							
		Un-known	**City**		**Town**		**Un-known**	**City**		**Town**				
Emission height (in m)	>100		0-20	20-100	0-20	20-100		0-20	20-100	0-20	20-100			
$PM_{2.5}$	75,600	155,300	278,100	156,900	192,600	156,900	147,300	263,700	148,800	182,700	148,800	0	0	0
PM_{coarse}	800	2,100	3,800	2,100	2,600	2,100	1,900	3,400	1,900	2,400	1,900	0	0	0
PM_{10}	53,200	109,400	195,800	110,500	135,600	110,500	103,700	185,600	104,700	128,600	104,700	0	0	0
NO_x	32,500	43,100	43,100	43,100	43,100	43,100	44,500	44,500	44,500	44,500	44,500	190	1,580	2,920
SO_2	35,900	40,200	40,200	40,200	40,200	40,200	40,600	40,600	40,600	40,600	40,600	880	-130	1,130
NMVOC	600	600	600	600	600	600	600	600	600	600	600	0	1,490	0
NH_3	37,600	37,500	37,500	37,500	37,500	37,500	37,400	37,400	37,400	37,400	37,400	0	-120	11,650

Categories "city" and "town" differ according to municipality size (city >100,000, 2,000<town<100,000)

Assumption: PM_{10} consists of 70% $PM_{2.5}$ and 30% PM_{coarse}. This assumption should be adjusted if source-specific composition information is available. For NO_x and SO_2, the costs only represent the damage caused by secondary particulate matter formation.

Source: Van der Kamp et al. (2024) and own calculations.

2.3 Value factors for air pollutants from road traffic

As stated above, the severity of health impacts is inversely related to the height of the emission source, i.e. the lower the emission release height, the graver the health impacts tend to be. Consequently, the health impacts from road traffic are particularly severe and require special attention, given the close proximity of the emission sources, in the form of vehicles, to the ground (release height 0-3m). For particulate matter emissions this effect is particularly pronounced, as with low emission release heights the particles are more frequently inhaled by human receptors, thereby unfolding more serious impacts on human health. The effect is even more aggravated in metropolitan areas with high population density, where a larger number of human receptors coincides with heavier road traffic, thereby further intensifying the adverse effects on human health. To account for this difference in the severity of health impacts in different surroundings, the value factors are adjusted using a factor that reflects the differing population densities in the respective surroundings (urban, suburban, rural).

Table 7: Value factors for the emission of air pollutants in transport (in €$_{2024}$ / t emission)

	Health damage				Non-health related damage
Surroundings	**Unknown**	**Urban**	**Suburban**	**Rural**	
$PM_{2.5}$	142,400	578,500	166,800	98,000	0
PM_{coarse}	1,800	8,800	2,200	1100	0
PM_{10}	15,900	65,800	18,700	10,800	0
NO_x	42,000	42,000	42,000	42,000	4,700
SO_2	39,200	39,200	39,200	39,200	1,900
NMVOC	600	600	600	600	1,500
NH_3	36,300	36,300	36,300	36,300	11,500

The categories Urban, Suburban and Rural differ according to population density (Urban > 1,500 / km^2, 300/ km^2< Suburban <1,500/ km^2, Rural < 300/ km^2), assumption: PM_{10} consists of 10% $PM_{2.5}$ and 90% PM_{coarse}. For NO_x and SO_2, the costs only represent the damage caused by secondary particulate matter formation.
Source: Van der Kamp et al. (2024) and own calculations.

2.4 Methodological background

For the update of this handbook, the assessment of health effects of air pollutants largely follows the recommendations in Amann et al. (2020b) to maintain the exposure-effect functions from the HRAPIE (health risks of air pollution in Europe) project with one exception: For the mortality risk from long term exposure to particulate matter, we use the exposure-effect relationship from Chen and Hoek (2020). The concentration-response functions from HRAPIE and Chen and Hoek (2020) are entered into a simplified computation framework that yields the increase in years of life lost (YOLL) from increased air pollutant concentrations. In comparison to the previous version of this handbook, the computed YOLL are around 30% higher, thereby significantly driving the increase in value factors for the emission of air pollutants. For the monetization of health effects from exposure to air pollutants, we use the figures on mortality and morbidity from Amann et al. (2020a). For almost all health endpoints assessed in Amann et al. (2020a), the monetized health damages have considerably increased in comparison to the previous version of this handbook. These two effects, i.e. the increase in YOLL in combination with higher values for monetized health impacts entail a significant overall increase in the value factors for the emission of air pollutants. They outweigh the dampening effect of lower emission levels of air pollutants that is reflected in the use of the 2020 scenario in EcoSenseWeb.

As Ammann et al. (2020a) point out, many research projects continue to rely on the HRAPIE exposure-effect functions and results, sometimes extending them by additional health effects. However, the continued reliance on the HRAPIE concentration-response functions tends to lead to an underestimation of air pollution related health effects (Amann et al. 2020a). Furthermore, it is still not possible to quantify the damages from direct NO_2 exposure, thereby leading to an underestimation of the damages per tonne of NO_2 emitted. The value factors for the emission of air pollutants detailed in the tables in this chapter should therefore be viewed as conservative estimates that are likely to underestimate the actual impacts of air pollutants on human health.

The value factors for air pollutants are specified as average costs per emitted unit. This serves the purpose of making the value factors more usable for practical applications such as cost-benefit analyses, as it allows to link specific emissions of air pollutants to resulting (monetized) damages. This application perspective is also why the value factors on air pollutants draw on emissions rather than immissions: It is often easier to determine the emissions from individual installations, projects, legislative proposals etc. than the associated immissions. The relationship between emissions and immissions is modelled as part of the impact pathway approach. The focus on practical applicability and transferability of value factors is a core element of this handbook.

The values provided in Tables 5 through 7 refer to the base year 2021, given in 2024 prices. In the original sources, the monetary values are given in $€_{2005}$. To reflect the present value of the Euro, the price level changes in Germany between 2005 and 2024 have been taken into account. We used the consumer price index of the German Federal Statistical Office to convert the value factors to $€_{2024}$.[13] As stated above, the monetary values in the original source, i.e. Amann et al. (2020a), are given in $€_{2005}$ and are not specific for Germany but apply to the EU27 area. To account for the difference in purchasing power between the EU27 average and Germany, the monetary values are corrected for Germany using purchasing power parities.[14] We have further considered that the willingness to pay for avoiding immaterial health damage (pain and suffering) increases with income. Therefore, the value factors are adjusted for changes of the gross domestic product per capita in Germany between 2005 and 2021 (including the use of an elasticity figure of 0.85, which is based on the NEEDS project and reflects the assumed increase in willingness to pay with income).[15]

[13] Destatis (2024). When stating $€_{2024}$ or price level of 2024 this means that the price development, i.e. the inflation up until the end of 2023 has been taken into account.

[14] OECD (2024)

[15] The data can be accessed at https://ec.europa.eu/eurostat/databrowser/view/NAMA_10_PC__custom_4998867/default/table?lang=en

3 Power and heat generation

Please note that the value factors in this chapter present a partial update: The new, most up-to-date value factors on GHG and air pollutant emissions were used to compute the monetized environmental impacts of power and heat generation. However, no adjustments have been made to the emission factors of power plants and energy sources, the composition of the energy mix, etc. A comprehensive revision of these components will become available with the publication of the Handbook on Environmental Value Factors 4.0 in 2025.

3.1 Value factors for electric power generation

The environmental impact of electric power generation depends on the power generation technology deployed, i.e. the energy source used to produce electricity. It can be captured using emission factors, that reflect the environmental impact for the production of one kilowatt-hour of electricity using a certain energy source. The German Environment Agency regularly publishes emission factors in the unit grams per kilowatt-hour of electricity (kWh_{el}, i.e. based on the unit of the electrical power produced) for fossil and renewable power generation technologies.

Direct emissions refer to emissions that arise in the immediate context of power generation, i.e. during the operational phase of energy generation with different technologies, such as the actual process of combusting coal. Indirect emissions arise during the other phases of the life cycle (construction, maintenance, decommissioning), e.g. during coal mining and plant construction.

Using emission factors and the value factors presented in Chapters 1 and 2, it is possible to compute the monetized environmental impacts of power generation related to GHG and air pollutant emissions. By comparing the resulting value factors per kWh_{el}, it is possible, inter alia, to assess the environmental damage avoided by generating power from renewable sources instead of using fossil fuels. However, it should be borne in mind that the value factors only factor in greenhouse gases and air pollutants. Other environmental impacts, such as the impairment of ecosystems or land use change, are not or only partially accounted for in the value factors.

When trying to arrive at value factors for power generation, two different basic approaches can be chosen: If the aim is to have a differentiated analysis, information and assumptions on the locations of the power generation facilities as well as their specific air pollutant emissions are required. For such cases, where individual, site-specific environmental impacts are to be assessed, we recommend using the differentiated value factors from Chapters 1 and 2. For an analysis at the national level, on the other hand, information on overall emissions in Germany is sufficient. Such more generic calculations are easier to follow and also easier to update once new emission factors become available. The deviations of the results from the more differentiated approach tend to be small and have no influence on the qualitative conclusions than can be drawn from such analyses. Therefore, the value factors in this chapter are based on overall emissions, which for the assessment of air pollutants implies that for both, direct and indirect emissions, the generic value factors were used.

Table 8: Value factors for electricity generation in Germany including upstream chains in €-cent$_{2024}$ / kWh$_{el}$

Electric power generation from	Air pollutants	Greenhouse gases (300 €/tCO2 eq)	Greenhouse gases (880 €/tCO2 eq)	Total environmental costs (300€/tCO2 eq)	Total environmental costs (880 €/tCO2 eq)
	Fossil energy sources				
Lignite	4.30	31.54	92.03	35.85	96.33
Hard coal	3.55	28.75	83.88	32.30	87.43
Natural gas	1.80	13.00	37.91	14.80	39.71
Oil	10.78	25.31	73.83	36.09	84.61
	Renewable energy sources				
Hydropower	0.09	0.40	1.17	0.49	1.26
Wind energy*	0.22	0.30	0.89	0.53	1.11
Photovoltaics	0.94	2.06	6.00	3.00	6.94
Biomass**	8.31	7.39	21.57	15.71	29.88

* Average value from onshore and offshore wind energy weighted according to generation shares;
** Average value weighted by generation shares for gaseous, liquid and solid biomass.
Source: Own representation based on Bachmann and van der Kamp (2018), van der Kamp et al. (2024), Anthoff (2024) and own calculations.

3.2 Value factors for heat generation

The approach for assessing the monetized environmental impacts of heat generation is similar to that for power generation. As for power generation, the German Environment Agency publishes emission factors for direct and indirect emissions from heat generation for different energy sources. To arrive at monetized environmental impacts for heat generation, the emissions factors are then weighted with the value factors on GHG and air pollutant emissions from Chapters 1 and 2. As for electric power generation we follow a more generic, national-level approach. If a site-specific assessment is required, the differentiated value factors from Chapters 1 and 2 should be used.

Table 9: Value factors for heat generation of the households in Germany in €-cent$_{2024}$ / kWh$_{final\ energy}$

Heat generation using	Air pollutants	Greenhouse gases (300 €/tCO2 eq)	Greenhouse gases (880 €/tCO2 eq)	Total environmental costs (300 €/tCO2 eq)	Total environmental costs (880 €/tCO2 eq)
	Fossil energy sources				
Heating oil	1.83	9.58	27.96	11.41	29.79
Natural gas	0.86	7.49	21.86	8.35	22.72

Heat generation using	Air pollutants	Greenhouse gases (300 €/tCO2 eq)	Greenhouse gases (880 €/tCO2 eq)	Total environmental costs (300 €/tCO2 eq)	Total environmental costs (880 €/tCO2 eq)
Lignite (briquette)	9.26	12.88	37.57	22.14	46.83
District heating with network losses*	2.96	9.55	27.86	12.51	30.82
Electricity heating with grid losses**	3.71	18.28	53.33	21.99	57.04
	Renewable energy sources				
Solar thermal	0.45	0.37	1.07	0.82	1.52
Surface geothermal energy	1.57	6.04	17.62	7.61	19.18
Deep geothermal energy	0.01	0.02	0.05	0.03	0.06
Biomass***	4.90	1.00	2.93	5.91	7.83

* The value factors vary, in some cases considerably, depending on the heat source.
** This is based on the average rate for power generation (incl. renewable energy sources and taking into account the upstream value chains for the generation of the respective fuels.
*** Average value for gaseous, liquid and solid biomass weighted by production shares.
Source: Own representation based on Bachmann and van der Kamp (2018), van der Kamp et al. (2024), Anthoff (2024) and own calculations.

4 Passenger and freight transport in Germany

As for power and heat generation, the environmental impacts of passenger and freight transport can be divided into direct and indirect emissions. Direct emissions arise from the operation of the various vehicle types, such as the combustion of fuels, abrasion and dust turbulence. Indirect emissions refer to the emissions and environmental impacts from the other life cycle phases, such as construction, maintenance and waste management as well as fuel supply logistics.

Besides leading to the emission of air pollutants and GHG, transport causes noise and further adverse impacts on nature and landscape, primarily due to landscape fragmentation and land sealing caused by the necessary underlying infrastructure. For some of these aspects, estimates for the monetized environmental impacts are available and are added to the emission-related value factors, where feasible. The approach and the resulting transport-related value factors are described below.

Please note that the value factors in this chapter present a partial update: The new, most up-to-date value factors on GHG and air pollutant emissions were used to compute the monetized environmental impacts of passenger and freight transport. However, no adjustments have been made to the emission factors of vehicles, the composition of the vehicle fleet, etc. A comprehensive revision of these components will become available with the publication of the Handbook on Environmental Value Factors 4.0 scheduled for 2025.

4.1 Assumptions for the emission assessment

As has been discussed in Chapter 2.3, the severity of air pollutant emission-related environmental and health impacts is dependent on the population density, among other things. It follows that the impacts are more pronounced in cities than in rural areas or on motorways. To estimate transport-related value factors (e.g. costs per vehicle kilometer), it is therefore necessary to assess the emissions in the respective setting (e.g. per vehicle kilometer) and to break down the proportion of mileage in urban areas, rural areas and on motorways. The percentages of mileage (Table 10) correspond to the data from the TREMOD model (Transport Emission Model) used by the German Environment Agency.

Table 10: Breakdown of mileage in road transport (urban, rural, motorway) by vehicle category

Vehicle type	Urban	Rural	Motorway
Cars	26%	41%	33%
Light commercial vehicles (LCV)	44%	27%	29%
Heavy goods vehicles (HGV)	14%	25%	61%
Motorcycles	39%	52%	9%
Public buses	57%	37%	6%
Coaches	9%	58%	34%

Source: HBEFA 3.3.

Emission factors from the database “Handbuch für Emissionsfaktoren des Straßenverkehrs” (Handbook of Road Transport Emission Factors) (HBEFA 3.3) for the year 2016 were used to assess the direct emissions of road traffic vehicles. The HBEFA provides emission factors in grams per vehicle kilometer for the air pollutants CO, NH_3, NMVOC, NO_X, $PPM_{2.5}$ and SO_2 as well as for the greenhouse gases CH_4, CO_2 and N_2O. Emission factors from the TREMOD model are used for direct emissions from passenger and freight trains.

The value factors for emissions from road and rail transport in Germany are computed for the average fleet composition of the various vehicle types as well as for the Euro standard classes (Euro 1 to Euro 6 for cars and Euro I to Euro VI for trucks[16]) of the vehicle types and their subclasses.

In the aviation sector, for the largest portion of the traveled distance, the combustion process takes place at high altitudes. Combustion processes at high altitudes unfold climate damages that go beyond the emission of greenhouse gases.[17] To reflect this effect, the value factors for the greenhouse gases emitted during flight operations are multiplied by the average factor of 3 – however, please note that the appropriate factor varies between individual flights depending on travel height, humidity etc. (see the corresponding recommendation in the chapter on greenhouse gas emissions).

To assess the monetized impacts throughout the construction, maintenance and disposal phases of the vehicles, data from the life cycle inventory Ecoinvent 3.3 were used. The emission factors are based on the data provided in Spielmann et al. (2007) on overall emissions and total mileage of the individual vehicle types.[18] To assess the emissions from fuel supply the TREMOD emission factors were used.[19]

4.2 Value factors for damage caused by land use and fragmentation

To assess the environmental damages from loss and fragmentation of natural habitats, we rely on calculations from the study "External Effects of Transport 2015" by the Swiss Federal Office for Spatial Development. The value factors from this study are displayed in Table 11.

A restoration cost approach is used to estimate the value factors: in case of habitat losses, the costs for (virtually) restoring lost biotope or ecosystem areas are used, whereas in case of habitat fragmentation, the costs for (virtually) constructing defragmentation structures provide the basis.[20]

For road traffic motorways, federal highways, state roads and district roads were considered, while train routes were used for rail transport. The land use for air transport was gathered from the statistic "Flächenerhebung nach Art der tatsächlichen Nutzung" (Area survey by type of actual use) of the German Federal Statistical Office.[21]

[16] In addition to the Euro standard classes 1 to 6 and I to VI, the pollutant emissions for engines used before the introduction of the exhaust emission standard were also considered. In the HBEFA 3.3, these vehicles are indicated as Euro 0 for cars and 80ties for trucks.

[17] See UBA (2023)

[18] Spielmann et al. (2007) indicate which processes were considered: "Included processes: The inventory includes processes of material, energy and water use in vehicle manufacturing. Rail and road transport of materials is accounted for. Plant infrastructure is included, addressing issues such as land use, building, road and parking construction."

[19] To calculate the emissions from fuel supply, the processes "market for diesel" and "market for petrol" from the ecoinvent database were used. These processes already include all transport routes of the fuels.

[20] Cf. INFRAS/Ecoplan (2018), p. 79 in conjunction with Ecoplan/INFRAS (2014), p. 18.

[21] Cf. Destatis (2017a)

Table 11: Figures for environmental costs of road transport due to land use and fragmentation, in €-cent$_{2024}$ per vehicle kilometer

Vehicle category	Costs due to land use and fragmentation [€-cent$_{2024}$/vehicle km]
Car	0.42
Bus	1.00
Small motorcyle	0.14
Motorcycle	0.19
Passenger train, local transport	48.96
Passenger train, long-distance	73.45
Passenger air transport (short and medium haul; <2,000 km)	10.57
Passenger air transport (Long haul; > 2,000 km)	19.40
Light commercial vehicles (LCV)	0.44
Heavy goods vehicle (HGV) <7.5t	0.51
HGV 7.5-14t	0.93
HGV 14-28t	1.00
HGV: Trailer 28-40t	1.26
Freight train	153.03
Freight air transport	32.00

The value factors for air transport proportionally account for belly freight.
Source: Bieler et a. (2018) and own calculations.

4.3 Value factors for noise

Due to the high population density and high traffic volume, broad sections of the German population are affected by noise. Many people are exposed to high levels of noise pollution, which adversely affect their health and reduce their quality of life. Road, rail and air traffic represent the main sources of noise pollution, for which value factors will be discussed in this chapter. When assessing the effect of noise pollution on human health and well-being, close attention must be paid to the circumstances and surroundings (noise characteristics, distance from the noise source, time of day, population density, etc.).

The monetized health impacts from traffic noise are differentiated according to noise level classes. A distinction is made between road, rail and air traffic in order to properly account for the acoustic properties and the resulting noise effects of these modes of transport.

The value factors provided in Table 12 can, for example, be used to monetize how noise reduction measures impact noise disturbance. It should be borne in mind that these are average values - for a more accurate assessment of the values, on-site noise measurements are necessary.

Table 12: Cost functions for noise effects based on L_{DEN} values

	Cost functions by category (€2024/person, a)												Total costs (€2024/person, a)		
	Intangible costs - YLD			Intangible costs - YLL			Costs healthcare system			Costs production losses			All categories		
dB(A)	Road	Rail	Air	Road	Rail	Air	Road	Rail	Air	Road	Rail	Air	Road	Rail	Air
Overall result for nuisance (excluding self-reported sleep disturbances)															
35-39	0	0	0										0	0	0
40-44	0	0	0										0	0	0
45-49	34.55	11.03	36.29										34.55	11.03	36.29
50-54	69.43	24.29	100.81										69.43	24.29	100.81
55-59	115.64	47.87	192.5										115.64	47.87	192.5
60-64	184.19	89.83	310.35										184.19	89.83	310.35
65-69	286.09	158.24	453.34										286.09	158.24	453.34
70-74	432.35	261.2	620.42										432.35	261.2	620.42
>= 75	633.95	406.75	810.59										633.95	406.75	810.59
Overall results on physical health															
45-49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50-54	0.14	0.1	0.06	0.27	0.22	0.21	1.16	0.14	1.04	0.05	0.01	0.02	1.62	0.47	1.33
55-59	0.65	0.47	0.36	1.73	1.36	1.3	4.54	0.65	3.82	0.22	0.05	0.11	7.15	2.53	5.58
60-64	1.56	1.15	1.12	4.37	3.38	3.94	9.15	1.99	8.06	0.52	0.12	0.38	15.6	6.66	13.51
65-69	2.82	2.17	2.74	7.11	5.51	8.77	15	4.59	15.65	0.88	0.27	1.14	25.81	12.55	28.29
70-74	4.27	3.41	4.96	9.92	7.69	15.28	21.62	7.94	25.6	1.27	0.46	2.27	37.08	19.51	48.11

	Cost functions by category (€$_{2024}$/person, a)												**Total costs (€$_{2024}$/person, a)**		
>= 75	5.73	4.64	7.19	12.72	9.88	21.78	28.24	11.29	35.55	1.67	0.64	3.4	48.36	26.46	67.93
Overall results for adverse effects on cognitive and mental health															
45-49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50-54	1.79	1.77	1.3	0.2	0.19	0	0.26	0.25	0	0.17	0.17	0	2.42	2.37	1.3
55-59	10.65	10.53	8.22	0.95	0.9	0	1.23	1.17	0	0.86	0.82	0	13.68	13.42	8.22
60-64	25.02	24.81	21.1	1.7	1.62	0.17	2.21	2.11	0.22	1.54	1.47	0.15	30.48	30	21.65
65-69	39.41	39.1	35.89	2.45	2.33	1.07	3.2	3.04	1.41	2.22	2.11	0.98	47.27	46.58	39.34
70-74	53.78	53.39	52.52	3.2	3.05	2.7	4.17	3.96	3.53	2.9	2.77	2.46	64.07	63.17	61.22
>= 75	68.17	67.67	69.16	3.95	3.77	4.35	5.15	4.9	5.66	3.58	3.41	3.94	80.85	79.74	83.09
Overall results across all end points (excluding self-reported sleep disturbances)															
35-39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45-49	34.55	11.03	36.29	0	0	0	0	0	0	0	0	0	34.55	11.03	36.29
50-54	71.37	26.17	102.16	0.47	0.41	0.21	1.42	0.37	1.04	0.22	0.17	0.02	73.48	27.13	103.44
55-59	126.94	58.87	201.07	2.68	2.26	1.3	5.78	1.83	3.82	1.09	0.86	0.11	136.48	63.82	206.29
60-64	210.78	115.8	332.58	6.08	5	4.11	11.36	4.1	8.29	2.06	1.59	0.53	230.26	126.48	345.51
65-69	328.3	199.53	491.96	9.57	7.84	9.84	18.2	7.63	17.05	3.1	2.38	2.11	359.18	217.37	520.96
70-74	490.4	317.99	677.91	13.13	10.74	17.99	25.8	11.9	29.13	4.17	3.22	4.73	533.5	343.86	729.75
>= 75	707.84	479.06	886.93	16.67	13.65	26.13	33.39	16.19	41.21	5.26	4.05	7.34	763.17	512.95	961.61

L_{DEN} = Day-Evening-Night Noise Level; YLD = years lived with disability; YLL = years of life lost;
Source: Doll and Sutter (2018); own calculations.

The results from noise mapping according to the EU Environmental Noise Directive can be combined with the value factors from Table 12 to compute the overall costs inflicted on the German population through traffic noise pollution. The findings of the noise mapping for the year 2017 are illustrated in Table 13. The table shows the number of people that were affected by noise from each mode of transport in the reference year 2016 as well as the monetized health impacts from that noise exposure.

These monetized health impacts in Germany totaled at 2.07 billion $€_{2024}$ from road traffic, 725 million $€_{2024}$ from rail traffic noise and 215 million $€_{2024}$ from air traffic noise.

Table 13: Traffic noise pollution suffered by the population in pursuance of the EU Environmental Noise Directive and the resulting healthcare costs (reference year of mapping: 2016)

	*L*DEN > 55-60 dB	*L*DEN > 60-65 dB	*L*DEN > 65-70 dB	*L*DEN > 70-75 dB	*L*DEN > 75 dB
Number of people affected by road traffic noise	3,961,400	2,409,200	1,649,300	632,300	65,200
Number of people affected by rail traffic noise	3,787,300	1,645,500	679,600	231,600	92,600
Number of people affected by air traffic noise	606,400	205,800	30,700	3,700	0
Healthcare costs due to road traffic noise [$€_{2024}$]	540,665,000	554,750,000	592,390,000	337,33,000	49,759,000
Healthcare costs due to rail traffic noise [$€_{2024}$]	241,708,000	208,124,000	147,725,000	79,639,000	47,499,000
Healthcare costs due to air traffic noise [$€_{2024}$]	125,096,000	71,105,000	15,994,000	2,700,000	0

Source: Noise mapping (Lärmkartierung) and own calculations. The EU Environmental Noise Directive tends to lead to an underestimation of the total number of people affected by noise, as the mapping does not cover all sources of traffic noise.

4.4 Value factors for transport-related activities

The value factors for transport related activities illustrated in Tables 14 through 21 are computed by linking the emission factors for the various vehicle categories and life cycle phases. The value factors are illustrated for different road types and surroundings (average of all routes, urban areas, rural areas and motorways according to the distribution in Table 10) as well as for climate costs with 1% and 0% PRTP.

It is possible to calculate mileage-related noise value factors (in € per vehicle kilometer, per passenger kilometer or per tonne kilometer) as pure levy quotients, i.e. existing noise pollution or the corresponding costs can be divided by the mileage, e.g. the corresponding vehicle kilometers (vehicle km). As an example, a noise-related toll value factor could be derived, which could then be charged for each kilometer driven. However, such a value factor is ill-suited to monetize the noise effects of random mileage-related measures or developments in the transport sector, because it does not consider differences between noise emissions and exposure. For example, the construction of a bypass road, may typically result in an increase in vehicle kilometers, while reducing noise exposure as bypass roads tend to lead through less populated areas. Likewise, an overall decline in annual traffic (in vehicle km) in Germany does not necessarily imply lower levels of noise pollution, as traffic may, for example, decrease in sparsely populated areas while at the same time increasing in densely populated areas or at night-time, when it is a particular nuisance. For this reason, no mileage-related noise value factors are included in the value factors for transport related activities in this update of the handbook.[22] However, in order to emphasize that traffic-related noise does induce environmental and health damages, the corresponding columns in the tables are marked with asterisks (***).

Table 14: a) Environmental costs per vehicle kilometer (average of all routes) for different vehicle types in Germany at a value factor of 300€/t CO_2-eq, in €-cent$_{2024}$ / vehicle kilometer

Vehicle category	Emiss-ion con-cept	Operation				Pre-processes		Land consu-mption and fragme-ntation	Total
		Green-house gases	Air pollu-tants Exhaust	Air pollu-tants Abra-sion	Noise	Infra-structure and vehicles	Energy supply		
Car	**Petrol**	4.60	0.63	0.06	***	4.01	1.73	0.39	**11.42**
Car	**Diesel**	3.95	3.20	0.06	***	4.60	1.77	0.39	**13.97**
Car	**Electric**	0.00	0.00	0.06	***	6.21	4.50	0.39	**11.16**
Small motorcycle	**Petrol**	2.40	1.40	0.01	***	4.14	1.15	0.13	**9.23**
Motorcycle	**Petrol**	3.00	1.12	0.01	***	4.12	1.94	0.17	**10.36**
Public bus	**Diesel**	31.56	23.12	0.34	***	9.16	10.84	0.94	**75.96**
Coach	**Diesel**	21.14	18.61	0.20	***	11.54	8.15	0.94	**60.58**

[22] In order to e.g. compare variants between two measures or route alternatives, the local, spatial and temporal distribution of the sources, propagation conditions and recipients are to be modelled and the resulting noise exposure is to be calculated for each individual case. This can subsequently be assessed using the relevant exposure-impact functions and, if applicable, the exposure-related noise value factors of the Methodological Convention.

Vehicle category	Emiss-ion con-cept	Operation				Pre-processes		Land consu-mption and fragme-ntation	Total
		Green-house gases	Air pollu-tants Exhaust	Air pollu-tants Abra-sion	Noise	Infra-structure and vehicles	Energy supply		
Passenger train, long-distance	**Electric**	0.00	0.00	1.48	***	393.90	389.22	69.42	**854.02**
Passenger train, local transport	**Weigh-ted Av.**	29.33	44.12	0.76	***	115.60	159.40	46.28	**395.49**
Passenger air transport, short and medium haul		770.98	517.67	0.00	***	37.51	256.54	9.98	**1592.68**
Passenger air transport, long-haul		1278.79	932.52	0.00	***	42.05	425.72	18.34	**2697.42**
LCV	**Petrol**	4.71	1.26	0.06	***	3.24	2.02	0.42	**11.71**
LCV	**Diesel**	3.95	4.29	0.06	***	3.56	2.16	0.42	**14.44**
LCV	**Electric**	0.00	0.00	0.06	***	5.59	9.02	0.42	**15.09**
HGV <7.5t	**Diesel**	9.48	4.93	0.16	***	4.74	5.54	0.47	**25.32**
HGV 7.5-14t	**Diesel**	12.98	5.59	0.16	***	7.00	6.45	0.87	**33.05**
HGV 14-28t	**Diesel**	17.64	6.98	0.16	***	9.60	8.39	0.95	**43.72**
HGV: Trailer 28-40t	**Diesel**	22.37	6.88	0.16	***	13.53	9.43	1.19	**53.56**
Freight train	**Weigh-ted av.**	27.76	52.29	1.76	***	540.10	353.91	144.61	**1120.43**
Freight-air transport		1647.43	1247.61	0.00	***	41.44	546.78	30.24	**3513.50**
Motor vessels (inland waterways transport)		843.00	1911.94	0.00	***	1358.32	262.87	0.00	**4376.13**
Watercraft assemblies (inland waterways transport)		1533.47	3517.82	0.00	***	2491.64	516.40	0.00	**8059.33**

LCV = Light commercial vehicle
Weighted Av. = weighted average electric/diesel.
The value factors for air transport proportionally account for belly freight.

Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool, Calculations by INFRAS as part of the research project, van der Kamp et al. (2024), Anthoff (2024) and own calculations.

Table 15: b) Environmental costs per vehicle kilometer (average of all routes) for different vehicle types in Germany at a value factor of 880€/t CO_2-eq, in €-cent$_{2024}$ / vehicle kilometer

		Operation				Pre-processes		Land consu-mption and fragme-ntation	Total
Vehicle category	Emiss-ion con-cept	Green-house gases	Air pollu-tants - Exhaust	Air pollu-tants Abra-sion	Noise	Infra-structure and vehicles	Energy supply		
Car	Petrol	13.44	0.63	0.06	***	7.49	3.71	0.39	**25.72**
Car	Diesel	11.52	3.20	0.06	***	8.45	3.86	0.39	**27.48**
Car	Electric	0.00	0.00	0.06	***	10.93	11.67	0.39	**23.05**
Small motorcycle	Petrol	6.99	1.40	0.01	***	7.07	2.13	0.13	**17.73**
Motorcycle	Petrol	8.76	1.12	0.01	***	8.84	3.59	0.17	**22.49**
Public bus	Diesel	92.10	23.12	0.34	***	18.26	23.69	0.94	**158.45**
Coach	Diesel	61.70	18.61	0.20	***	22.69	17.81	0.94	**121.95**
Passenger train, long-distance	Electric	0.00	0.00	1.48	***	726.85	965.11	69.42	**1762.86**
Passenger train, local transport	Weigh-ted Av.	85.59	44.12	0.76	***	213.32	389.88	46.28	**779.95**
Passenger air transport, short and medium haul		2250.19	517.67		***	77.79	566.87	9.98	**3422.50**
Passenger air transport, long-haul		3732.30	932.52		***	87.15	940.72	18.34	**5711.03**
LCV	Petrol	13.76	1.26	0.06	***	5.99	4.34	0.42	**25.83**
LCV	Diesel	11.52	4.29	0.06	***	6.49	4.73	0.42	**27.51**
LCV	Electric	0.00	0.00	0.06	***	9.73	18.29	0.42	**28.50**
HGV <7.5t	Diesel	27.67	4.93	0.16	***	8.67	9.60	0.47	**51.50**
HGV 7.5-14t	Diesel	37.89	5.59	0.16	***	12.90	12.02	0.87	**69.43**
HGV 14-28t	Diesel	51.50	6.98	0.16	***	17.56	15.96	0.95	**93.11**

Vehicle category	Emiss-ion con-cept	Operation				Pre-processes		Land consu-mption and fragme-ntation	Total
		Green-house gases	Air pollu-tants - Exhaust	Air pollu-tants Abra-sion	Noise	Infra-structure and vehicles	Energy supply		
HGV: Trailer 28-40t	**Diesel**	65.30	6.88	0.16	***	24.77	19.02	1.19	**117.32**
Freight train	**Weigh-ted Av.**	81.01	52.29	1.76	***	1003.11	870.69	144.61	**2153.47**
Freight-air transport		4808.20	1247.61		***	85.90	1210.23	30.24	**7382.18**
Motor vessels (inland waterways transport)		2460.38	1911.94		***	1365.83	542.65		**6280.80**
Water craft assemblies (inland waterways transport)		4475.60	3517.82		***	2505.43	1066.04		**11564.89**

LCV = Light commercial vehicle
Weighted Av. = weighted average electric/diesel.
The value factors for air transport, proportionally account for belly freight.
Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project, van der Kamp et al. (2024), Anthoff (2024) and own calculations.

Table 16: a) Environmental costs per vehicle kilometer (motorway) for different vehicle types in Germany at a value factor of 300€/t CO_2-eq in €-cent$_{2024}$ / vehicle kilometer

		Operation				Pre-processes		Land consumption and fragmentation	Total
Vehicle - category	Emission concept	Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Noise	Infrastructure and vehicles	Energy supply		
Car	**Petrol**	5.27	0.8	0.05	***	4.01	1.73	0.39	**12.25**
Car	**Diesel**	4.03	3.98	0.05	***	4.6	1.77	0.39	**14.82**
Car	**Electric**	0	0	0.05	***	6.21	4.5	0.39	**11.15**
Small motorcycle	**Petrol**	3.68	2.14	0.01	***	4.14	1.15	0.13	**11.25**
Motorcycle	**Petrol**	3.86	2.74	0.01	***	4.12	1.94	0.17	**12.84**
Public bus	**Diesel**	21.25	12.46	0.09	***	9.16	10.84	0.94	**54.74**
Coach	**Diesel**	20.17	16.1	0.09	***	11.54	8.15	0.94	**56.99**
LCV	**Petrol**	4.94	1.45	0.05	***	3.24	2.02	0.42	**12.12**
LCV	**Diesel**	4.03	6.22	0.05	***	3.56	2.16	0.42	**16.44**
LCV	**Electric**	0	0	0.05	***	5.59	9.02	0.42	**15.08**
HGV <7.5t	**Diesel**	9.77	4.78	0.09	***	4.74	5.54	0.47	**25.39**
HGV 7.5-14t	**Diesel**	13.16	5.21	0.09	***	7	6.45	0.87	**32.78**
HGV 14-28t	**Diesel**	17.39	5.41	0.09	***	9.6	8.39	0.95	**41.83**
HGV: Trailer 28-40t	**Diesel**	21.63	5.84	0.09	***	13.53	9.43	1.19	**51.71**

Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project, van der Kamp et al. (2024), Anthoff (2024).

Table 17: b) Environmental costs per vehicle kilometer (motorway) for different vehicle types in Germany at a value factor of 880€/t CO_2-eq, in €-cent$_{2024}$ / vehicle kilometer

		Operation				Pre-processes		Land consumption and fragmentation	Total
Vehicle - category	Emission concept	Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Noise	Infrastructure and vehicles	Energy supply		
Car	**Petrol**	15.37	0.8	0.05	***	7.49	3.71	0.39	**27.81**
Car	**Diesel**	11.75	3.98	0.05	***	8.45	3.86	0.39	**28.48**
Car	**Electric**	0	0	0.05	***	10.93	11.67	0.39	**23.04**
Small motorcycle	**Petrol**	10.74	2.14	0.01	***	7.07	2.13	0.13	**22.22**
Motorcycle	**Petrol**	11.27	2.74	0.01	***	8.84	3.59	0.17	**26.62**
Public bus	**Diesel**	62.03	12.46	0.09	***	18.26	23.69	0.94	**117.47**
Coach	**Diesel**	58.88	16.1	0.09	***	22.69	17.81	0.94	**116.51**
LCV	**Petrol**	14.42	1.45	0.05	***	5.99	4.34	0.42	**26.67**
LCV	**Diesel**	11.75	6.22	0.05	***	6.49	4.73	0.42	**29.66**
LCV	**Electric**	0	0	0.05	***	9.73	18.29	0.42	**28.49**
HGV <7.5t	**Diesel**	28.53	4.78	0.09	***	8.67	9.6	0.47	**52.14**
HGV 7.5-14t	**Diesel**	38.4	5.21	0.09	***	12.9	12.02	0.87	**69.49**
HGV 14-28t	**Diesel**	50.77	5.41	0.09	***	17.56	15.96	0.95	**90.74**
HGV: Trailer 28-40t	**Diesel**	63.13	5.84	0.09	***	24.77	19.02	1.19	**114.04**

Source: Emission factors of direct emissions are from HBEFA v3.3 and Tremod; emission factors of indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project, van der Kamp et al. (2024), Anthoff (2024).

Table 18: a) Environmental costs per vehicle kilometer (rural) for different vehicle types in Germany at a value factor of 300€/t CO_2-eq in €-cent$_{2024}$ / vehicle kilometer

		Operation				Pre-processes		Land consumption and fragmentation	Total
Vehicle category	Emissions concept	Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Noise	Infrastructure and vehicles	Energy supply		
Car	**Petrol**	3.86	0.58	0.03	***	4.01	1.73	0.39	**10.6**
Car	**Diesel**	3.42	2.59	0.03	***	4.6	1.77	0.39	**12.8**
Car	**Electric**	0	0	0.03	***	6.21	4.5	0.39	**11.14**
Small motorcycle	**Petrol**	2.31	1.33	0.01	***	4.14	1.15	0.13	**9.07**
Motorcycle	**Petrol**	2.8	1.08	0.01	***	4.12	1.94	0.17	**10.13**
Public bus	**Diesel**	27.34	16.31	0.13	***	9.16	10.84	0.94	**64.71**
Coach	**Diesel**	20.29	17.38	0.13	***	11.54	8.15	0.94	**58.43**
Passenger train, long-distance	**Electric**	0	0	1.01	***	393.9	389.22	69.42	**853.55**
Passenger train, local transport	**Weighted. Av.**	29.33	43.6	0.52	***	115.6	159.4	46.28	**394.72**
LCV	**Petrol**	4.06	1.12	0.03	***	3.24	2.02	0.42	**10.89**
LCV	**Diesel**	3.42	3.72	0.03	***	3.56	2.16	0.42	**13.32**
LCV	**Electric**	0	0	0.03	***	5.59	9.02	0.42	**15.06**
HGV < 7.5t	**Diesel**	8.85	4.5	0.11	***	4.74	5.54	0.47	**24.22**
HGV 7.5-14t	**Diesel**	12.22	5.05	0.11	***	7	6.45	0.87	**31.7**
HGV 14-28t	**Diesel**	17.15	6.96	0.11	***	9.6	8.39	0.95	**43.17**
HGV: Trailer 28-40t	**Diesel**	22.28	7.13	0.11	***	13.53	9.43	1.19	**53.66**
Freight train	**Weighted Av.**	27.76	51.41	1.2	***	540.1	353.91	144.61	**1118.99**

LCV = Light commercial vehicle
Weighted Av. = weighted average electric/diesel.
Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project, van der Kamp et al. (2024), Anthoff (2024).

Table 19: b) Environmental costs per vehicle kilometer (rural) for different vehicle types in Germany at a value factor of 880€/t CO_2-eq in €-cent$_{2024}$ / vehicle kilometer

		Operation				Pre-processes		Land consu-mption and fragme-ntation	Total
Vehicle category	**Emiss-ion conc-ept**	**Green-house gases**	**Air pollu-tants Exhaust**	**Air pollu-tants Abra-sion**	**Noise**	**Infra-structure and vehicles**	**Energy supply**		
Car	**Petrol**	11.27	0.58	0.03	***	7.49	3.71	0.39	**23.47**
Car	**Diesel**	9.98	2.59	0.03	***	8.45	3.86	0.39	**25.3**
Car	**Electric**	0	0	0.03	***	10.93	11.67	0.39	**23.03**
Small motorcycle	**Petrol**	6.74	1.33	0.01	***	7.07	2.13	0.13	**17.4**
Motorcycle	**Petrol**	8.16	1.08	0.01	***	8.84	3.59	0.17	**21.85**
Public bus	**Diesel**	79.79	16.31	0.13	***	18.26	23.69	0.94	**139.12**
Coach	**Diesel**	59.21	17.38	0.13	***	22.69	17.81	0.94	**118.16**
Passenger train, long-distance	**Electric**	0	0	1.01	***	726.85	965.11	69.42	**1762.39**
Passenger train, local transport	**Weight ed Av.**	85.59	43.6	0.52	***	213.32	389.88	46.28	**779.18**
LCV	**Petrol**	11.84	1.12	0.03	***	5.99	4.34	0.42	**23.74**
LCV	**Diesel**	9.98	3.72	0.03	***	6.49	4.73	0.42	**25.38**
LCV	**Electric**	0	0	0.03	***	9.73	18.29	0.42	**28.48**
HGV < 7.5t	**Diesel**	25.83	4.5	0.11	***	8.67	9.6	0.47	**49.2**
HGV 7.5-14t	**Diesel**	35.68	5.05	0.11	***	12.9	12.02	0.87	**66.62**
HGV 14-28t	**Diesel**	50.06	6.96	0.11	***	17.56	15.96	0.95	**91.6**
HGV: Trailer 28-40t	**Diesel**	65.02	7.13	0.11	***	24.77	19.02	1.19	**117.23**
Freight train	**Weight ed Av.**	81.01	51.41	1.2	***	1003.11	870.69	144.61	**2152.04**

LCV = Light commercial vehicle
Weighted Av. = weighted average electric/diesel.
Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project, van der Kamp et al. (2024), Anthoff (2024).

Table 20: a) Environmental costs per vehicle kilometer (urban) for different vehicle types in Germany at a value factor of 300€/t CO_2-eq in €-cent$_{2024}$ / vehicle kilometer

Vehicle category	Emission concept	Operation				Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Noise	Infrastructure and vehicles	Energy supply		
Car	**Petrol**	4.91	0.55	0.23	***	4.01	1.73	0.39	**11.83**
Car	**Diesel**	4.53	3.47	0.23	***	4.6	1.77	0.39	**14.99**
Car	**Electric**	0	0	0.23	***	6.21	4.5	0.39	**11.34**
Small motorcycle	**Petrol**	2.17	1.28	0.06	***	4.14	1.15	0.13	**8.93**
Motorcycle	**Petrol**	3.06	0.73	0.06	***	4.12	1.94	0.17	**10.09**
Public bus	**Diesel**	35.18	29.97	1.86	***	9.16	10.84	0.94	**87.94**
Coach	**Diesel**	29.14	36.65	1.86	***	11.54	8.15	0.94	**88.28**
Passenger train, long-distance	**Electric**	0	0	6.16	***	393.9	389.22	69.42	**858.7**
Passenger train, local transport	**Weighted Av.**	29.33	49.28	3.14	***	115.6	159.4	46.28	**403.03**
LCV	**Petrol**	4.94	1.26	0.23	***	3.24	2.02	0.42	**12.11**
LCV	**Diesel**	4.53	4.3	0.23	***	3.56	2.16	0.42	**15.19**
LCV	**Electric**	0	0	0.23	***	5.59	9.02	0.42	**15.25**
HGV <7.5t	**Diesel**	8.65	7.84	1.73	***	4.74	5.54	0.47	**28.98**
HGV 7.5-14t	**Diesel**	13.73	10.87	1.73	***	7	6.45	0.87	**40.66**
HGV 14-28t	**Diesel**	21.81	16.96	1.73	***	9.6	8.39	0.95	**59.45**
HGV: Trailer 28-40t	**Diesel**	29.89	17.53	1.73	***	13.53	9.43	1.19	**73.3**
Freight train	**Weighted Av.**	27.76	60.96	7.31	***	540.1	353.91	144.61	**1134.65**

LCV = Light commercial vehicle
Weighted Av.= Weighted Average Electric/Diesel.
Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project.

Table 21: b) Environmental costs per vehicle kilometer (urban) for different vehicle types in Germany at a value factor of 880€/t CO_2-eq in €-cent$_{2024}$ / vehicle kilometer

		Operation				Pre-processes		Land consu-mption and fragme-ntation	Total
Vehicle category	**Emiss-ion con-cept**	**Green-house gases**	**Air pollu-tants Exhaust**	**Air pollu-tants Abras ion**	**Noise**	**Infra-structure and vehicles**	**Energy supply**		
Car	**Petrol**	14.34	0.55	0.23	***	7.49	3.71	0.39	**26.72**
Car	**Diesel**	13.21	3.47	0.23	***	8.45	3.86	0.39	**29.62**
Car	**Electric**	0	0	0.23	***	10.93	11.67	0.39	**23.23**
Small motorcycle	**Petrol**	6.33	1.28	0.06	***	7.07	2.13	0.13	**16.99**
Motorcycle	**Petrol**	8.92	0.73	0.06	***	8.84	3.59	0.17	**22.32**
Public bus	**Diesel**	102.67	29.97	1.86	***	18.26	23.69	0.94	**177.39**
Coach	**Diesel**	85.04	36.65	1.86	***	22.69	17.81	0.94	**164.99**
Passenger train, long-distance	**Electric**	0	0	6.16	***	726.85	965.11	69.42	**1767.54**
Passenger train, local transport	**Weigh-ted Av.**	85.59	49.28	3.14	***	213.32	389.88	46.28	**787.49**
LCV	**Petrol**	14.43	1.26	0.23	***	5.99	4.34	0.42	**26.66**
LCV	**Diesel**	13.21	4.3	0.23	***	6.49	4.73	0.42	**29.38**
LCV	**Electric**	0	0	0.23	***	9.73	18.29	0.42	**28.67**
HGV <7.5t	**Diesel**	25.25	7.84	1.73	***	8.67	9.6	0.47	**53.57**
HGV 7.5-14t	**Diesel**	40.06	10.87	1.73	***	12.9	12.02	0.87	**78.46**
HGV 14-28t	**Diesel**	63.65	16.96	1.73	***	17.56	15.96	0.95	**116.82**
HGV: Trailer 28-40t	**Diesel**	87.24	17.53	1.73	***	24.77	19.02	1.19	**151.48**
Freight train	**Weigh-ted Av.**	81.01	60.96	7.31	***	1003.11	870.69	144.61	**2167.69**

LCV = Light commercial vehicle
Weighted Av.= Weighted Average Electric/Diesel.
Source: Emission factors for direct emissions are from HBEFA v3.3 and Tremod; emission factors for indirect emissions are from Tremod, Ecoinvent 3.3 and Mobitool. Calculations by INFRAS as part of the research project.

Detailed data on the monetized environmental impacts per vehicle kilometer for the different Euronorm classes can be found in the appendix.

To enable a conversion of value factors per vehicle kilometer for the different vehicle types into value factors per passenger kilometer (pkm) and tonne kilometer (tkm), information on the rate of occupation/utilization by vehicle type is needed. For this purpose, data from the 2018 market investigation of the Federal Network Agency on utilization rates were used for trains and recommendations from TREMOD 5.8 were used for all other vehicles. This information is summarized in Table 22 below.

Table 22: Rate of occupation/utilization by vehicle type

Vehicle type	Passengers / vehicle	Tonnes /vehicle
Car	1.49	
Small motorcycle	1.02	
Motorcycle	1.11	
Public bus	16.5	
Coach	30.4	
Passenger train, long-distance	276	
Passenger train, local transport	81	
Passenger air transport (short- and medium-haul)	105	
Passenger air transport (long-haul)	257	
HGV <7.5t		0.94
HGV 7.5-14t		1.59
HGV 14-28t		3.44
HGV: Trailer 28-40t		10.75
Freight train		499
Freight-air transport		42.1
Inland waterways transport motor vessels		1,060
Inland waterways transport water craft assemblies		1,945

The value factors for air transport, proportionally account for belly freight.
No utilisation data is available for light commercial vehicles (LCV).
Source: TREMOD 5.8 or Bundesnetzagentur, Marktuntersuchung Eisenbahn 2018.

With these occupation / utilization rates, all costs indicated as €-cent per vehicle kilometer can be converted into €-cent per passenger kilometer (pkm) or tonne kilometer (tkm).

Table 23 exemplarily illustrates the resulting average environmental costs (across all routes, emission factors for 2016) per passenger or tonne kilometer. As noise costs are not calculated based on mileage, they are also not included here.

Table 23: Environmental costs per passenger or tonne kilometre for various vehicle types in Germany in €-cent$_{2024}$ / pkm or tkm

Vehicle type		Unit	Total environmental costs (GHG value factor 300 €/t CO_2 eq.)	Total environmental costs (GHG value factor 880 €/t CO_2 eq.)
Car	Petrol	€-cent/Pkm	7.66	17.24
Car	Diesel	€-cent/Pkm	9.36	18.42
Car	Electric	€-cent/Pkm	7.48	15.46
Small motorcycle	Petrol	€-cent/Pkm	9.07	17.42
Motorcycle	Petrol	€-cent/Pkm	9.35	20.27
Public bus	Diesel	€-cent/Pkm	4.6	9.6
Coach	Diesel	€-cent/Pkm	1.99	4.01
Passenger train, long-distance	Electric	€-cent/Pkm	3.09	6.39
Passenger train, local transport	Weighted av.	€-cent/Pkm	4.88	9.63
Passenger air transport	Short & Medium-distance	€-cent/Pkm	15.22	32.71
Passenger air transport	Long distance	€-cent/Pkm	10.51	22.24
HGV <7.5t	Diesel	€-cent/tkm	26.82	54.56
HGV 7.5-14t	Diesel	€-cent/tkm	20.79	43.67
HGV 14-28t	Diesel	€-cent/tkm	12.7	27.05
HGV: Trailer 28-40t	Diesel	€-cent/tkm	4.98	10.91
Freight train	Weighted av.	€-cent/tkm	2.25	4.32
Freight-air traffic		€-cent/tkm	83.55	175.55
Motor vessels (inland waterways transport)		€-cent/tkm	4.13	5.92
Water craft assemblies (inland waterways transport)		€-cent/tkm	4.14	5.95

Weighted. av. = Weighted average electric/diesel.
The value factors for air transport proportionally account for belly freight. Source: Calculations by INFRAS as part of the research project.

5 Nitrogen (N) and phosphorus (P) emissions

Please note that the value factors in this chapter present a partial update: The new, most up-to-date value factors on air pollutant and GHG emissions were used to compute the monetized environmental impacts of nitrogen emissions into the air. However, for the remaining value factors only the price level was adjusted to 2024 - an update will become available with the publication of the Handbook on Environmental Value Factors 4.0 in 2025.

Environmental damages from nitrogen and phosphorus emissions arise along various impact pathways. Nitrogen emissions, among other things, pollute the groundwater and air and thereby entail health costs as well as water treatment costs; whereas nitrogen and phosphorus emissions, among other things, put a strain on surface waters through eutrophication and acidification and thus lead to the impairment and loss of ecosystems. The monetized environmental damages that stem from emissions into the air, groundwater as well as surface waters are presented individually below. When applying the value factors, the relevant impact pathways must be determined for each specific application. No damage costs could be identified for the acidification of soils and the resulting ecosystem damages.

5.1 Emissions into the air (direct and indirect)

No data regarding the harmful effects of phosphorus emissions into the air are available and consequently no value factors can be specified. For emissions of nitrogen into the air, we recommend using the following value factors, broken down into the relevant impact categories, when no specific information on the emission source is available (values are consistent with the value factors for N-compounds in the chapter on air pollutants and the value for N_2O in the chapter on greenhouse gases).

Table 24: Environmental costs of nitrogen (N) emissions to air (direct and indirect, unknown source)

N-compound	Impact category	Value factor €$_{2024}$ /kg N
Nitrogen oxides (NOx)	- health	113.3
	- biodiversity	9.6
	- crop failures	5.2
	- buildings/materials	0.6
	Total	**128.7**
Ammonia (NH_3)	- health	63.3
	- biodiversity	14.2
	- crop failures [23]	-0.1
	- buildings/materials	0
	Total	**77.4**
Nitrous oxide (laughing gas - N_2O)	**Climate (0% PRTP)**	**393.5**
	Climate (1% PRTP)	**163.8**

Source: Schäppi et al. (2019), Anthoff (2024), van der Kamp et al. (2024) and own calculations; costs for biodiversity losses include damages as a result of eutrophication and acidification through deposition.

Note: In contrast to Chapters 1 and 2, the value factors here refer to 1kg N, not to 1kg of the respective chemical compound (NO_x, NH_3, N_2O); indirect emissions arise, e.g., from the emission of N_2O from soils or from the contribution of NO_x to the formation of particulate matter.

5.2 Emissions into surface water and groundwater

When determining the damage caused by the emission of nitrogen and phosphorus into surface waters, it should be noted that it is only through the interaction of these two substances that the damaging effect through eutrophication arises. As plants need a ratio of approximately 16 parts nitrogen to 1 part phosphorus to grow, in almost all cases one of the two substances has a growth-limiting effect. Consequently, the emission of the other substance into the corresponding water body does not cause any additional damage – at least in the short term.

However, exclusively focusing on the limiting substance neglects that in general the concentration of both substances is too high in most water bodies, implying that both substances have a potential for causing damages. The value factors specified below should therefore be interpreted as a **lower bound for damages,** as a value factor of 0 is applied for the non-limiting

[23] Crop failures due to soil acidification are not considered here due to lack of data.

substance, thereby ignoring that in most cases the concentration of the non-limiting substance is also above the level that would be appropriate for a good status of the water body.

The emission of nitrogen into surface waters also contributes to acidification. However, no damage costs could be determined for this effect.

In the table below, the monetized environmental impacts of N and P are specified assuming that the respective substance is the limiting factor for the eutrophication of the water body in question. Therefore, the entire environmental impact is attributed to the respective substance. When applying the below value factors, it must be determined on a case-by-case basis which substance has a limiting effect. To avoid double counting when ascertaining the total costs, all of the environmental costs are to be attributed to this substance.

Table 25: Value factors for nitrogen emissions to groundwater and of nitrogen and phosphorus as respective growth-limiting factors in surface waters

Substance	Impact pathway	Value factor $€_{2024}$ /kg N
Nitrogen	Groundwater	2.2
	Inland waters	8.5
	Coastal and marine waters	24.5
Phosphorus	Inland waters	180.1
	Coastal and marine waters	517.7

Source: Schäppi et al. (2019), own calculations.

When nitrogen and phosphorus are emitted into surface waters, the damaging effects first materialize in the inland water body and subsequently in the coastal and marine waters (except in the rather rare case of direct emissions to coastal waters). The effects must therefore be added.

In most cases, when assessing phosphorus and nitrogen emissions, it is unknown whether the affected waterbody is limited by phosphorous or nitrogen. For these cases, the following value factors are recommended:

Table 26: Value factors for nitrogen and phosphorus emissions into surface waters when water bodies' limiting substance is unknown

	Value factor nitrogen $€_{2024}$ / kg N	Value factor phosphorus $€_{2024}$ / kg P
Emission into surface water	24.5	180.1

Source: Schäppi et al. (2019), own calculations.

These average value factors for emissions into surface waters are based on the assumption that the respective pollutant is the sole cause of the damage in the respective type of water body. This reflects that in most inland waters, plant growth is limited by phosphorus, whereas in most marine and coastal waters nitrogen is the limiting substance. Therefore, for the total damage caused by emissions into surface waters (inland waters + sea), the value factor of 24.5 €/kg (value factor for emission into marine waters) should be used for nitrogen, and the value factor of 180.1 €/kg (value factor for emissions into inland waters) for phosphorus. This way double counting is avoided.

5.3 Value factors for nitrogen and phosphorus from agriculture

The agricultural sector is one of the major emitters of nitrogen and phosphorus due to the application of manure and mineral fertilizers. Besides the intended uptake by plants, nitrogen and phosphorus also enter the environment through various pathways, thereby causing environmental damages.

Average value factors for nitrogen application in agricultural practice:

14,54 $€_{2024}$ per kg nitrogen (0% PRTP)

11,23 $€_{2024}$ per kg nitrogen (1% PRTP).

This value is the result of calculating a weighted average of the agricultural area in Germany (cf. UBA (2020) [24]) of the effects of NO_X, N_2O and NH_3 emissions from the application of mineral and organic fertilizers as well as from the management of organic soils, nitrate leaching with seepage water from agricultural land and N input from agricultural land into surface waters via runoff, erosion and drainage.

Average value factors for phosphorus application in agricultural practice:

5,33 $€_{2024}$ per kg phosphorus.

This value is an average of the effects of P emissions from the application of mineral and organic fertilizers. The total amounts of phosphorus[25] applied were put in relation to the amounts of phosphorus entering the water bodies through input pathways, which are mainly attributable to agricultural activity (erosion, groundwater, surface runoff, drainage)[26].

[24] UBA: Reactive nitrogen fluxes in Germany 2010-2014 (DESTINO Report 2), May 2020, Fig. 12-1 p. 140

[25] Farm manure: DESTATIS (2017b); mineral fertilizer: DESTATIS (2019); conversion factor P_2O_5 to P (= 0.436): Landesanstalt für Landwirtschaft und Gartenbau, Sachsen-Anhalt (2018) (State Institute for Agriculture and Horticulture, Saxony-Anhalt (2018)).

[26] Results from Modeling of Regionalized Emissions (MoRe). Values for 2015.

6 Building materials

Please note that due to the nature of the model underlying the calculations on building materials, it was not possible to update the value factors for climate and air pollutants within this chapter. The monetized environmental impacts of building materials presented below are still based on the emission factors as well as value factors on air pollutants and climate damage from the previous version of this handbook, "Methodological Convention 3.1". As for the remaining chapters, the price level has been adjusted to 2024.

The production of building materials generates a wide range of environmental impacts: the extraction of raw materials destroys ecosystems, emits greenhouse gases and air pollutants, and releases toxic substances into soils and water bodies. Further emissions of various kinds accrue during transport and processing.

When assessing the monetized environmental impacts of building materials, it is important to distinguish between the use of primary building materials and the use of recycled building materials. By using recycled building materials, the environmental impacts of raw material extraction can be avoided. The processing costs can also be reduced if the processing of the recycled building materials is less energy intensive than for primary building materials.

As in the entire document, the 2016 emission factors are the basis of the value factors for building materials. This implies that processes that were introduced after 2016 or increases in the use of renewable energies after 2016 are not reflected in the value factors.

The value factors for building materials are the sum of the monetized environmental impacts that accrue along the supply chain. Data on such effects are collected in life cycle assessment (LCA) databases – to the extent that they are available. The data used in this handbook are largely sourced from the EcoInvent database.[27] The value factors reported below do not consider the use phase of the building materials (e.g. the environmental impacts of building use), nor their deconstruction, recycling or disposal. Hence, they do not cover the entire life cycle. Consequently, no conclusive recommendations for specific construction methods can be derived from these data alone.

Furthermore, it must be borne in mind that the LCA data do not consider all environmental effects. Especially in the initial steps of the supply chain (raw material extraction), the data are often incomplete (concerning the consequences for biodiversity, accidents, etc.). On top of that, the study that underlies the valuation of ecosystem damage (according to Ott et al. 2006) produces very conservative estimates. The specified **value factors therefore represent lower limits that are likely to significantly underestimate the actual damages incurred, depending on the building material.**

Two important factors for the comparison of buildings should be kept in mind when using the value factors for building materials recommended below: Firstly, in addition to the building materials used, the construction method (e.g. insulated or not) is essential with regard to, e.g., the resulting expenditure for heat and insulation. Likewise, an aluminium construction, for example, is significantly lighter in weight than a steel construction of similar function, which must be considered when interpreting the value factors per tonne of building material.

Secondly, the actual amount of materials used depends on the specific function of the building. Consequently, building materials can only be compared if they are used in buildings of similar

[27] For specific information on the data used, see Bijleveld/de Bruyn/Sutter (2019).

function. The use of the buildings must also be considered with regard to these aspects, as this also has a substantial impact on the environmental costs incurred in the course of the buildings' life cycle.

The value factors for building materials were derived based on the cradle-to-gate concept. The cradle-to-gate concept covers all upstream chains and production processes of the building material, however the environmental impacts that accrue during transport, use and disposal of the finished building material are not included. The inclusion of these life cycle phases may in some cases lead to changes regarding the ranking of monetized damages per tonne between different building materials. This is particularly true for timber: the cradle-to-gate concept entails that the corresponding carbon sequestration during the use phase is not considered, although the use of timber for construction may store carbon for decades or even centuries. Furthermore, reforestation of cleared areas may lead to further, new carbon sequestration and the energetic use of timber, either at the end of the timber products use phase or of by-products resulting from the timber processing may substitute fossil fuels. In conjunction, these effects may result in substantial environmental benefits of using timber from sustainable forestry as a construction material that are not reflected in the cradle-to-gate analysis framework. Keeping these aspects in mind, the following can be stated regarding the value factors:

- Non-ferrous metals exhibit relatively high monetized environmental impacts per tonne, despite the incomplete consideration of raw material extraction.
- Steel and plastics (insulation and PVC pipes) are carbon intensive materials and also have relatively high environmental costs.
- Sand and crushed stone have the lowest monetized impact per tonne as they are quite easily extracted and require little or no further processing (only optional crushing and washing). Bricks have slightly higher environmental costs compared to sand and crushed stone due to the production steps for brick production.
- Concrete and asphalt have a relatively low monetized impact per tonne, however, as they are used in very large quantities in construction projects, they have a very large overall environmental impact.

To a large extent the high environmental costs for most of the timber options are related to land use (land use accounts for between 40% and 75%). Despite the high costs, the conservative consideration of biodiversity damages from timber production implies that the true damages are likely to be significantly underestimated. This is especially true for many types of timber from tropical areas.

Table 27: Value factors for building materials (+) and environmental benefits from recycling building materials (-)

Category	Variant	Unit	Characteristics	Value factor in €2024/unit
Steel	Finished cold rolled coil, cradle-to-gate	1,000 kg		680
Steel	Hot dip galvanised coil, cradle-to-gate	1,000 kg		750
Steel	Rebar, cradle-to-gate	1,000 kg		640
Steel	Steel section, cradle-to-gate	1,000 kg		680
Steel	Welded pipe, cradle-to-gate	1,000 kg		730
Steel, recycling potential	all above categories	1,000 kg		-410
Non-ferrous metals	Aluminium sheet, 60% recycled content	1,000 kg	60% scrap	2,910
Non-ferrous metals, recycling potential	Aluminium sheet, 60% recycled content	1,000 kg	60% scrap	-1,130
Non-ferrous metals	Copper pipe, 71% recycled content	1,000 kg	71% scrap	8,380
Non-ferrous metals, recycling potential	Copper pipe, 71% recycled content	1,000 kg	71% scrap	-2,550
Timber	Sawn softwood EU	$1m^3$ 1,000 kg	540 kg/m^3 (at 20% humidity)	370 690
Timber	Sawn hardwood EU	$1m^3$ 1,000 kg	780 kg/m^3 (at 20% humidity)	210 270
Timber	Sawn tropical hardwood, Cameroon (CM)	$1m^3$ 1,000 kg	1,200 kg/m^3 (at 20% humidity)	1,690 1,410
Timber	Sawn tropical softwood, Brazil (BR)	$1m^3$ 1,000 kg	600 kg/m^3 (at 20% humidity)	1,180 1,960
Timber	Round hardwood Eucalyptus, Thailand (TH)	$1m^3$ 1,000 kg	990 kg/m^3 (at 20% humidity)	100 100
Timber	Plywood panel (indoor use)	1,000 kg	780 kg/m^3 (at 20% humidity)	630

Category	Variant	Unit	Characteristics	Value factor in €2024/unit
Timber	Oriented Strand Board (OSB)	1,000 kg	540 kg/m^3 (at 20% humidity)	400
Concrete	Concrete C20/25	1,000 kg		22
Concrete	Concrete C30/37	1,000 kg		27
Concrete	Concrete C35/45	1,000 kg		30
Concrete	Concrete C45/55	1,000 kg		35
Concrete	Concrete C50/60	1,000 kg		38
Asphalt	Asphalt road pavement, 0% reclaimed asphalt pavement (RAP)	1m^2; 1.8 kg/m^2		20
Asphalt	Asphalt road pavement, 7% reclaimed asphalt pavement (RAP)	1m^2; 1.8 kg/m^2		18
Asphalt	Asphalt road pavement, 24% reclaimed asphalt pavement (RAP)	1m^2; 1.8 kg/m2		17
Stony building materials	Gravel	1,000 kg		2
Stony building materials	Sand	1,000 kg		2
Stony building materials	Clay brick	1,000 kg		84
Stony building materials	Sandlime brick	1,000 kg		53
Plastics/insulation	PVC pipe	1,000 kg		680
Plastics/insulation	Polystyrene foam (EPS) insulation	1,000 kg	Density 20 kg/m^3	840
Plastics/insulation	Glass wool insulation	1,000 kg	Density 10-100 kg/m^3	720
Plastics/insulation	Mineral wool insulation	1,000 kg	Density 46 kg/m^3	530
Plastics/insulation	Polyurethane rigid foam insulation	1,000 kg	Density 33 kg/m^3	1,530

Note: The monetized environmental impacts of the different steel variants factor in the average proportions of steel scrap used in Germany in the production of the respective variants. The overall recycling rate in steel production in Germany is approx. 44% (see statistical yearbook of the steel industry). Recycling potential represents the environmental benefit from additional recycled material brought to the market by recycling the building material. The corresponding value factors therefore have a negative sign. If a building material already contains a recycled content, the recycling potential is only calculated for the remaining share of primary building material.
Source: Bijleveld M. et al (2019).

7 Climate costs in agriculture

Please note that the value factors in this chapter present a partial update: The new, most up-to-date value factors on GHG were used to compute the climate impacts of agriculture. However, no adjustments have been made to the emission factors and other underlying data. A comprehensive revision of these components will become available with the publication of the Handbook on Environmental Value Factors 4.0 in 2025.

Agricultural production is responsible for a considerable share of greenhouse gas emissions in Germany. To facilitate the application and use of climate damage costs, in this chapter the climate impacts are broken down for selected crops and animal products.

Value factors for the cultivation of important agricultural crops are recommended below. The crops which are produced in the largest quantities in Germany are wheat, barley, potatoes and silage maize. They are either processed for food or animal feed. Another important crop is soy, which is used as animal feed. Besides these crops, we also consider oilseeds in this assessment of climate costs in agricultural production, namely domestic rapeseed oil as well as palm oil imports (from Malaysia).

With respect to "animal production", the production of milk[28] as well as beef, pork and poultry meat are considered. All animal products are valued in kilograms live weight at farmgate. Further refining steps as well as packaging are not included in the value factors. The value factors therefore refer to the agricultural output at farmgate, not to the final goods (i.e. 1 liter of milk at farmgate and not 1 liter of milk after processing or in the supermarket).

Plant products (incl. oilseeds):

- Wheat
- Barley
- Potatoes
- Maize (grain and silage maize)
- Soy (Europe and South America)
- Rapeseed oil
- Palm oil (import)

Animal products:

- Milk
- Beef

[28] A separate REFOPLAN project has been carried out on the environmental costs of milk production: "Visibility of hidden environmental costs of agriculture using the example of milk production systems" (FKZ: 3717 11 238 0).

- Pork
- Poultry

We calculate value factors for these agricultural products using both climate value factors illustrated in Chapter 1, i.e. using a 0% PRTP (880 $€_{2024}$ / t CO_2-eq) and 1% PRTP (300 $€_{2024}$ / t CO_2-eq), both referring to emissions in 2024. The best available data sets refer to cultivation in Switzerland (wheat, barley, potatoes, pork, poultry, all of the above from organic farming ; grain maize, silage maize, soy, all of the latter from integrated and organic farming, rapeseed oil average, suckler cow husbandry, all of the latter from integrated farming), Germany (wheat, barley, milk, beef large-scale fattening, pork, all of the above from conventional farming), Canada (potatoes without indication of production type), Brazil (South American soy), Malaysia (palm oil) and France (poultry conventional farming).

The data on milk and beef are based on Bystricky et al. (2015). Most other data were sourced from Ecoinvent Version 3.5. For both, pork and poultry, the Ecoinvent database does not contain any values for Germany or close foreign countries. These data are sourced from the Agroscope Research Station (ART 2012).

The following table specifies the climate costs of plant-based food production. A distinction is made between conventional, integrated production (IP)[29] and organic production.

Table 28: Climate related value factors for the production of plant-based food and animal feed in €-cent$_{2024}$ (climate value factors 300 $€_{2024}$ / t CO_2-eq and 880 $€_{2024}$ / t CO_2-eq)

Products	Production type	300 € / t CO_2-eq €-cent / kg	880 € / t CO_2-eq €-cent / kg
Wheat	Conventional	16.80	49.28
	Organic	12.25	35.94
Barley	Conventional	15.31	44.88
	Organic	11.03	32.37
Potatoes	no information	6.31	18.48
	Organic	3.80	11.14
Maize (grains)	integrated production	11.00	32.26
	Organic	16.25	47.66
Silage maize	integrated production	1.48	4.35
	Organic	1.42	4.15
Soy (Europe)	integrated production	22.35	65.56
	Organic	18.28	53.63
Soy (South America)	Conventional	138.91	407.44

Source: Own calculation based on Ecoinvent Version 3.5, UBA (2019b) and Anthoff (2024), depending on availability data are for Germany, Switzerland, Canada and Brazil.

[29] Integrated production (IP) is an intermediate step between conventional agriculture and organic agriculture. Integrated production uses methods that have the least possible negative impact on the environment, but without adopting all the restrictions of organic farming. In Switzerland, IP regulations are clearly defined. In Germany there is no clear functional equivalent.

As can be seen in Table 28, climate costs in organic farming tend to be lower than in conventional farming. The production of potatoes and silage maize are associated with the lowest climate impact.

By far the highest climate costs are caused by imported soy from South America (Brazil). The value factor accounts for land conversion, but not the transport to Europe. As a significant part of the feed in agriculture is imported soy, the data set on imported soy was mostly considered for comparison purposes. Due to the climate impact of land use change, the climate costs associated with imported soy are about six times higher than for soy produced in Europe. The difference is even larger when relying on organic farming methods in Europe.

Table 29: Climate related value factors of oilseed production in €-cent$_{2024}$ (climate value factors 300 €$_{2024}$ / t CO_2-eq and 880 €$_{2024}$ / t CO_2-eq)

Products	Production type	300 € / t CO_2-eq €-cent / kg	880 € / t CO_2-eq €-cent / kg
Rapeseed oil	Average	50.25	147.40
Palm oil (Malaysia)	Incl. land use change	112.83	330.97

Source: Own calculation based on Ecoinvent Version 3.5, UBA (2019b) and Anthoff (2024).

Table 29 illustrates the climate related environmental costs from oilseed production per kilogram. The high value factors for palm oil produced in Malaysia are to a large extent due to the climate impact of land use change, when primary forests are cleared for palm oil plantations.

The following table shows the climate related monetized impacts associated with animal based food production.

Table 30: Climate related value factors for animal products in €-cent$_{2024}$ (climate value factors 300 €$_{2024}$ / t CO_2-eq and 880 €$_{2024}$ / t CO_2-eq)

Products	Production type	300 € / t CO_2-eq €-cent / kg	880 € / t CO_2-eq €-cent / kg
Milk (ECM)	Conventional	40	116
	Bandwidth in literature	25 - 88	71 - 256
Beef (live weight)	Cattle fattening, conventional	235	690
	Suckler cow husbandry, integrated production	423	1241
Pork (live weight)	Conventional	98	290
	Organic	102	299
Poultry (live weight)	Conventional	69	202
	Organic	63	185

ECM = energy-corrected milk quantity: milk converted to the same energy content in order to be able to compare milk with different fat and protein contents. Large-scale fattening refers to the fattening of calves from dairy farming; suckler cow farming refers to the rearing of cattle solely for meat production.
Source: Own calculation based on Ecoinvent version 3.5, Bystricky et al., 2015, ART 2012, UBA (2019b) and Anthoff (2024).

For the production of milk[30], climate related value factors can be calculated based on emission factors from the literature, on average ranging between 25 and 88 €-cents$_{2024}$ (1% PRTP) or 71 and 256 €-cents$_{2024}$ (0% PRTP) per kg of milk (ECM) [31]. We recommend using an average value based on Bystricky et al. (2015) and UBA (2019b). This average is found at around 40 €-cent$_{2024}$ (or 116 €-cent$_{2024}$) per kg of milk (ECM) at farmgate.

Assessing the climate costs for meat production yields an average climate cost value factor of 2.35 €$_{2024}$ (or 6.90 €$_{2024}$) per kg beef live weight for conventional large-scale cattle fattening (calves from dairy farming, in Germany) and 4.23 €$_{2024}$ (or 12.41 €$_{2024}$) per kg beef live weight for suckler cow farming (pure meat production) (integrated production in Switzerland). The data show that the climate costs of large-scale cattle fattening are lower than those of suckler cow husbandry, mainly because in the case of large-scale cattle fattening, part of the emissions from suckler cows can be attributed to milk production.

The climate related value factors for a kilogram of pork (live weight) range between 98 €-cents$_{2024}$ (or 2.90 €$_{2024}$) per kg for conventional production and 102 €-cents$_{2024}$ (or 2.99 €$_{2024}$) per kg for organic production, depending on the region.

For an application of the value factors from a consumer perspective, other system boundaries would have to be chosen, as the amount of slaughtered meat from a kg of live weight differs depending on the type of animal. In addition, when comparing foods from a consumer perspective, emissions from further processing and transport should also be considered.

All environmental value factors presented here are expressed in €-cents$_{2024}$ or €$_{2024}$ per kg. When comparing foods from a nutritional perspective, on the other hand, the energy content is an important aspect. This means that the climate related value factors should be weighted with the kilojoule values per kilogram to adequately compare the climate impact of pork with that of potatoes, for example.

[30] A much more differentiated analysis of the environmental costs of milk production was conducted in the REFOPLAN project "Sichtbarmachung versteckter Umweltkosten der Landwirtschaft am Beispiel von Milchproduktionssystemen" (FKZ: 3717 11 238 0).

[31] Energy corrected milk quantity (ECM).

8 Appendix

Table 31 and Table 32 display the value factors according to Euro standards for the different vehicle types.[32] For the different types of trucks, an additional distinction is made according to transport weight, and an additional category is included for heavy goods vehicles. In order to make the tables easier to navigate, the calculated value factors for construction, maintenance, disposal and fuel supply as well as the damage to nature and landscape caused by road construction are summarized according to the life cycle phases.

Table 31: a) Value factors transport: differentiated by emission category (Euronorm) for the different vehicle types at a value factor of 300€/t CO_2-eq, in €-cent$_{2024}$ / vehicle kilometer

		Operation			Pre-processes		Land consumption and fragmentation	Total
Vehicle category	EURO standard	Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and vehicles	Energy supply		
Car, Diesel	Euro 0	4.68	3.82	0.06	4.60	2.10	0.39	15.65
	Euro 1	5.12	4.06	0.06	4.60	2.29	0.39	16.52
	Euro 2	4.83	3.93	0.06	4.60	2.16	0.39	15.97
	Euro 3	4.45	3.65	0.06	4.60	1.99	0.39	15.14
	Euro 4	4.23	2.84	0.06	4.60	1.89	0.39	14.02
	Euro 5	3.86	3.70	0.06	4.60	1.73	0.39	14.34
	Euro 6	3.61	2.10	0.06	4.60	1.61	0.39	12.37
Car, petrol	Euro 0	6.58	4.94	0.06	4.01	2.76	0.39	18.74
	Euro 1	5.98	3.97	0.06	4.01	2.50	0.39	16.91
	Euro 2	5.76	2.51	0.06	4.01	2.43	0.39	15.17
	Euro 3	5.31	0.59	0.06	4.01	2.26	0.39	12.62
	Euro 4	4.78	0.55	0.06	4.01	2.03	0.39	11.82
	Euro 5	4.27	0.38	0.06	4.01	1.81	0.39	10.92
	Euro 6	4.02	0.38	0.06	4.01	1.71	0.39	10.57
Small motorbike (petrol)	Euro 0	3.44	3.00	0.01	4.14	1.65	0.13	12.38
	Euro 1	3.59	1.48	0.01	4.14	1.72	0.13	11.08
	Euro 2	2.82	0.89	0.01	4.14	1.36	0.13	9.36
	Euro 3	2.30	0.67	0.01	4.14	1.11	0.13	8.36
Motorbike (petrol)	Euro 0	3.23	1.77	0.01	4.12	2.09	0.17	11.41
	Euro 1	3.06	1.44	0.01	4.12	1.98	0.17	10.79

[32] The differentiation of emission factors according to European standards is based on HBEFA v3.3.

Vehicle category	EURO standard	Operation: Greenhouse gases	Operation: Air pollutants Exhaust	Operation: Air pollutants Abrasion	Pre-processes: Infrastructure and vehicles	Pre-processes: Energy supply	Land consumption and fragmentation	Total
	Euro 2	2.83	1.25	0.01	4.12	1.83	0.17	10.21
	Euro 3	2.93	0.73	0.01	4.12	1.90	0.17	9.87
Light commercial vehicle (petrol)	Euro 0	6.86	9.02	0.06	3.24	2.94	0.42	22.54
	Euro 1	6.09	5.96	0.06	3.24	2.61	0.42	18.37
	Euro 2	5.41	2.83	0.06	3.24	2.32	0.42	14.28
	Euro 3	5.43	0.66	0.06	3.24	2.33	0.42	12.13
	Euro 4	4.70	0.51	0.06	3.24	2.02	0.42	10.95
	Euro 5	4.20	0.36	0.06	3.24	1.80	0.42	10.08
	Euro 6	3.75	0.35	0.06	3.24	1.60	0.42	9.42
Light commercial vehicle (diesel)	Euro 0	8.45	10.67	0.06	3.56	3.37	0.42	26.53
	Euro 1	7.75	8.71	0.06	3.56	3.09	0.42	23.58
	Euro 2	6.94	7.16	0.06	3.56	2.77	0.42	20.91
	Euro 3	5.71	5.68	0.06	3.56	2.28	0.42	17.70
	Euro 4	5.41	4.26	0.06	3.56	2.16	0.42	15.87
	Euro 5	5.03	3.61	0.06	3.56	2.01	0.42	14.68
	Euro 6	4.67	1.25	0.06	3.56	1.86	0.42	11.81
Public bus	Euro 0	31.47	74.69	0.34	9.16	10.81	0.94	127.41
	Euro 1	27.29	45.84	0.34	9.16	9.37	0.94	92.93
	Euro 2	27.52	45.94	0.34	9.16	9.45	0.94	93.36
	Euro 3	30.32	39.88	0.34	9.16	10.42	0.94	91.06
	Euro 4	31.60	26.63	0.34	9.16	10.86	0.94	79.53
	Euro 5	32.56	19.53	0.34	9.16	11.18	0.94	73.71
	Euro 6	32.05	1.54	0.34	9.16	11.01	0.94	55.04
Coach	Euro 0	22.09	47.34	0.20	11.54	8.51	0.94	90.62
	Euro 1	20.47	35.45	0.20	11.54	7.89	0.94	76.49
	Euro 2	19.47	34.59	0.20	11.54	7.50	0.94	74.25
	Euro 3	20.69	27.57	0.20	11.54	7.97	0.94	68.91
	Euro 4	20.75	17.34	0.20	11.54	7.99	0.94	58.76
	Euro 5	21.64	12.77	0.20	11.54	8.34	0.94	55.43
	Euro 6	21.89	1.63	0.20	11.54	8.44	0.94	44.64

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and vehicles	Energy supply		
Heavy goods vehicle (< = 7.5t)	80ties	10.79	22.39	0.16	7.00	6.31	0.87	47.52
	Euro I	9.33	15.28	0.16	7.00	5.45	0.87	38.10
	Euro II	9.04	15.12	0.16	7.00	5.28	0.87	37.48
	Euro III	9.51	10.79	0.16	7.00	5.56	0.87	33.88
	Euro IV EGR	9.67	7.28	0.16	7.00	5.65	0.87	30.63
	Euro IV SCR	9.35	5.57	0.16	7.00	5.46	0.87	28.41
	Euro V EGR	9.79	5.37	0.16	7.00	5.72	0.87	28.92
	Euro V SCR	9.36	3.36	0.16	7.00	5.47	0.87	26.21
	Euro VI	9.49	0.49	0.16	7.00	5.54	0.87	23.55
Heavy goods vehicle (>7.5t-12t)	80ties	14.47	35.76	0.16	7.00	7.19	0.87	65.45
	Euro I	12.85	21.39	0.16	7.00	6.39	0.87	48.66
	Euro II	12.47	21.36	0.16	7.00	6.19	0.87	48.05
	Euro III	13.11	15.42	0.16	7.00	6.51	0.87	43.08
	Euro IV EGR	13.21	10.24	0.16	7.00	6.56	0.87	38.03
	Euro IV SCR	12.77	8.07	0.16	7.00	6.34	0.87	35.22
	Euro V EGR	13.38	7.68	0.16	7.00	6.64	0.87	35.74
	Euro V SCR	12.77	5.32	0.16	7.00	6.34	0.87	32.47
	Euro VI	12.99	0.84	0.16	7.00	6.45	0.87	28.32
Heavy goods vehicle (>12t-14t)	80ties	15.28	37.81	0.16	7.00	7.59	0.87	68.71
	Euro I	13.54	22.83	0.16	7.00	6.73	0.87	51.12
	Euro II	13.16	22.83	0.16	7.00	6.54	0.87	50.56
	Euro III	13.76	16.74	0.16	7.00	6.84	0.87	45.36
	Euro IV EGR	13.80	11.05	0.16	7.00	6.85	0.87	39.73

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and vehicles	Energy supply		
	Euro IV SCR	13.32	8.39	0.16	7.00	6.62	0.87	36.36
	Euro V EGR	14.06	8.24	0.16	7.00	6.98	0.87	37.31
	Euro V SCR	13.40	5.62	0.16	7.00	6.66	0.87	33.71
	Euro VI	13.63	0.94	0.16	7.00	6.77	0.87	29.38
Heavy goods vehicle (>14t-20t)	80ties	18.51	45.25	0.16	9.60	8.81	0.95	83.28
	Euro I	15.71	27.19	0.16	9.60	7.47	0.95	61.08
	Euro II	15.26	27.50	0.16	9.60	7.26	0.95	60.72
	Euro III	15.97	20.25	0.16	9.60	7.60	0.95	54.53
	Euro IV EGR	15.78	13.49	0.16	9.60	7.51	0.95	47.49
	Euro IV SCR	15.16	10.76	0.16	9.60	7.21	0.95	43.85
	Euro V EGR	16.05	10.33	0.16	9.60	7.64	0.95	44.73
	Euro V SCR	15.25	7.53	0.16	9.60	7.25	0.95	40.74
	Euro VI	15.63	1.28	0.16	9.60	7.43	0.95	35.05
Heavy goods vehicle (>20t-26t)	80ties	21.68	47.10	0.16	9.60	10.31	0.95	89.81
	Euro I	18.87	33.13	0.16	9.60	8.98	0.95	71.69
	Euro II	18.48	33.52	0.16	9.60	8.79	0.95	71.49
	Euro III	19.16	25.15	0.16	9.60	9.11	0.95	64.13
	Euro IV EGR	18.83	16.89	0.16	9.60	8.96	0.95	55.39
	Euro IV SCR	18.20	12.25	0.16	9.60	8.66	0.95	49.82
	Euro V EGR	19.19	12.74	0.16	9.60	9.13	0.95	51.77
	Euro V SCR	18.35	8.36	0.16	9.60	8.73	0.95	46.14
	Euro VI	18.66	1.35	0.16	9.60	8.88	0.95	39.60

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and vehicles	Energy supply		
Heavy goods vehicle (>26t-28t)	Euro I	19.68	34.61	0.16	9.60	9.36	0.95	74.37
	Euro II	19.67	34.20	0.16	9.60	9.36	0.95	73.94
	Euro III	20.29	25.85	0.16	9.60	9.65	0.95	66.51
	Euro IV EGR	20.02	17.37	0.16	9.60	9.52	0.95	57.62
	Euro IV SCR	19.35	12.68	0.16	9.60	9.20	0.95	51.94
	Euro V EGR	20.34	13.00	0.16	9.60	9.68	0.95	53.73
	Euro V SCR	19.41	8.63	0.16	9.60	9.23	0.95	47.98
	Euro VI	19.76	1.40	0.16	9.60	9.40	0.95	41.28
Heavy goods vehicle (>28t-32t)	Euro I	22.93	39.95	0.16	9.60	9.66	0.95	83.26
	Euro II	22.72	39.45	0.16	9.60	9.57	0.95	82.46
	Euro III	23.42	29.38	0.16	9.60	9.87	0.95	73.38
	Euro IV EGR	23.39	19.63	0.16	9.60	9.85	0.95	63.58
	Euro IV SCR	22.64	14.26	0.16	9.60	9.54	0.95	57.15
	Euro V EGR	23.84	14.61	0.16	9.60	10.04	0.95	59.21
	Euro V SCR	22.76	9.50	0.16	9.60	9.59	0.95	52.56
	Euro VI	23.20	1.51	0.16	9.60	9.77	0.95	45.19
Heavy goods vehicle (>32t)	Euro I	22.61	39.79	0.16	9.60	9.53	0.95	82.63
	Euro II	22.25	39.96	0.16	9.60	9.37	0.95	82.29
	Euro III	22.92	30.16	0.16	9.60	9.65	0.95	73.44
	Euro IV EGR	22.71	20.17	0.16	9.60	9.57	0.95	63.17
	Euro IV SCR	22.04	13.89	0.16	9.60	9.28	0.95	55.92
	Euro V EGR	23.20	15.02	0.16	9.60	9.77	0.95	58.70

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and vehicles	Energy supply		
	Euro V SCR	22.22	9.31	0.16	9.60	9.36	0.95	51.60
	Euro VI	22.53	1.48	0.16	9.60	9.49	0.95	44.22
Road trains/semitrailers (>20-28t)	80ties	21.44	46.49	0.16	9.60	9.03	0.95	87.67
	Euro I	19.05	32.93	0.16	9.60	8.03	0.95	70.71
	Euro II	18.53	32.44	0.16	9.60	7.81	0.95	69.48
	Euro III	19.22	24.25	0.16	9.60	8.10	0.95	62.27
	Euro IV EGR	19.15	16.28	0.16	9.60	8.07	0.95	54.21
	Euro IV SCR	18.48	12.28	0.16	9.60	7.79	0.95	49.26
	Euro V EGR	19.48	12.19	0.16	9.60	8.20	0.95	50.58
	Euro V SCR	18.58	8.20	0.16	9.60	7.83	0.95	45.32
	Euro VI	18.94	1.27	0.16	9.60	7.98	0.95	38.89
Road trains/semitrailers (>28-34t)	80ties	22.47	48.96	0.16	9.60	9.47	0.95	91.61
	Euro I	20.04	34.55	0.16	9.60	8.44	0.95	73.74
	Euro II	19.56	33.94	0.16	9.60	8.24	0.95	72.45
	Euro III	20.25	25.42	0.16	9.60	8.53	0.95	64.91
	Euro IV EGR	20.19	16.92	0.16	9.60	8.50	0.95	56.32
	Euro IV SCR	19.56	12.48	0.16	9.60	8.24	0.95	50.99
	Euro V EGR	20.59	12.55	0.16	9.60	8.68	0.95	52.53
	Euro V SCR	19.75	8.21	0.16	9.60	8.32	0.95	46.99
	Euro VI	20.04	1.23	0.16	9.60	8.44	0.95	40.42
Road trains/semitrailers (>34-40t)	80ties	25.56	55.52	0.16	13.53	10.77	1.19	106.73
	Euro I	22.41	39.20	0.16	13.53	9.44	1.19	85.94

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and vehicles	Energy supply		
	Euro II	22.12	39.15	0.16	13.53	9.32	1.19	85.48
	Euro III	22.73	29.71	0.16	13.53	9.58	1.19	76.89
	Euro IV EGR	22.58	19.69	0.16	13.53	9.51	1.19	66.66
	Euro IV SCR	21.91	14.31	0.16	13.53	9.23	1.19	60.34
	Euro V EGR	23.10	14.76	0.16	13.53	9.73	1.19	62.48
	Euro V SCR	22.12	9.53	0.16	13.53	9.32	1.19	55.85
	Euro VI	22.44	1.38	0.16	13.53	9.45	1.19	48.15

Engines that were in circulation before the introduction of the exhaust emission standard are designated Euro 0 for cars and 80ties for trucks in HBEFA 3.3.
Source: Calculations by INFRAS as part of the research project, Anthoff (2024) and van der Kamp et al. (2024).

Table 32: b) Value factors transport: differentiated by emission category (Euronorm) for the different vehicle types at a value factor of 880€/t $CO_{2\,eq}$, in €-cent$_{2024}$ / vehicle kilometer

Vehicle category	EURO standard	Operation: Greenhouse gases	Operation: Air pollutants Exhaust	Operation: Air pollutants Abrasion	Pre-processes: Infrastructure and -vehicles	Pre-processes: Energy supply	Land consumption and fragmentation	Total
Car, Diesel	Euro 0	13.66	3.82	0.06	8.45	4.58	0.39	30.96
	Euro 1	14.95	4.06	0.06	8.45	5.01	0.39	32.92
	Euro 2	14.09	3.93	0.06	8.45	4.72	0.39	31.64
	Euro 3	12.99	3.65	0.06	8.45	4.35	0.39	29.89
	Euro 4	12.35	2.84	0.06	8.45	4.14	0.39	28.23
	Euro 5	11.25	3.70	0.06	8.45	3.77	0.39	27.63
	Euro 6	10.52	2.10	0.06	8.45	3.53	0.39	25.05
Car, petrol	Euro 0	19.20	4.94	0.06	7.49	5.94	0.39	38.02
	Euro 1	17.44	3.97	0.06	7.49	5.37	0.39	34.72
	Euro 2	16.81	2.51	0.06	7.49	5.22	0.39	32.48
	Euro 3	15.51	0.59	0.06	7.49	4.85	0.39	28.89
	Euro 4	13.96	0.55	0.06	7.49	4.37	0.39	26.81
	Euro 5	12.45	0.38	0.06	7.49	3.90	0.39	24.66
	Euro 6	11.73	0.38	0.06	7.49	3.67	0.39	23.72
Small motorbike (petrol)	Euro 0	10.05	3.00	0.01	7.07	3.05	0.13	23.31
	Euro 1	10.46	1.48	0.01	7.07	3.18	0.13	22.34
	Euro 2	8.24	0.89	0.01	7.07	2.51	0.13	18.85
	Euro 3	6.73	0.67	0.01	7.07	2.05	0.13	16.65
Motorbike (petrol)	Euro 0	9.43	1.77	0.01	8.84	3.86	0.17	24.09
	Euro 1	8.92	1.44	0.01	8.84	3.65	0.17	23.04
	Euro 2	8.25	1.25	0.01	8.84	3.38	0.17	21.90
	Euro 3	8.55	0.73	0.01	8.84	3.50	0.17	21.81
Light commercial vehicle (petrol)	Euro 0	20.03	9.02	0.06	5.99	6.32	0.42	41.83
	Euro 1	17.76	5.96	0.06	5.99	5.60	0.42	35.78
	Euro 2	15.80	2.83	0.06	5.99	4.98	0.42	30.08
	Euro 3	15.84	0.66	0.06	5.99	5.00	0.42	27.97
	Euro 4	13.73	0.51	0.06	5.99	4.33	0.42	25.04

Vehicle category	EURO standard	Operation: Greenhouse gases	Operation: Air pollutants Exhaust	Operation: Air pollutants Abrasion	Pre-processes: Infrastructure and - vehicles	Pre-processes: Energy supply	Land consumption and fragmentation	Total
	Euro 5	12.25	0.36	0.06	5.99	3.86	0.42	22.94
	Euro 6	10.93	0.35	0.06	5.99	3.45	0.42	21.20
Light commercial vehicle (diesel)	Euro 0	24.66	10.67	0.06	6.49	7.37	0.42	49.66
	Euro 1	22.62	8.71	0.06	6.49	6.76	0.42	45.05
	Euro 2	20.27	7.16	0.06	6.49	6.06	0.42	40.45
	Euro 3	16.66	5.68	0.06	6.49	4.98	0.42	34.28
	Euro 4	15.80	4.26	0.06	6.49	4.72	0.42	31.75
	Euro 5	14.67	3.61	0.06	6.49	4.39	0.42	29.63
	Euro 6	13.63	1.25	0.06	6.49	4.07	0.42	25.91
Public bus	Euro 0	91.84	74.69	0.34	18.26	23.63	0.94	209.70
	Euro 1	79.64	45.84	0.34	18.26	20.49	0.94	165.50
	Euro 2	80.33	45.94	0.34	18.26	20.66	0.94	166.47
	Euro 3	88.50	39.88	0.34	18.26	22.77	0.94	170.69
	Euro 4	92.24	26.63	0.34	18.26	23.73	0.94	162.14
	Euro 5	95.02	19.53	0.34	18.26	24.44	0.94	158.54
	Euro 6	93.53	1.54	0.34	18.26	24.06	0.94	138.67
Coach	Euro 0	64.46	47.34	0.20	22.69	18.60	0.94	154.24
	Euro 1	59.74	35.45	0.20	22.69	17.24	0.94	136.26
	Euro 2	56.83	34.59	0.20	22.69	16.40	0.94	131.66
	Euro 3	60.37	27.57	0.20	22.69	17.42	0.94	129.20
	Euro 4	60.55	17.34	0.20	22.69	17.47	0.94	119.20
	Euro 5	63.15	12.77	0.20	22.69	18.23	0.94	117.98
	Euro 6	63.90	1.63	0.20	22.69	18.44	0.94	107.81
Trucks (< = 7.5t)	80ties	31.50	22.39	0.16	12.90	10.94	0.87	78.76
	Euro I	27.24	15.28	0.16	12.90	9.45	0.87	65.90
	Euro II	26.39	15.12	0.16	12.90	9.16	0.87	64.60
	Euro III	27.76	10.79	0.16	12.90	9.64	0.87	62.11
	Euro IV EGR	28.22	7.28	0.16	12.90	9.80	0.87	59.22
	Euro IV SCR	27.29	5.57	0.16	12.90	9.47	0.87	56.26

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and - vehicles	Energy supply		
	Euro V EGR	28.58	5.37	0.16	12.90	9.92	0.87	57.80
	Euro V SCR	27.31	3.36	0.16	12.90	9.48	0.87	54.07
	Euro VI	27.68	0.49	0.16	12.90	9.61	0.87	51.71
Trucks (>7.5t-12t)	80ties	42.25	35.76	0.16	12.90	13.40	0.87	105.33
	Euro I	37.51	21.39	0.16	12.90	11.90	0.87	84.73
	Euro II	36.40	21.36	0.16	12.90	11.54	0.87	83.22
	Euro III	38.27	15.42	0.16	12.90	12.14	0.87	79.76
	Euro IV EGR	38.55	10.24	0.16	12.90	12.23	0.87	74.94
	Euro IV SCR	37.27	8.07	0.16	12.90	11.82	0.87	71.09
	Euro V EGR	39.04	7.68	0.16	12.90	12.38	0.87	73.03
	Euro V SCR	37.27	5.32	0.16	12.90	11.82	0.87	68.34
	Euro VI	37.92	0.84	0.16	12.90	12.03	0.87	64.71
Trucks (>12t-14t)	80ties	44.59	37.81	0.16	12.90	14.14	0.87	110.48
	Euro I	39.52	22.83	0.16	12.90	12.53	0.87	88.81
	Euro II	38.40	22.83	0.16	12.90	12.18	0.87	87.34
	Euro III	40.16	16.74	0.16	12.90	12.74	0.87	83.56
	Euro IV EGR	40.26	11.05	0.16	12.90	12.77	0.87	78.01
	Euro IV SCR	38.88	8.39	0.16	12.90	12.33	0.87	73.53
	Euro V EGR	41.03	8.24	0.16	12.90	13.01	0.87	76.21
	Euro V SCR	39.10	5.62	0.16	12.90	12.40	0.87	71.05
	Euro VI	39.78	0.94	0.16	12.90	12.62	0.87	67.27
Trucks (>14t-20t)	80ties	54.04	45.25	0.16	17.56	16.75	0.95	134.70
	Euro I	45.85	27.19	0.16	17.56	14.21	0.95	105.92
	Euro II	44.53	27.50	0.16	17.56	13.80	0.95	104.50
	Euro III	46.62	20.25	0.16	17.56	14.45	0.95	99.99

Vehicle category	EURO standard	Operation: Greenhouse gases	Operation: Air pollutants Exhaust	Operation: Air pollutants Abrasion	Pre-processes: Infrastructure and - vehicles	Pre-processes: Energy supply	Land consumption and fragmentation	Total
	Euro IV EGR	46.07	13.49	0.16	17.56	14.28	0.95	92.50
	Euro IV SCR	44.26	10.76	0.16	17.56	13.72	0.95	87.41
	Euro V EGR	46.85	10.33	0.16	17.56	14.52	0.95	90.37
	Euro V SCR	44.51	7.53	0.16	17.56	13.80	0.95	84.50
	Euro VI	45.61	1.28	0.16	17.56	14.14	0.95	79.69
Trucks (>20t-26t)	80ties	63.28	47.10	0.16	17.56	19.61	0.95	148.66
	Euro I	55.08	33.13	0.16	17.56	17.07	0.95	123.95
	Euro II	53.92	33.52	0.16	17.56	16.71	0.95	122.82
	Euro III	55.92	25.15	0.16	17.56	17.33	0.95	117.07
	Euro IV EGR	54.96	16.89	0.16	17.56	17.03	0.95	107.55
	Euro IV SCR	53.13	12.25	0.16	17.56	16.47	0.95	100.51
	Euro V EGR	56.00	12.74	0.16	17.56	17.36	0.95	104.77
	Euro V SCR	53.54	8.36	0.16	17.56	16.60	0.95	97.16
	Euro VI	54.47	1.35	0.16	17.56	16.88	0.95	91.36
Trucks (>26t-28t)	Euro I	57.45	34.61	0.16	17.56	17.81	0.95	128.54
	Euro II	57.42	34.20	0.16	17.56	17.80	0.95	128.08
	Euro III	59.23	25.85	0.16	17.56	18.36	0.95	122.11
	Euro IV EGR	58.43	17.37	0.16	17.56	18.11	0.95	112.57
	Euro IV SCR	56.47	12.68	0.16	17.56	17.50	0.95	105.32
	Euro V EGR	59.37	13.00	0.16	17.56	18.40	0.95	109.44
	Euro V SCR	56.65	8.63	0.16	17.56	17.56	0.95	101.50
	Euro VI	57.68	1.40	0.16	17.56	17.88	0.95	95.62
Trucks (>28t-32t)	Euro I	66.93	39.95	0.16	17.56	19.50	0.95	145.05
	Euro II	66.32	39.45	0.16	17.56	19.32	0.95	143.75

Vehicle category	EURO standard	Operation: Greenhouse gases	Operation: Air pollutants Exhaust	Operation: Air pollutants Abrasion	Pre-processes: Infrastructure and - vehicles	Pre-processes: Energy supply	Land consumption and fragmentation	Total
	Euro III	68.35	29.38	0.16	17.56	19.91	0.95	136.31
	Euro IV EGR	68.26	19.63	0.16	17.56	19.89	0.95	126.45
	Euro IV SCR	66.07	14.26	0.16	17.56	19.25	0.95	118.25
	Euro V EGR	69.59	14.61	0.16	17.56	20.27	0.95	123.14
	Euro V SCR	66.44	9.50	0.16	17.56	19.35	0.95	113.95
	Euro VI	67.70	1.51	0.16	17.56	19.72	0.95	107.60
Trucks (>32t)	Euro I	65.99	39.79	0.16	17.56	19.22	0.95	143.67
	Euro II	64.94	39.96	0.16	17.56	18.92	0.95	142.48
	Euro III	66.88	30.16	0.16	17.56	19.48	0.95	135.19
	Euro IV EGR	66.30	20.17	0.16	17.56	19.31	0.95	124.45
	Euro IV SCR	64.32	13.89	0.16	17.56	18.74	0.95	115.61
	Euro V EGR	67.70	15.02	0.16	17.56	19.72	0.95	121.11
	Euro V SCR	64.85	9.31	0.16	17.56	18.89	0.95	111.72
	Euro VI	65.77	1.48	0.16	17.56	19.16	0.95	105.07
Road trains/semitrailers (>20-28t)	80ties	62.57	46.49	0.16	17.56	18.23	0.95	145.96
	Euro I	55.60	32.93	0.16	17.56	16.20	0.95	123.39
	Euro II	54.07	32.44	0.16	17.56	15.75	0.95	120.94
	Euro III	56.08	24.25	0.16	17.56	16.34	0.95	115.33
	Euro IV EGR	55.90	16.28	0.16	17.56	16.28	0.95	107.12
	Euro IV SCR	53.95	12.28	0.16	17.56	15.72	0.95	100.61
	Euro V EGR	56.84	12.19	0.16	17.56	16.56	0.95	104.26
	Euro V SCR	54.22	8.20	0.16	17.56	15.80	0.95	96.89
	Euro VI	55.26	1.27	0.16	17.56	16.10	0.95	91.30

Vehicle category	EURO standard	Operation			Pre-processes		Land consumption and fragmentation	Total
		Greenhouse gases	Air pollutants Exhaust	Air pollutants Abrasion	Infrastructure and - vehicles	Energy supply		
Road trains/semitrailers (>28-34t)	80ties	65.58	48.96	0.16	17.56	19.10	0.95	152.31
	Euro I	58.48	34.55	0.16	17.56	17.04	0.95	128.73
	Euro II	57.09	33.94	0.16	17.56	16.63	0.95	126.32
	Euro III	59.10	25.42	0.16	17.56	17.22	0.95	120.41
	Euro IV EGR	58.91	16.92	0.16	17.56	17.16	0.95	111.67
	Euro IV SCR	57.08	12.48	0.16	17.56	16.63	0.95	104.86
	Euro V EGR	60.11	12.55	0.16	17.56	17.51	0.95	108.84
	Euro V SCR	57.64	8.21	0.16	17.56	16.79	0.95	101.31
	Euro VI	58.50	1.23	0.16	17.56	17.04	0.95	95.43
Road trains/semitrailers (>34-40t)	80ties	74.61	55.52	0.16	24.77	21.73	1.19	177.97
	Euro I	65.42	39.20	0.16	24.77	19.06	1.19	149.79
	Euro II	64.57	39.15	0.16	24.77	18.81	1.19	148.65
	Euro III	66.34	29.71	0.16	24.77	19.32	1.19	141.48
	Euro IV EGR	65.91	19.69	0.16	24.77	19.20	1.19	130.92
	Euro IV SCR	63.95	14.31	0.16	24.77	18.63	1.19	123.01
	Euro V EGR	67.43	14.76	0.16	24.77	19.64	1.19	127.95
	Euro V SCR	64.57	9.53	0.16	24.77	18.81	1.19	119.02
	Euro VI	65.48	1.38	0.16	24.77	19.08	1.19	112.05

Engines that were in circulation before the introduction of the exhaust emission standard are designated Euro 0 for cars and 80ties for trucks in HBEFA 3.3.
Source: Calculations by INFRAS as part of the research project, Anthoff (2024 and van der Kamp et al. (2024).

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