SWEDISH LIFE CYCLE CENTER

EPS weighting factors - version 2020d

Report number: 2020:06
November 2020 - Göteborg, Sweden
The report is also available
as Report No C555 from IVL Swedish
Environmental Research Institute
ISBN 978-91-7883-226-2

November 2020
Gothenburg, Sweden
Swedish Life Cycle Center, Chalmers University of Technology
Report no (Swedish Life Cycle Center’s report series): 2020:06
Authors: Bengt Steen, Chalmers, Tomas Rydberg, IVL
Contact lifecyclecenter.se

Summary

The EPS system was developed in its first versions in the 1990ies for identifying environmental priority strategies in product design and in other situations where there is a need to choose between two or more design alternatives. Later it has been used for other purposes like investments and Environmental, Social, and Corporate Governance (ESG). This report describes the 2020 default version, called EPS 2020d, and particularly its weighting factors. It replaces the 2015d and 2015dx versions

Project organizations

Table of Contents

Project information

Project title

Naturkapital och värdeskapande, Natural capital and value creation

Funded by

Swedish Energy Agency, FORMAS

Aim

- Test and implement a metric for resource efficiency. The metric is formed by relating the value creation by a product or service system (PSS) to the impact on the natural capital caused by said PSS in a life cycle perspective.
- Test the method in five case studies and communicate results broadly nationally as well as internationally
- Assess default values for natural capital impact expressed in the EPS enviro-accounting method for a selection of PSS and implement the values in a database and make available as a result of the project.
- A thorough analysis of how resource efficiency is dealt with in existing standards.
- Respond to and provide input to ongoing and upcoming standardization work in ISO and CEN.

Project leader

Tomas Rydberg

Coordination of the project

Christin Liptow

Project management team

Tomas Rydberg, Christin Liptow, Bengt Steen

Time period

2018-11-15 – 2020 – 2020-10-31

Acknowledgements

Funding by the Swedish Energy Agency project No 47272-1 and FORMAS project No 2019-02249 is greatly acknowledged

EPS weighting factors- version 2020d

Bengt Steen[1)] and Tomas Rydberg[2)]

[1)]Environmental system analysis, Chalmers University of Technology, [2)]IVL Swedish Environment Research Institute

Introduction

Sustainable development is understood by most people as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs"(1987). A logical consequence of this is that the natural capital must be left to our children at least at the same state as we inherited it from our parents. Another logical consequence is that any decrease of the natural capital by a human activity creates a debt, equal to the cost of restoring it, or equal to a compensation accepted by the persons subject to the consequences of loss of natural capital. As future generations cannot accept any compensation, only impacts on the present generation can be considered for compensation. The EPS system builds on this logic, on the ISO standards for LCA (ISO 14040 and ISO 14044) and on the standard ISO 14008 for monetary valuation of environmental impacts and aspects.

The EPS system was developed in its first versions in the 1990ies for identifying environmental priority strategies in product design and in other situations where there is a need to choose between two or more design alternatives. Later it has been used for other purposes like investments and Environmental, Social, and Corporate Governance (ESG). This report describes the 2020 default version, called EPS 2020d, and particularly its weighting factors. It replaces the 2015d and 2015dx versions (Steen 2016).

The EPS system architecture is shown in figure 1.

The goal is to allow decisionmakers like product developers, investors, purchasers etc. to get a fast recommendation on which of two or more product life cycle alternatives that is to prefer from a sustainability point of view, and to inform about if the alternatives are acceptable or not with regard to the ordinary economic values the products create. To be useful in a creative process, the analysis must be fast. This is why the EPS system is designed to function in a similar way as ordinary economic considerations in a decision situation: a rough more or less instantaneous estimation followed by a deeper analysis if the issue is of interest.

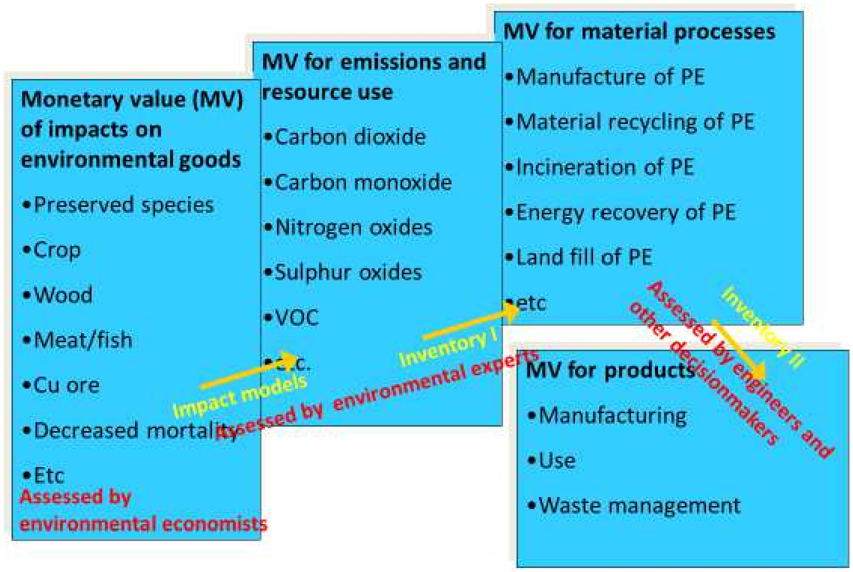

Figure 1 EPS architecture.

The EPS system starts with identifying which environmental goods that shall be considered as part of the natural capital and estimates values for environmental impact indicators on the environmental goods, e.g. the value of 1 kg less crop. The monetary valuation is made by environmental economists or similar expertise and follows the framework standard ISO 14008 (ISO 2019).

In table 1 some characteristics are given for the monetary environmental impact values

Table 1 General method characteristics for the monetary values, as required by ISO 14008.

Method issue	Method choice
Environmental impact valued	Specified for each good
Increase or decrease valued	Decrease
Environmental impact indicator	Specified for each good
Indicator unit	Specified for each good
Quantity of environmental impact the value is for	One indicator unit
Environmental baseline	Business as usual
Monetary valuation method	Specific to each good
Justification of method choice	Specific to each good
Base year	2018
Currency	€
Uncertainty	Specific to each good
Spatial coverage	Global
Temporal coverage	As long as the impact lasts
Affected population	Global, intergenerational
People, whose values are determined	OECD population
Equity weighting	None
Marginal, average or median	Logarithmic average ≈ median

In a second step the monetary values of emissions and resources (elementary flows) are determined, through impact models for all relevant pathways. A pathway links an elementary flow to an environmental impact indicator. There may be several pathways or mechanisms that link an elementary flow to an impact indicator. Typically, there are 10-20 pathways modeled per emission. The models used in this version of EPS are described in detail elsewhere (Steen 2019). Impact modelling is preferably made by experts in ecology, human health and pollutant dispersion.

In a third step, monetary values are determined for environmental impacts from material processes. By material processes is understood processes like production, transport, combustion, recycling etc. In figure 1, the examples are “production of polyethylene (PE)”, “material recycling of PE”, “incineration of PE”, “energy recovery of PE” and “landfill of PE”. Such monetary values can be used in parallel to ordinary cost estimations.

In the fourth step, the product developer, purchaser or other decisionmaker calculates the monetary impact value of the product(s), investment(s) or other alternative(s) under consideration.

Below are the results from these five steps.

Monetary values of impacts on environmental goods

According to ISO 14008, there are two central concepts for monetary valuation of environmental impacts. One is the “environmental good”, which is the object in the environment that is valued. The other is the “impact indicator”, which is the measure of change in the quality of the environmental good and which is given a monetary value. The change may be either increasing or decreasing, but it must be clearly stated which. In our case it is the cost of decreasing quality. The best estimate and uncertainty values determined for EPS v 2020d are given in table 2-3. The values in table 2 are market values, except for biodiversity, where it is preservation costs. The values in table 3 are replacements or restauration costs. A more detailed description of how the values were derived is given in (Steen 2019). Note that human health is an impact indicator, not an environmental good, and that human health is understood in an economic way, i.e. capability to satisfy basic needs, not as the overall goal of welfare (as defined by WHO).

Table 2 Monetary values of impacts on ecosystem services

Environmental good	Impact indicator	Unit	Monetary impact value (€)	
			Best estimate	Uncertainty
Production capacity of crops	Decreased productioncapacity	kg	0.263	1.24
Production capacity for meat	Decreased productioncapacity	kg	2.35	1.32
Production capacity for fish	Decreased productioncapacity	kg	2.2	1.3
Production capacity for wood	Decreased productioncapacity	m3	65.5	1.2
Biodiversity, global	Share of threat to redlisted species	dimensionless	6.92E+10	1.5
Production capacity for drinking water	Decreased productioncapacity	m3	1.7	2.26
Clean air, clean water, uncontaminated food, and good climate	Years of lost life expectancy, YLL	personyear	9.73E+04	1.3
Clean air, clean water, uncontaminated food, and good climate	Working capacity	personhour	27.3	1.25
Clean air, clean water, uncontaminated food, and good climate	Undernutrition	personyear	5840	1.1
Clean air, clean water, uncontaminated food, and good climate	Diarrhea	personyear	10220	1.5
Clean air, clean water, uncontaminated food, and good climate	Malaria episodes	personyear	18590	1.1
Clean air, clean water, uncontaminated food, and good climate	Gravation of angina pectoris	personyear	5840	1.5
Clean air, clean water, uncontaminated food, and good climate	Cardiovascular disease personyear	personyear	9734	2.4
Clean air, clean water, uncontaminated food, and good climate	Infarcts personyear	personyear	7995	1.3
Clean air, clean water, uncontaminated food, and good climate	Asthma cases	personyear	4185	2
Clean air, clean water, uncontaminated food, and good climate	Chronic obstructive pulmonary disease, mild and moderate	personyear	16546	2
Clean air, clean water, uncontaminated food, and good climate	Cancer	personyear	19466	2
Clean air, clean water, uncontaminated food, and good climate	Skin cancer	personyear	4866	2
Clean air, clean water, uncontaminated food, and good climate	Low vision	personyear	16546	2
Clean air, clean water, uncontaminated food, and good climate	Poisoning personyear	personyear	58400	1.2
Clean air, clean water, uncontaminated food, and good climate	Intellectual disability: mild	personyear	3017	4
Clean air, clean water, uncontaminated food, and good climate	Osteoporosis personyear	personyear	124586	3
Clean air, clean water, uncontaminated food, and good climate	Renal dysfunction personyear	personyear	62294	2

Table 3 Monetary values of impacts on abiotic resources

Environmental good	Impact indicator	Unit	Monetary impact value (€)	
Fossil resources				
Coal resources kg	Extraction of coal from ground	kg	0.258	1.3
Lignite resources	Extraction of lignite from ground	kg	0.076	1.2
Oil resources	Extraction of oil from ground	kg	0.727	1.3
Natural gas resources kg	Extraction of natural gas from ground	kg	0.455	1.3
Metal resources				
Aluminium, Al	Extraction of Al in ore form	kg	0.159	1.3
Iron, Fe	Extraction of Fe in ore form	kg	1	1.6
Silver, Ag	Extraction of Ag in ore form	kg	1.05E+05	2
Arsenic, As	Extraction of As in ore form	kg	3.49E+03	2
Gold, Au	Extraction of Au in ore form	kg	2.91E+06	2
Bismuth, Bi	Extraction of Bi in ore form	kg	4.03E+04	2
Cadmium, Cd	Extraction of Cd in ore form	kg	5.34E+04	2
Cerium, Ce	Extraction of Ce in ore form	kg	8.18E+01	2
Cobolt, Co	Extraction of Co in ore form	kg	2.05E+02	2
Chromium, Cr	Extraction of Cr in ore form	kg	3.91E+01	2
Copper, Cu	Extraction of Cu in ore form	kg	1.31E+02	2
Dysprosium, Dy	Extraction of Dy in ore form	kg	1.50E+03	2
Erbium, Er	Extraction of Er in ore form	kg	2.28E+03	2
Europium, Eu	Extraction of Eu in ore form	kg	5.95E+03	2
Gallium, Ga	Extraction of Ga in ore form	kg	3.08E+02	2
Gadolinium, Gd	Extraction of Gd in ore form	kg	1.38E+03	2
Germanium, Ge	Extraction of Ge in ore form	kg	3.27E+03	2
Hafnium, Hf	Extraction of Hf in ore form	kg	9.03E+02	2
Mercury, Hg	Extraction of Hg in ore form	kg	7.82E+04	2
Holmium, Ho	Extraction of Ho in ore form	kg	6.55E+03	2
Indium, In	Extraction of In in ore form	kg	1.05E+05	2
Iridium, Ir	Extraction of Ir in ore form	kg	2.38E+08	2
Lanthanum, La	Extraction of La in ore form	kg	1.75E+02	2
Luthetium, Lu	Extraction of Lu in ore form	kg	1.64E+04	2
Manganese, Mn	Extraction of Mn in ore form	kg	5.09E+00	2
Molybdenum, Mo	Extraction of Mo in ore form	kg	3.49E+03	2
Niob, Nb	Extraction of Nb in ore form	kg	4.36E+02	2
Neodymium, Nd	Extraction of Nd in ore form	kg	2.02E+02	2
Nickel, Ni	Extraction of Ni in ore form	kg	1.24E+02	2
Osmium, Os	Extraction of Os in ore form	kg	1.05E+08	2
Lead, Pb	Extraction of Pb in ore form	kg	3.08E+02	2
Palladium, Pd	Extraction of Pd in ore form	kg	9.88E+06	2
Praseodymium, Pr	Extraction of Pr in ore form	kg	7.37E+02	2
Platinum, Pt	Extraction of Pt in ore form	kg	8.73E+06	2
Rhenium, Re	Extraction of Re in ore form	kg	1.31E+07	2
Rhodium, Rh	Extraction of Rh in ore form	kg	2.91E+08	2
Ruthenium, Ru	Extraction of Ru in ore form	kg	1.75E+08	2
Antimony, Sb	Extraction of Sb in ore form	kg	2.62E+04	2
Scandium, Sc	Extraction of Sc in ore form	kg	3.74E+02	2
Samarium, Sm	Extraction of Sm in ore form	kg	1.16E+03	2
Tin, Sn	Extraction of Sn in ore form	kg	6.35E+02	2

Table 3 (continued)

Tantalum, Ta	Extraction of Ta in ore form	kg	5.24E+03	2
Terbium, Tb	Extraction of Tb in ore form	kg	8.18E+03	2
Tellurium, Te	Extraction of Te in ore form	kg	5.24E+06	2
Thorium, Th	Extraction of Th in ore form	kg	1.87E+03	2
Titanium, Ti	Extraction of Ti in ore form	kg	9.09E-01	2
Thallium, Tl	Extraction of Tl in ore form	kg	5.24E+03	2
Thulium, Tm	Extraction of Tm in ore form	kg	1.59E+04	2
Uranium, U	Extraction of U in ore form	kg	4.89E+02	2
Tungsten, W	Extraction of W in ore form	kg	5.24E+03	2
Vanadium, V	Extraction of V in ore form	kg	4.91E+01	2
Yttrium, Y	Extraction of Y in ore form	kg	2.38E+02	2
Ytterbium, Yb	Extraction of Yb in ore form	kg	2.38E+03	2
Zinc, Zn	Extraction of Zn in ore form	kg	4.18E+01	2
Zirconium, Zr	Extraction of Zr in ore form	kg	2.73E+01	2
Alkali metals			0	
Lithium, Li	Extraction of Li in salt form	kg	4.55	2
Sodium, Na	Extraction of Na in salt form	kg	0	1
Potassium, K	Extraction of K in salt form	kg	0	1
Rubidium, Rb	Extraction of Rb in salt form	kg	0	1
Cesium, Cs	Extraction of Cs in salt form	kg	709	2
Alkali earth metals				
Beryllium, Be	Extraction of Be in mineral form	kg	8.73E+03	5
Magnesium, Mg	Extraction of Mg in mineral form	kg	0	1
Calcium, Ca	Extraction of Ca in mineral form	kg	0	1
Strontium, Sr	Extraction of Sr in mineral form	kg	0.181	2
Barium, Ba	Extraction of Ba in mineral form	kg	10	2
Radium, Ra	Extraction of Ra in mineral form	kg	n.a.	n.a.
Non-metal resources excl. halides				
Hydrogen, H	Extraction of H in natural gas form	kg	0.4	2
Boron, B	Extraction of B in mineral form	kg	9.09	2
Carbon, C	Extraction of C in fossil mineral form	kg	0.258	1.3
Silicon, Si	Extraction of Si in mineral form	kg	0	1
Nitrogen, N	Extraction of N from air	kg	0	1
Phosphorous, P	Extraction of P in mineral form	kg	7.45	2
Oxygen, O	Extraction of O from air	kg	0	1
Sulphur, S	Extraction of S in mineral form	kg	0.182	2
Selenium, Se	Extraction of Se in mineral form	kg	45.5	5
Halides				
Fluorine, F	Extraction of F in mineral form	kg	5.45	2
Chlorine, Cl	Extraction of Cl in salt form	kg	0	1
Bromine, Br	Extraction of Br in salt form	kg	0	1
Iodine, I	Extraction of I in salt form	kg	27.3	2
Noble gases				
Helium, He	Extraction of He from natural gas	kg	0	1
Argon, Ar	Extraction of Ar from air	kg	0	1
Neon, Ne	Extraction of Ar from air	kg	0	1
Krypton, Kr	Extraction of Ar from air	kg	0	1
Xenon, Xe	Extraction of Ar from air	kg	0	1

Weighting factors for emissions

Monetary values of impacts on environmental goods from emissions to air

For each pathway, i.e. the link between an emission and an impact indicator there is a pathway specific impact (or characterization) factor, quantifying how many environmental impact indicator units, that are changed from one emission unit. When multiplying the pathway specific impact factor with the monetary value of the environmental impact indicator unit the monetary value of the pathway specific environmental impact is obtained. For each pathway there is a best estimate and an uncertainty measure assessed. The sum of all pathway specific monetary environmental impact total values is the total monetary environmental impact value for an emissions unit. Detailed information of pathway specific impact factors is given elsewhere (Steen 2019). The total monetary environmental impact values for emissions to air are shown in tables 4– 8.

Table 4 Monetary values of impacts on environmental goods from emissions of inorganic gases and particles.

Emission	**Receiving media**	**Unit**	**Monetary impact value, €**	**Notes**
Carbon dioxide, CO2	air	kg	2.88E-01	
Carbon monoxide, CO	air	kg	1.08E+00	
Nitrogen oxides, NOx	air	kg, as NO2	-2.64E+01	
Nitrous oxide, N2O	air	kg	7.67E+01	
Ammonia, NH3	air	kg	-4.34E+01	
Sulphur oxides, SOx	air	kg	-8.45E+00	
Hydrogen Fluoride	air	kg	-6.64E+00	
Hydrogen Chloride	air	kg	-6.80E+00	
Hydrogen Sulphide	air	kg	-1.97E+01	
PM2.5	air	kg	2.32E+02	
PAH in particles	air	kg	4.83E+00	in addition to PM2.5
As in particles	air	kg	3.25E+02	
Cd in particles	air	kg	2.73E+01	
Cr in particles	air	kg	3.43E+02	

Table 5 Monetary values of impacts on environmental goods from emissions of halogenated organic gases

Emission	**Receiving media**	**Unit**	**Monetary impact value, €**
CFC-11	air	kg	1.55E+03
CFC-12	air	kg	3.33E+03
CFC-13	air	kg	4.45E+03
CFC-111	air	kg	2.75E+03
CFC-112	air	kg	2.75E+03
CFC-113	air	kg	1.91E+03
CFC-114	air	kg	2.78E+03
CFC-115	air	kg	2.45E+03
CFC-211	air	kg	2.75E+03
CFC-212	air	kg	2.75E+03
CFC-213	air	kg	2.75E+03
CFC-214	air	kg	2.75E+03
CFC-215	air	kg	2.75E+03
CFC-216	air	kg	2.75E+03
CFC-217	air	kg	2.75E+03
HCFC-21	air	kg	5.22E+01
HCFC-22	air	kg	6.05E+02
HCFC-31	air	kg	2.01E+02
HCFC-121	air	kg	2.01E+02
HCFC-122	air	kg	2.17E+01
HCFC-122a	air	kg	9.05E+01
HCFC-123	air	kg	2.84E+01
HCFC-123a	air	kg	1.29E+02
HCFC-124	air	kg	1.83E+02
HCFC-131	air	kg	2.01E+02
HCFC-132c	air	kg	1.18E+02
HCFC-133	air	kg	2.02E+02
HCFC-141	air	kg	2.02E+02
HCFC-141b	air	kg	2.71E+02
HCFC-142	air	kg	2.02E+02
HCFC-142b	air	kg	6.74E+02
HCFC-151	air	kg	2.02E+02
HCFC-221	air	kg	2.02E+02
HCFC-222	air	kg	2.02E+02
HCFC-223	air	kg	2.02E+02
HCFC-224	air	kg	2.02E+02
HCFC-225	air	kg	2.02E+02
HCFC-225ca	air	kg	4.50E+01
HCFC-225cb	air	kg	1.82E+02
HCFC-226	air	kg	2.02E+02
HCFC-231	air	kg	2.02E+02
HCFC-232	air	kg	2.02E+02
HCFC-233	air	kg	2.03E+02
HCFC-234	air	kg	2.04E+02
HCFC-235	air	kg	2.07E+02
HCFC-241	air	kg	2.02E+02
HCFC-242	air	kg	2.02E+02
HCFC-243	air	kg	2.14E+02
HCFC-244	air	kg	2.02E+02
HCFC-251	air	kg	2.01E+02
HCFC-252	air	kg	2.01E+02

Table 5 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
HCFC-253	air	kg	2.01E+02
HCFC-261	air	kg	2.01E+02
HCFC-262	air	kg	2.01E+02
HCFC-23	air	kg	2.71E+01
HCFC-24	air	kg	1.38E+02
HCFC-25	air	kg	1.83E+02
HCFC-26	air	kg	5.75E+02
HCFC-27	air	kg	4.93E+01
HCFC-28	air	kg	1.53E+02
HCFC-271	air	kg	2.01E+02
(E)-1-Chloro-3,3,3-trifluoroprop-1-ene	air	kg	5.73E-01
HFC-23	air	kg	3.97E+03
HFC-32	air	kg	2.34E+02
HFC-41	air	kg	4.04E+01
HFC-43-10mee	air	kg	4.59E+02
HFC-125	air	kg	1.06E+03
HFC-134	air	kg	3.83E+02
HFC-134a	air	kg	4.44E+02
HFC-143	air	kg	1.14E+02
HFC-143a	air	kg	1.58E+03
HFC-152	air	kg	5.73E+00
HFC-152a	air	kg	4.79E+01
HFC-161	air	kg	1.15E+00
HFC-227ca	air	kg	8.82E+02
HFC-227ea	air	kg	1.11E+03
HFC-236cb	air	kg	4.12E+02
HFC-236ea	air	kg	4.58E+02
HFC-236fa	air	kg	2.58E+03
HFC-245ca	air	kg	2.47E+02
HFC-245cb	air	kg	1.52E+03
HFC-245ea	air	kg	8.17E+01
HFC-245eb	air	kg	1.01E+02
HFC-245fa	air	kg	2.96E+02
HFC-263fb	air	kg	2.64E+01
HFC-272ca	air	kg	5.02E+01
HFC-329p	air	kg	7.86E+02
HFC-365mfc	air	kg	2.77E+02
HFC-43-10mee	air	kg	5.60E+02
HFC-1132a	air	kg	2.87E-01
HFC-1141	air	kg	2.87E-01
(Z)-HFC-1225ye	air	kg	2.87E-01
(E)-HFC-1225ye	air	kg	2.87E-01
(Z)-HFC-1234ze	air	kg	2.87E-01
HFC-1234yf	air	kg	2.87E-01
(E)-HFC-1234ze	air	kg	2.87E-01
(Z)-HFC-1336	air	kg	5.73E-01
HFC-1243zf	air	kg	2.87E-01
HFC-1345zfc	air	kg	2.87E-01
3,3,4,4,5,5,6,6,6-Nonafluorohex-1-ene	air	kg	2.87E-01
3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluorooct-1-ene	air	kg	2.87E-01

Table 5 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-Heptadecafluorodec-1-ene	air	kg	2.87E-01
CCl4	air	kg	5.95E+02
Methyl Chloroform (C2H3Cl3) 1,1,1-trichloroethane	air	kg	4.85E+01
Methyl bromide	air	kg	1.20E+01
Methylene bromide	air	kg	2.87E-01
Halon-1201	air	kg	1.46E+02
Halon-1202	air	kg	9.38E+01
Halon-1211	air	kg	7.49E+02
Halon-1301	air	kg	2.40E+03
Halon-2301	air	kg	6.02E+01
Halon-2311/Halothane	air	kg	1.43E+01
Halon-2401	air	kg	6.39E+01
Halon-2402	air	kg	7.48E+02
Nitrogen trifluoride	air	kg	5.13E+03
Sulphur hexafluoride	air	kg	7.48E+03
(Trifluoromethyl)sulphur pentafluoride	air	kg	5.56E+03
Sulphuryl fluoride	air	kg	1.36E+03
PFC-14	air	kg	2.11E+03
PFC-116	air	kg	3.54E+03
PFC-c216	air	kg	2.93E+03
PFC-218	air	kg	2.83E+03
PFC-318	air	kg	3.04E+03
PFC-31-10	air	kg	2.93E+03
Perfluorocyclopentene	air	kg	5.73E-01
PFC-41-12	air	kg	2.72E+03
PFC-51-14	air	kg	2.52E+03
PFC-61-16	air	kg	2.49E+03
PFC-71-18	air	kg	2.42E+03
PFC-91-18	air	kg	2.29E+03
Perfluorodecalin(cis)	air	kg	2.30E+03
Perfluorodecalin(trans)	air	kg	2.00E+03
PFC-1114	air	kg	2.87E-01
PFC-1216	air	kg	2.87E-01
Perfluorobuta-1,3-diene	air	kg	2.87E-01
Perfluorobut-1-ene	air	kg	2.87E-01
Perfluorobut-2-ene	air	kg	5.73E-01
HFE-125	air	kg	4.00E+03
HFE-134 (HG-00)	air	kg	1.87E+03
HFE-143a	air	kg	1.81E+02
HFE-227ea	air	kg	2.12E+03
HCFE-235ca2 (enflurane)	air	kg	2.02E+02
HCFE-235da2 (isoflurane)	air	kg	1.71E+02
HFE-236ca	air	kg	1.43E+03
HFE-236ea2 (desflurane)	air	kg	6.14E+02
HFE-236fa	air	kg	3.37E+02
HFE-245cb2	air	kg	2.27E+02
HFE-245fa1	air	kg	2.86E+02
HFE-245fa2	air	kg	2.81E+02
2,2,3,3,3-Pentafluoropropan-1-ol	air	kg	6.59E+00
HFE-254cb1	air	kg	1.05E+02

Table 5 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
HFE-263fb2	air	kg	5.73E-01
HFE-263m1	air	kg	1.03E+01
3,3,3-Trifluoropropan-1-ol	air	kg	2.87E-01
HFE-329mcc2	air	kg	1.03E+03
HFE-338mmz1	air	kg	8.83E+02
HFE-338mcf2	air	kg	3.21E+02
Sevoflurane (HFE-347mmz1)	air	kg	7.51E+01
HFE-347mcc3 (HFE-7000)	air	kg	1.84E+02
HFE-347mcf2	air	kg	2.95E+02
HFE-347pcf2	air	kg	3.07E+02
HFE-347mmy1	air	kg	1.26E+02
HFE-356mec3	air	kg	1.34E+02
HFE-356mff2	air	kg	5.73E+00
HFE-356pcf2	air	kg	2.49E+02
HFE-356pcf3	air	kg	1.55E+02
HFE-356pcc3	air	kg	1.43E+02
HFE-356mmz1	air	kg	4.87E+00
HFE-365mcf3	air	kg	2.87E-01
HFE-365mcf2	air	kg	2.04E+01
HFE-374pc2	air	kg	2.17E+02
4,4,4-Trifluorobutan-1-ol	air	kg	2.87E-01
2,2,3,3,4,4,5,5-Octafluorocyclopentanol	air	kg	4.59E+00
HFE-43-10pccc124 (H-Galden 1040x, HG-11)	air	kg	9.61E+02
HFE-449s1 (HFE-7100)	air	kg	1.46E+02
n-HFE-7100	air	kg	1.68E+02
i-HFE-7100	air	kg	1.41E+02
HFE-569sf2 (HFE-7200)	air	kg	1.98E+01
n-HFE-7200	air	kg	2.27E+01
i-HFE-7200	air	kg	1.55E+01
HFE-236ca12 (HG-10)	air	kg	1.79E+03
HFE-338pcc13 (HG-01)	air	kg	9.94E+02
1,1,1,3,3,3-Hexafluoropropan-2-ol	air	kg	6.34E+01
HG-02	air	kg	9.32E+02
HG-03	air	kg	9.75E+02
HG-20	air	kg	1.78E+03
HG-21	air	kg	1.33E+03
HG-30	air	kg	2.46E+03
1-Ethoxy-1,1,2,2,3,3,3-heptafluoropropane	air	kg	2.12E+01
Fluoroxene	air	kg	2.87E-01
1,1,2,2-Tetrafluoro-1-(fluoromethoxy)ethane	air	kg	3.01E+02
2-Ethoxy-3,3,4,4,5-pentafluorotetrahydro-2,5-bis[1,2,2,2-tetrafluoro-1-(trifluoromethyl)ethyl]-furan	air	kg	1.95E+01
Fluoro(methoxy)methane	air	kg	4.30E+00
Difluoro(methoxy)methane	air	kg	5.02E+01
Fluoro(fluoromethoxy)methane	air	kg	4.56E+01
Difluoro(fluoromethoxy)methane	air	kg	2.14E+02
Trifluoro(fluoromethoxy)methane	air	kg	2.61E+02
HG'-01	air	kg	7.71E+01
HG'-02	air	kg	8.23E+01
HG'-03	air	kg	7.68E+01
HFE-329me3	air	kg	1.50E+03

Table 5 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
3,3,4,4, 5,5,6,6,7,7,7-Undecafluoroheptan-1-ol	air	kg	2.87E-01
3,3,4,4,5,5,6,6,7,7,8,8,9,9, 9-Pentadecafluorononan-1-ol	air	kg	2.87E-01
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10, 11,11,11-Nonadecafluoroundecan-1-ol	air	kg	2.87E-01
2-Chloro-1,1,2-trifluoro-1-methoxyethane	air	kg	4.27E+01
PFPMIE (perfluoropolymethyl isopropyl ether)	air	kg	3.09E+03
HFE-216	air	kg	2.87E-01
Trifluoromethyl formate	air	kg	2.04E+02
Perfluoroethyl formate	air	kg	2.02E+02
Perfluoropropyl formate	air	kg	1.31E+02
Perfluorobutyl formate	air	kg	1.36E+02
2,2,2-Trifluoroethyl formate	air	kg	1.18E+01
3,3,3-Trifluoropropyl formate	air	kg	6.02E+00
1,2,2,2-Tetrafluoroethyl formate	air	kg	1.63E+02
1,1,1,3,3,3-Hexafluoropropan-2-yl formate	air	kg	1.16E+02
Perfluorobutyl acetate	air	kg	5.73E-01
Perfluoropropyl acetate	air	kg	5.73E-01
Perfluoroethyl acetate	air	kg	8.60E-01
Trifluoromethyl acetate	air	kg	8.60E-01
Methyl carbonofluoridate	air	kg	3.33E+01
1,1-Difluoroethyl carbonofluoridate	air	kg	9.46E+00
1,1-Difluoroethyl 2,2,2-trifluoroacetate	air	kg	1.09E+01
Ethyl 2,2,2-trifluoroacetate	air	kg	5.73E-01
2,2,2-Trifluoroethyl 2,2,2-trifluoroacetate	air	kg	2.29E+00
Methyl 2,2,2-trifluoroacetate	air	kg	1.84E+01
Methyl 2,2-difluoroacetate	air	kg	1.15E+00
Difluoromethyl 2,2,2-trifluoroacetate	air	kg	9.46E+00
2,2,3,3,4,4,4-Heptafluorobutan-1-ol	air	kg	1.18E+01
1,1,2-Trifluoro-2-(trifluoromethoxy) -ethane	air	kg	4.27E+02
1-Ethoxy-1,1,2,3,3,3-hexafluoropropane	air	kg	8.03E+00
1,1,1,2,2,3,3-Heptafluoro-3-(1,2,2,2-tetrafluoroethoxy)-propane	air	kg	2.11E+03
2,2,3,3-Tetrafluoro-1-propanol	air	kg	4.59E+00
2,2,3,4,4,4-Hexafluoro-1-butanol Hexafluoropropyl methyl ether	air	kg	6.02E+00
2,2,3,3,4,4,4-Heptafluoro-1-butanol	air	kg	5.73E+00
1,1,2,2-Tetrafluoro-3-methoxy-propane	air	kg	2.87E-01
Perfluoro-2-methyl-3-pentanone	air	kg	2.87E-01
3,3,3-Trifluoro-propanal	air	kg	2.87E-01
2-Fluoroethanol	air	kg	2.87E-01
2,2-Difluoroethanol	air	kg	1.15E+00
2,2,2-Trifluoroethanol	air	kg	6.88E+00
1,1'-Oxybis[2-(difluoromethoxy) -1,1,2,2-tetrafluoroethane	air	kg	1.65E+03
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12-hexadecafluoro-2,5,8,11-Tetraoxadodecane	air	kg	1.50E+03
1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12,13,13,15,15-Eicosafluoro-2,5,8,11,14-Pentaoxapentadecane	air	kg	1.22E+03
CF4	air	kg	1.81E+03
C2F6	air	kg	3.58E+03
c-C4F8	air	kg	2.61E+03
C6F14	air	kg	1.95E+03
CHFBr2	air	kg	5.05E+01
C2HFBr4	air	kg	3.96E+01
C2HF2Br3	air	kg	5.27E+01
C2HF3Br2	air	kg	5.05E+01

Table 5 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
C2HF4Br	air	kg	4.83E+01
C2H2FBr3	air	kg	3.96E+01
C2H2F2Br2	air	kg	4.61E+01
C2H2F3Br	air	kg	5.27E+01
C2H3FBr2	air	kg	4.61E+01
C2H3F2Br	air	kg	4.18E+01
C2H4FBr	air	kg	3.04E+01
C3HFBr6	air	kg	4.83E+01
C3HF2Br5	air	kg	5.05E+01
C3HF3Br4	air	kg	5.05E+01
C3HF4Br3	air	kg	5.71E+01
C3HF5Br2	air	kg	5.92E+01
C3HF6Br	air	kg	7.23E+01
C3H2FBr5	air	kg	5.05E+01
C3H2F2Br4	air	kg	5.27E+01
C3H2F3Br3	air	kg	9.20E+01
C3H2F4Br2	air	kg	1.14E+02
C3H2F5Br	air	kg	1.90E+02
C3H3FBr4	air	kg	5.71E+01
C3H3F2Br3	air	kg	6.36E+01
C3H3F3Br2	air	kg	5.49E+01
C3H3F4Br	air	kg	7.89E+01
C3H4FBr3	air	kg	3.22E+01
C3H4F2Br2	air	kg	3.96E+01
C3H4F3Br	air	kg	3.81E+01
C3H5FBr2	air	kg	3.33E+01
C3H5F2Br	air	kg	3.81E+01
C3H6FBr	air	kg	3.65E+01
CH2BrCl	air	kg	3.13E+01

Table 6 Monetary values of impacts on environmental goods from emissions of volatile organic gases (VOC)

Emission	Receiving media	Unit	Monetary impact value, €
Methane	air	kg	8.21E+00
Ethan	air	kg	1.50E+00
Propane	air	kg	1.96E+00
N-butane	air	kg	2.22E+00
I-butane	air	kg	2.00E+00
N-pentane	air	kg	2.56E+00
I-pentane	air	kg	1.80E+00
Neopentane	air	kg	1.38E+00
Hexane	air	kg	2.71E+00
2-metylpentane	air	kg	2.38E+00
3-metylpentane	air	kg	2.50E+00
2,2-Dimethylbutane	air	kg	1.85E+00
2,3-Dimethylbutane	air	kg	1.48E+00
N-heptane	air	kg	2.65E+00
2-Methylhexane	air	kg	1.74E+00
3-Methylhexane	air	kg	1.67E+00
N-oktane	air	kg	2.62E+00
2-metylheptane	air	kg	2.45E+00
N-nonane	air	kg	2.61E+00
2-metyloktane	air	kg	2.45E+00
N-decane	air	kg	2.58E+00
2-methylnonane	air	kg	2.47E+00
N-undecane	air	kg	2.53E+00
N-dodecane	air	kg	2.53E+00
Cyclohexane	air	kg	1.56E+00
Metyl-cyclohexane	air	kg	2.27E+00
Cyclohexanone	air	kg	1.41E+00
Cyclohexanol	air	kg	1.64E+00
Ethene	air	kg	3.00E+00
Propene	air	kg	3.07E+00
1-butene	air	kg	3.05E+00
2-butene	air	kg	2.85E+00
Methylpropene	air	kg	2.08E+00
1-pentene	air	kg	2.98E+00
2-pentene	air	kg	3.09E+00
2-Methylbutan-1-ol	air	kg	2.42E+00
2-methyl-2-butene	air	kg	2.82E+00
3-Methylbut-1-ene	air	kg	2.15E+00
Hex-1-ene	air	kg	2.46E+00
Hex-2-ene	air	kg	2.76E+00
1,3-Butadiene	air	kg	2.62E+00
Methacrolein	air	kg	3.44E+00
Styrene	air	kg	2.47E+00
Acetylene	air	kg	1.84E+00
Benzene	air	kg	3.95E+01
Toluene	air	kg	3.93E+01
O-xylene	air	kg	3.97E+01
M-xylene	air	kg	4.02E+01
P-xylene	air	kg	4.02E+01
Etylbenzene	air	kg	3.98E+01
1,2,3-Trimetylbenzene	air	kg	3.95E+01
1,2,4-Trimetylbenzene	air	kg	3.98E+01
1,3,5-Trimetylbenzene	air	kg	3.96E+01

Table 6 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
M-ethyltoluene	air	kg	4.01E+01
O-ethyltoluene	air	kg	3.95E+01
P-ethyltoluene	air	kg	4.00E+01
N-propylbenzene	air	kg	3.98E+01
I-propylbenzene	air	kg	3.96E+01
3,5-Dimethylethylbenzene	air	kg	4.06E+01
3,5-Diethyltoluene	air	kg	4.06E+01
Methanol	air	kg	8.62E+00
Ethanol	air	kg	9.36E+00
Propanol	air	kg	9.49E+00
I-propanol	air	kg	9.26E+00
Butanol	air	kg	9.93E+00
I-butanol	air	kg	9.29E+00
s-butanol	air	kg	9.33E+00
t-butanol	air	kg	8.90E+00
3-pentanol	air	kg	9.40E+00
2-Methylbutan-1-ol	air	kg	9.38E+00
3-Methylbutan-2-ol	air	kg	9.32E+00
2-Methylbutan-2-ol	air	kg	8.97E+00
Diacetone alcohol	air	kg	9.16E+00
Ethylene glycol	air	kg	8.96E+00
Propylene glycol	air	kg	9.19E+00
Acetone	air	kg	1.54E+00
Methyl ethyl ketone	air	kg	1.89E+00
Methyl i-butyl ketone	air	kg	2.17E+00
Methylpropylketone	air	kg	1.75E+00
Diethylketone	air	kg	1.54E+00
Methyl-i-propylketone	air	kg	1.47E+00
Hexan-2-one	air	kg	1.83E+00
Hexan-3-one	air	kg	1.88E+00
Methyl-t-butylketone	air	kg	1.45E+00
Formaldehyde	air	kg	1.07E+00
Acetaldehyde	air	kg	1.85E+00
Propionaldehyde	air	kg	2.13E+00
Butyraldehyde	air	kg	2.25E+00
I-butyraldehyde	air	kg	1.77E+00
Valeraldehyde	air	kg	2.29E+00
Glyoxal	air	kg	8.29E-01
Methyl-Glyoxal	air	kg	1.74E+00
Acrolein	air	kg	2.36E+00
Methanethiol	air	kg	1.90E+00
Benzaldehyde	air	kg	3.84E+01
Methyl formate	air	kg	8.44E+00
Methyl-Acetate	air	kg	8.61E+00
ethylacetate	air	kg	8.95E+00
n-Propyl acetate	air	kg	9.08E+00
i-Propyl acetate	air	kg	8.96E+00
n-butylacetate	air	kg	9.35E+00
2-Ethylhexyl acetate	air	kg	9.24E+00
Dimethylether	air	kg	1.18E+00

Table 6 (continued)

Emission	Receiving media	Unit	Monetary impact value, €
Diethyl-Ether	air	kg	1.64E+00
Methyl-t-Butyl-Ether	air	kg	1.64E+00
Diisopropylether	air	kg	1.65E+00
Ethyl-t-butylether	air	kg	1.24E+00
2-Methoxyethanol	air	kg	8.95E+00
2-Ethoxyethanol	air	kg	9.16E+00
1-Butoxypropanol	air	kg	9.37E+00
2-Butoxyethanol	air	kg	9.34E+00
1-Methoxy-2-propanol	air	kg	9.13E+00
Formic acid	air	kg	3.87E-01
Acetic Acid	air	kg	7.49E-01
Propanoic acid	air	kg	9.83E-01
Methyl chloride	air	kg	3.46E+00
Methylene chloride	air	kg	2.69E+00
Chloroform	air	kg	4.64E+00
1,1-dichloroethane	air	kg	4.10E-01
1,1-dichloroethylene	air	kg	3.26E-01
1,2-Dichloroethylene	air	kg	9.36E-01
Tetrachloroethylene	air	kg	1.32E+00
Trichloroethylene	air	kg	1.43E+00
Methyl chloroform	air	kg	4.60E+01
Methyl Mercaptan	air	kg	2.25E+00
Diethyl Sulfide	air	kg	2.25E+00
Diethyl Disulfide	air	kg	1.85E+00
Average NMVOC	air	kg	9.01E+00

Table 7 Monetary values of impacts on environmental goods from emissions of radioactive substances to air

Emission	Receiving media	Unit	Monetary impact value, €
C-14	air	TBq	1.09E+07
H-3	air	TBq	1.55E+02
I-129	air	TBq	5.14E+05
Kr-85	air	TBq	2.57E+02
Pb-210	air	TBq	1.28E+05
Po-210	air	TBq	1.28E+05
Ra-226	air	TBq	7.71E+04
Rn-222	air	TBq	1.93E+03
Th-230	air	TBq	3.85E+06
U-234	air	TBq	1.03E+06
U-238	air	TBq	8.99E+05

Table 8 Monetary values of impacts on environmental goods from emissions of noise from car and truck transports

Emission category	Unit 1	Unit 2	Impact cost	Impact cost
(dB)			€/ car km	€/car km
60-65	car km	ton km	1.09E-02	2.35E-04
70-71	car km	ton km	2.18E-02	4.68E-04
71-72	car km	ton km	2.75E-02	5.89E-04
72-73	car km	ton km	3.46E-02	7.42E-04
73-74	car km	ton km	4.35E-02	9.36E-04
74-75	car km	ton km	5.49E-02	1.17E-03
75-76	car km	ton km	6.91E-02	1.48E-03
76-77	car km	ton km	8.70E-02	1.86E-03
77-78	car km	ton km	1.09E-01	2.35E-03
78-79	car km	ton km	1.38E-01	2.95E-03
79-80	car km	ton km	1.74E-01	3.72E-03
80-81	car km	ton km	2.18E-01	4.68E-03
81-82	car km	ton km	2.75E-01	5.89E-03
82-83	car km	ton km	3.46E-01	7.42E-03
83-84	car km	ton km	4.35E-01	9.36E-03
84-85	car km	ton km	5.49E-01	1.17E-02
85-86	car km	ton km	6.91E-01	1.48E-02
86-87	car km	ton km	8.70E-01	1.86E-02
87-88	car km	ton km	1.09E+00	2.35E-02
88-89	car km	ton km	1.38E+00	2.95E-02
89-90	car km	ton km	1.74E+00	3.72E-02

Monetary values of impacts on environmental goods from emissions to soil

The use of pesticides is an emission to soil with a significant monetary impact value. Table 9 shows the monetary values of emissions of several pesticides. Besides being toxic to humans and impacting on biodiversity some contain scarce metals and contribute to resource depletion. Impacts from production is mostly contributing most to the impact cost. For pesticides containing As, Cu, Hg, Tl and Zn, resource depletion contributes most. For 18% of the pesticides, Years of lost life (YLL) caused by acute poisoning contribute most to the impacts cost. The resource depletion could be modeled in the inventory as an input of scarce substances, but for practical reasons is included in the impact assessment here.

Table 9 Monetary values of impacts on environmental goods from emissions of pesticides to soil

Substance name	CASRN	Receiving media	Unit	Monetary impact value, €
2,3,6-TBA	000050-31-7	soil	kg	2.17E-01
2,4-D	000094-75-7	soil	kg	8.56E-01
2,4-DB	000094-82-6	soil	kg	4.61E-01
2-Napthyloxyacetic acid	000120-23-0	soil	kg	5.37E-01
3-Chloro-1,2-propanediol	000096-24-2	soil	kg	2.86E+00
4-CPA	000122-88-3	soil	kg	3.80E-01
Acephate	030560-19-1	soil	kg	1.64E+00
Acifluorfen	050594-66-6	soil	kg	1.10E+00
Acrolein	000107-02-8	soil	kg	1.10E+01
Alachlor	015972-60-8	soil	kg	3.48E-01
Alanycarb	083130-01-2	soil	kg	1.00E+00
Aldicarb	000116-06-3	soil	kg	3.44E+02
Allethrin	000584-79-2	soil	kg	4.71E-01
Allyl alcohol	000107-18-6	soil	kg	5.00E+00
Alpha-cypermethrin	067375-30-8	soil	kg	4.05E+00
Ametryn	000834-12-8	soil	kg	2.91E+00
Amitraz	033089-61-1	soil	kg	4.04E-01
Anilofos	064249-01-0	soil	kg	1.34E+00
Azaconazole	060207-31-0	soil	kg	1.04E+00
Azamethiphos	035575-96-3	soil	kg	1.05E+00
Azinphos-ethyl	002642-71-9	soil	kg	2.73E+01
Azinphos-methyl	000086-50-0	soil	kg	2.07E+01
Azocyclotin	041083-11-8	soil	kg	1.77E+02
Bendiocarb	022781-23-3	soil	kg	5.81E+00
Benfuracarb	082560-54-1	soil	kg	1.58E+00
Bensulide	000741-58-2	soil	kg	1.81E+00
Bensultap	017606-31-4	soil	kg	3.49E-01
Bentazone	025057-89-0	soil	kg	3.19E-01
Beta-cyfluthrin	068359-37-5	soil	kg	2.93E+01
Bifenthrin	082657-04-3	soil	kg	6.55E+00
Bilanafos	071048-99-2	soil	kg	1.91E+00
Bioallethrin	000584-79-2	soil	kg	4.61E-01
Blasticidin-S	002079-00-7	soil	kg	2.00E+01
Brodifacoum	056073-10-0	soil	kg	1.07E+03
Bromadiolone	028772-56-7	soil	kg	2.85E+02
Bromethalin	063333-35-7	soil	kg	1.60E+02
Bromoxynil	001689-84-5	soil	kg	1.69E+00
Bromuconazole	116255-48-2	soil	kg	8.80E-01
Bronopol	000052-51-7	soil	kg	1.26E+00
Butamifos	036335-67-8	soil	kg	1.23E+00
Butocarboxim	034681-10-2	soil	kg	2.06E+00
Butoxycarboxim	034681-23-7	soil	kg	1.14E+00
Butralin	033629-47-9	soil	kg	3.09E-01
Butroxydim	138164-12-2	soil	kg	2.00E-01
Butylamine	013952-84-6	soil	kg	8.45E-01
Cadusafos	095465-99-9	soil	kg	9.54E+00
Calcium arsenate	007778-44-1	soil	kg	6.73E+02
Calcium cyanide	000592-01-8	soil	kg	8.20E+00
Captafol	002425-06-1	soil	kg	8.48E-02

Table 9 (continued)

Substance name	CASRN	Receiving media	Unit	Monetary impact value, €
Carbaryl	000063-25-2	soil	kg	1.07E+00
Carbofuran	001563-66-2	soil	kg	3.99E+01
Carbosulfan	055285-14-8	soil	kg	1.30E+00
Cartap	015263-53-3	soil	kg	1.04E+00
Chloralose	015879-93-3	soil	kg	8.03E-01
Chlordane	000057-74-9	soil	kg	6.99E-01
Chlorethoxyfos	054593-83-8	soil	kg	1.78E+02
Chlorfenapyr	122453-73-0	soil	kg	1.49E+00
Chlorfenvinphos	000470-90-6	soil	kg	1.10E+01
Chlormephos	024934-91-6	soil	kg	4.67E+01
Chlormequat (chloride)	000999-81-5	soil	kg	4.81E-01
Chloroacetic acid	000079-11-8	soil	kg	4.96E-01
Chlorophacinone	003691-35-8	soil	kg	1.03E+02
Chlorphonium chloride	000115-78-6	soil	kg	2.38E+00
Chlorpyrifos	002921-88-2	soil	kg	3.05E+00
Clomazone	081777-89-1	soil	kg	2.38E-01
Copper hydroxide	020427-59-2	soil	kg	8.56E+01
Copper oxychloride	001332-40-7	soil	kg	7.83E+01
Copper sulfate	007758-98-7	soil	kg	5.32E+01
Coumaphos	000056-72-4	soil	kg	4.57E+01
Coumatetralyl	005836-29-3	soil	kg	2.00E+01
Cuprous oxide	001317-39-1	soil	kg	1.17E+02
Cyanazine	021725-46-2	soil	kg	1.11E+00
Cyanophos	002636-26-2	soil	kg	1.50E+00
Cyfluthrin	068359-37-5	soil	kg	2.15E+01
Cyhalothrin	068085-85-8	soil	kg	2.91E+00
Cyhexatin	013121-70-5	soil	kg	1.97E+02
Cymoxanil	057966-95-7	soil	kg	2.71E-01
Cypermethrin	052315-07-8	soil	kg	1.28E+00
Cyphenothrin [(1R)-isomers]	039515-40-7	soil	kg	1.01E+00
Cyproconazole	094361-06-5	soil	kg	3.18E-01
Dazomet	000533-74-4	soil	kg	5.75E-01
DDT	000050-29-3	soil	kg	2.83E+00
Deltamethrin	052918-63-5	soil	kg	2.37E+00
Demeton-S-methyl	000919-86-8	soil	kg	9.05E+00
Diazinon	000333-41-5	soil	kg	1.84E+00
Dicamba	001918-00-9	soil	kg	1.91E-01
Dichlorobenzene	000106-46-7	soil	kg	1.20E-01
Dichlorophen	000097-23-4	soil	kg	2.60E-01
Dichlorprop	007547-66-2	soil	kg	4.04E-01
Dichlorvos	000062-73-7	soil	kg	6.76E+00
Diclofop	040483-25-2	soil	kg	5.70E-01
Dicofol	000115-32-2	soil	kg	4.67E-01
Dicrotophos	000141-66-2	soil	kg	1.55E+01
Difenacoum	056073-07-5	soil	kg	1.78E+02
Difenoconazole	119446-68-3	soil	kg	2.24E-01
Difenzoquat	043222-48-6	soil	kg	6.84E-01
Difethialone	104653-34-1	soil	kg	5.71E+02
Dimepiperate	061432-55-1	soil	kg	3.64E-01
Dimethachlor	050563-36-5	soil	kg	2.04E-01

Table 9 (continued)

Substance name	CASRN	Receiving media	Unit	Monetary impact value, €
Dimethenamid	087674-68-8	soil	kg	8.87E-01
Dimethipin	055290-64-7	soil	kg	3.30E-01
Dimethoate	000060-51-5	soil	kg	3.19E+00
Dimethylarsinic acid	000075-60-5	soil	kg	1.90E+03
Diniconazole	083657-24-3	soil	kg	5.04E-01
Dinobuton	000973-21-7	soil	kg	2.29E+00
Dinocap	039300-45-3	soil	kg	3.30E-01
Dinoterb	001420-07-1	soil	kg	1.28E+01
Diphacinone	000082-66-6	soil	kg	1.39E+02
Diphenamid	000957-51-7	soil	kg	3.34E-01
Diquat	002764-72-9	soil	kg	1.39E+00
Disulfoton	000298-04-4	soil	kg	1.24E+02
Dithianon	003347-22-6	soil	kg	5.43E-01
DNOC	000534-52-1	soil	kg	1.28E+01
Dodine	002439-10-3	soil	kg	3.24E-01
Edifenphos	017109-49-8	soil	kg	2.92E+00
Endosulfan	000115-29-7	soil	kg	4.01E+00
Endothal-sodium	000125-67-9	soil	kg	6.27E+00
EPN	002104-64-5	soil	kg	2.36E+01
EPTC	000759-94-4	soil	kg	2.28E-01
Esfenvalerate	066230-04-4	soil	kg	3.68E+00
Ethiofencarb	029973-13-5	soil	kg	1.63E+00
Ethion	000563-12-2	soil	kg	1.54E+00
Ethoprophos	013194-48-4	soil	kg	1.07E+01
Famphur	000052-85-7	soil	kg	7.41E+00
Fenamiphos	022224-92-6	soil	kg	2.21E+01
Fenazaquin	120928-09-8	soil	kg	2.39E+00
Fenitrothion	000122-14-5	soil	kg	1.49E+00
Fenobucarb	003766-81-2	soil	kg	5.20E-01
Fenothiocarb	062850-32-2	soil	kg	3.05E-01
Fenpropathrin	064257-84-7	soil	kg	4.85E+00
Fenpropidin	067306-00-7	soil	kg	2.85E-01
Fenpyroximate	134098-61-6	soil	kg	1.31E+00
Fenthion	000055-38-9	soil	kg	1.42E+00
Fentin acetate[(ISO)]	000900-95-8	soil	kg	1.87E+02
Fentin hydroxide[(ISO)]	000076-87-9	soil	kg	2.08E+02
Fenvalerate	051630-58-1	soil	kg	7.14E-01
Ferimzone	089269-64-7	soil	kg	4.45E-01
Fipronil	120068-37-3	soil	kg	4.91E+00
Flocoumafen	090035-08-8	soil	kg	1.28E+03
Fluchloralin	033245-39-5	soil	kg	1.09E+00
Flucythrinate	070124-77-5	soil	kg	5.23E+00
Flufenacet	014245-95-8	soil	kg	1.69E+00
Fluoroacetamide	000640-19-7	soil	kg	2.59E+01
Fluoroglycofen	077501-60-1	soil	kg	4.57E-01
Flurprimidol	056425-91-3	soil	kg	1.45E+00
Flusilazole	085509-19-9	soil	kg	1.14E+00
Flutriafol	076674-21-0	soil	kg	9.73E-01
Fluxofenim	088485-37-4	soil	kg	1.48E+00
Fomesafen	072178-02-0	soil	kg	9.81E-01

Table 9 (continued)

Substance name	CASRN	Receiving media	Unit	Monetary impact value, €
Formetanate	022259-30-9	soil	kg	1.52E+01
Fuberidazole	003878-19-1	soil	kg	9.55E-01
Furalaxyl	057646-30-7	soil	kg	3.44E-01
Furathiocarb	065907-30-4	soil	kg	7.63E+00
Gamma-HCH , Lindane	000058-89-9	soil	kg	3.64E+00
Glufosinate	053369-07-6	soil	kg	1.48E+00
Guazatine	108173-90-6	soil	kg	1.39E+00
Haloxyfop	069806-34-4	soil	kg	1.93E+00
HCH	000608-73-1	soil	kg	3.20E+00
Heptenophos	023560-59-0	soil	kg	4.25E+00
Hexachlorobenzene	000118-74-1	soil	kg	3.62E-02
Hexazinone	051235-04-2	soil	kg	1.93E-01
Hydramethylnon	067485-29-4	soil	kg	1.53E+00
Imazalil	035554-44-0	soil	kg	1.41E+00
Imidacloprid	138261-41-3	soil	kg	7.14E-01
Iminoctadine	013516-27-3	soil	kg	1.07E+00
Indoxacarb	173584-44-6	soil	kg	1.79E+00
Ioxynil	001689-83-4	soil	kg	2.16E+01
Ioxynil octanoate	003861-47-0	soil	kg	1.48E+01
Iprobenfos	026087-47-8	soil	kg	1.36E+00
Isoprocarb	002631-40-5	soil	kg	7.97E-01
Isoprothiolane	050512-35-1	soil	kg	3.13E-01
Isoproturon	034123-59-6	soil	kg	1.82E-01
Isouron	055861-78-4	soil	kg	5.11E-01
Isoxathion	018854-04-8	soil	kg	3.61E+00
Lambda-cyhalothrin	091465-08-6	soil	kg	6.40E+00
Lead arsenate	007784-40-9	soil	kg	9.70E+02
MCPA	000094-74-6	soil	kg	4.61E-01
MCPA-thioethyl	025319-90-8	soil	kg	4.32E-01
MCPB	000094-81-5	soil	kg	4.74E-01
Mecarbam	002595-54-2	soil	kg	9.62E+00
Mecoprop	007085-19-0	soil	kg	3.48E-01
Mecoprop-P	016484-77-8	soil	kg	3.09E-01
Mefluidide	053780-34-0	soil	kg	1.19E+00
Mepiquat	015302-91-7	soil	kg	2.19E-01
Mercuric chloride	007487-94-7	soil	kg	5.81E+04
Mercuric oxide	021908-53-2	soil	kg	7.24E+04
Mercurous chloride	010112-91-1	soil	kg	6.65E+04
Metalaxyl	057837-19-1	soil	kg	4.81E-01
Metaldehyde	000108-62-3	soil	kg	1.41E+00
Metamitron	041394-05-2	soil	kg	2.74E-01
Metam-sodium [(ISO)]	000137-42-8	soil	kg	1.22E+00
Metconazole	125116-23-6	soil	kg	4.88E-01
Methacrifos	062610-77-9	soil	kg	1.46E+00
Methamidophos	010265-92-6	soil	kg	1.23E+01
Methasulfocarb	066952-49-6	soil	kg	2.90E+00
Methidathion	000950-37-8	soil	kg	1.36E+01
Methiocarb	002032-65-7	soil	kg	1.60E+01
Methomyl	016752-77-5	soil	kg	1.88E+01
Methyl isothiocyanate	000556-61-6	soil	kg	4.52E+00

Table 9 (continued)

Substance name	CASRN	Receiving media	Unit	Monetary impact value, €
Methylarsonic acid	000124-58-3	soil	kg	1.87E+03
Metolcarb	001129-41-5	soil	kg	1.20E+00
Metribuzin	021087-64-9	soil	kg	1.02E+00
Mevinphos	026718-65-0	soil	kg	8.74E+01
Molinate	002212-67-1	soil	kg	4.79E-01
Monocrotophos	006923-22-4	soil	kg	2.39E+01
Myclobutanil	088671-89-0	soil	kg	2.04E-01
Nabam	000142-59-6	soil	kg	9.04E-01
Naled	000300-76-5	soil	kg	1.35E+00
Nicotine	000054-11-5	soil	kg	6.39E+00
Nitrapyrin	001929-82-4	soil	kg	3.02E-01
Nuarimol	063284-71-9	soil	kg	5.89E-01
Octhilinone	026530-20-1	soil	kg	2.49E-01
Omethoate	001113-02-6	soil	kg	7.51E+00
Oxadixyl	077732-09-3	soil	kg	1.76E-01
Oxamyl	023135-22-0	soil	kg	5.33E+01
Oxydemeton-methyl	000301-12-2	soil	kg	5.91E+00
Paclobutrazol	076738-62-0	soil	kg	2.50E-01
Paraquat	001910-42-5	soil	kg	2.13E+00
Parathion	000056-38-2	soil	kg	2.54E+01
Parathion-methyl	000298-00-0	soil	kg	2.37E+01
Paris green	012002-03-8	soil	kg	5.63E+02
Pebulate	001114-71-2	soil	kg	3.18E-01
Pendimethalin	040487-42-1	soil	kg	3.09E-01
Pentachlorophenol	000087-86-5	soil	kg	4.00E+00
Permethrin	052645-53-1	soil	kg	6.43E-01
Phenthoate	002597-03-7	soil	kg	1.56E+00
Phenylmercury acetate	000062-38-4	soil	kg	4.65E+04
Phorate	000298-02-2	soil	kg	1.61E+02
Phosalone	002310-17-0	soil	kg	3.33E+00
Phosmet	000732-11-6	soil	kg	3.60E+00
Phosphamidon	013171-21-6	soil	kg	4.64E+01
Phoxim	014816-18-3	soil	kg	9.61E-01
Piperophos	024151-93-7	soil	kg	1.68E+00
Pirimicarb	023103-98-2	soil	kg	2.18E+00
Pirimiphos-methyl	029232-93-7	soil	kg	9.73E-01
Prallethrin	023031-36-9	soil	kg	6.99E-01
Prochloraz	067747-09-5	soil	kg	2.04E-01
Profenofos	041198-08-7	soil	kg	1.53E+00
Propachlor	001918-16-7	soil	kg	2.17E-01
Propanil	000709-98-8	soil	kg	2.32E-01
Propetamphos	031218-83-4	soil	kg	3.86E+00
Propiconazole	060207-90-1	soil	kg	2.14E-01
Propoxur	000114-26-1	soil	kg	3.37E+00
Prosulfocarb	052888-80-9	soil	kg	2.03E-01
Prothiofos	034643-46-4	soil	kg	1.05E+00
Pyraclofos	077458-01-6	soil	kg	2.01E+00
Pyrazophos	013457-18-6	soil	kg	1.37E+00
Pyrazoxyfen	071561-11-0	soil	kg	1.99E-01
Pyrethrins	008003-34-7	soil	kg	4.30E-01
Pyridaben	096489-71-3	soil	kg	4.10E-01
Pyridaphenthion	000119-12-0	soil	kg	1.12E+00
Pyroquilon	057369-32-1	soil	kg	1.00E+00

Table 9 (continued)

Substance name	CASRN	Receiving media	Unit	Monetary impact value, €
Quinalphos	013593-03-8	soil	kg	5.95E+00
Quinoclamine	002797-51-5	soil	kg	2.39E-01
Quizalofop	076578-12-6	soil	kg	1.96E-01
Quizalofop-p-tefuryl	119738-06-6	soil	kg	3.20E-01
Rotenone	000083-79-4	soil	kg	3.96E-01
Simetryn	001014-70-6	soil	kg	2.06E-01
Sodium arsenite	007784-46-5	soil	kg	1.17E+03
Sodium chlorate	007775-09-9	soil	kg	2.71E-01
Sodium cyanide	000143-33-9	soil	kg	5.33E+01
Sodium fluoroacetate	000062-74-8	soil	kg	1.60E+03
Spiroxamine	118134-30-8	soil	kg	6.43E-01
Strychnine	000057-24-9	soil	kg	2.00E+01
Sulfluramid	004151-50-2	soil	kg	6.04E-01
Sulfotep	003689-24-5	soil	kg	6.54E+01
TCA (acid)	000076-03-9	soil	kg	8.03E-01
Tebuconazole	107534-96-3	soil	kg	1.92E-01
Tebufenpyrad	119168-77-3	soil	kg	5.41E-01
Tebupirimfos	096182-53-5	soil	kg	2.47E+02
Tebuthiuron	034014-18-1	soil	kg	5.26E-01
Tefluthrin	079538-32-2	soil	kg	1.63E+01
Terbufos	013071-79-9	soil	kg	1.61E+02
Terbumeton	033693-04-8	soil	kg	6.66E-01
Tetraconazole	112281-77-3	soil	kg	1.43E+00
Thallium sulfate	007446-18-6	soil	kg	4.20E+03
Thiacloprid	111988-49-9	soil	kg	8.34E-01
Thiobencarb	028249-77-6	soil	kg	2.73E-01
Thiocyclam	031895-22-4	soil	kg	1.13E+00
Thiodicarb	059669-26-0	soil	kg	4.89E+00
Thiofanox	039196-18-4	soil	kg	4.00E+01
Thiometon	000640-15-3	soil	kg	3.68E+00
Thiram	000137-26-8	soil	kg	6.72E-01
Tralkoxydim	087820-88-0	soil	kg	3.46E-01
Tralomethrin	066841-25-6	soil	kg	3.76E+00
Triadimefon	043121-43-3	soil	kg	5.35E-01
Triadimenol	055219-65-3	soil	kg	3.59E-01
Triazamate	112143-82-5	soil	kg	4.28E+00
Triazophos	024017-47-8	soil	kg	4.66E+00
Trichlorfon	000052-68-6	soil	kg	2.18E+00
Triclopyr	055335-06-3	soil	kg	4.54E-01
Tricyclazole	041814-78-2	soil	kg	1.08E+00
Tridemorph	081412-43-3	soil	kg	4.96E-01
Triflumizole	099387-89-0	soil	kg	1.36E+00
Uniconazole	083657-22-1	soil	kg	1.83E-01
Vamidothion	002275-23-2	soil	kg	3.95E+00
Warfarin	000081-81-2	soil	kg	3.20E+01
XMC	002655-14-3	soil	kg	5.94E-01
Xylylcarb	002425-10-7	soil	kg	8.45E-01
Zeta-cypermethrin	052315-07-8	soil	kg	3.72E+00
Zinc phosphide	001314-84-7	soil	kg	4.07E+01
Ziram	000137-30-4	soil	kg	9.24E+00

Monetary values of impacts on environmental goods from emissions to water

Emissions to water from industry and other human activities have long been controlled and surveyed. Most emissions do not cause significant harm to the safeguard subjects assessed in the EPS 2020d impact assessment method. They are controlled by permit regulations with safety margins to impacts. Effect like enhanced concentration of metals in marine species is not a significant impact, unless it results in decreased food production. Table10 shows environmental impact values from some emissions that have significant monetary impact on the safeguard subjects.

Table 10 Monetary values of environmental impacts from emission to water

Emission	Receiving media	Unit	Monetary impact value, €
BOD	freshwater	kg O2	3.20E-04
Ntot	freshwater	kg N	2.18E-03
Ntot	seawater	kg N	5.45E-03
Ptot	freshwater	kg P	4.14E-02
As	freshwater	kg	7.30E+03
Cd	freshwater	kg	2.38E+04
Hg	all	kg	3.95E+02

Weighting factors at the midpoint level

In mainstream LCIA several environmental impact categories are included. The UNEP/SETAC GLAM initiative and the EU JRC LCIA recommendations have recommended several such indicators. Often, these indicators are expressed in equivalency factors versus a characteristic substance, e.g. carbon dioxide equivalents. In those cases, the weighting factors determined for the characteristic substance can be used, more or less directly. Some modification may have to be made, such as for CO_2, whose impact is not only restricted to climate change. CO_2 has also a fertilizing effect, but this contribution to the weighting factor can be subtracted as all pathway specific weighting factors has been determined in the determination of the overall weighting factor for CO_2.

In some cases, e.g. human and ecological toxicity, or water scarcity, where there is no common mechanism that links elementary flows to endpoints, or to impacts that can be valued, an estimation of weighting factors at midpoint level becomes uncertain and even speculative. In table 11, weighting factors for midpoint indicators recommended by the GLAM project in the UNEP/SETAC Life cycle initiative are listed.

The monetary value of the CO_2-eqivalent indicator should ideally be somewhat lower than listed, as some CO_2-effects are not climate related. Fertilizing effects and ocean acidification should ideally be subtracted. However, IPCC did not estimate the quantitative fertilization effect on wood and crop production in its latest AR5 report, and the acidification impact is negligible in economic terms.

The monetary value of biodiversity is estimated from the cost of accepted prevention measures. In the EPS 2020d method this is allocated to land use and emissions via the share of threats to red-listed species according to IUCN. In principle such an allocation can also be made by using PDF (potential disappeared fraction of species). PDF as recommended by UNEP/SETAC builds on the IUCN but is more elaborated and includes weighting between several taxa and threat levels. It should thus be a better ground for allocation, but the additional data required are not easily found. Such an indicator would have to be PDF/(sum of all global PDF). As far as we understand, the sum of all PDFs is less than 1, but no specific figure has been found.

Table 11 Weighting factors for midpoint impact indicators recommended by UNEP/SETAC's GLAM project (UNEP/SETAC 2016, 2019)

Midpoint impact indicator	Indicator Unit	Weighting factor	Note
		€/indicator unit	
GWP 100	kg CO2 equivalents	0.288	
Premature deaths from PM2.5 or precursor	DALY /kg emitted	77300	
Water use: water scarcity		n/a	Unclear link to damages
Water use: human health effects	DALY /m3 consumed	77300	
Land occupation impact on biodiversity	PDF	69180000000/PDFglo	share of global sum of PDF
Land transformation impact on biodiversity		n/a	in EPS all land use impacts are accounted for in the occupation activity
Acidification, terrestrial	kg SO2 equivalents	0.003715785	global average
Eutrofication, freshwater	kg phosphorus-equivalents	0.041363636	
Eutrification, marine	kg nitrogen-equivalents,	0.005454545	
Human Toxicity	kg intake per kg substance	n/a	too unspecific for meaningful valuation
Human Toxicity, cancer effects	cases/ kg intake	n/a	too unspecific for meaningful valuation
Human Toxicity, non-cancer effects	cases/ kg intake	n/a	too unspecific for meaningful valuation
Ecotoxicity, all forms	CTUe/kg	n/a	link to endpoints missing
Natural Resources (minerals)	kg Sb-eq	28800	Relevant for scarce minerals. For Al, Fe and fossil minerals specific WF should be used
Land Use Impacts on Soil Quality	kg C deficit	n/a	lack of models for impact pathways

Weighting factors at the damage level

In the GLAM project, environmental impacts indicators at damage levels are DALY (Disability Adjusted Life Years) for human health, PDF (Potentially Disappeared Fraction of species) for ecosystem health, and economic value for natural resources.

DALY is often valued in monetary terms, but the methods may vary. In the EPS 2020 method, DALY is valued in terms of market price for labor, but applied not only to the working time, but also to all waken time, where people can act to satisfy their basic needs. As reported in table 2, 1 DALY was valued to 97300 € per person-year.

The biodiversity value in EPS v 2020 is determined to 6.92E+10 € for all biodiversity. The weighting factors for emission and land use impacts on biodiversity in EPS 2020 are determined by allocation of the value for all biodiversity according to the shares of threat to endangered species. This allocation rule was chosen because of global available data from IUCN on threat causes. In principle other allocation measures can be applied like the PDF (Potentially Disappeared Fraction of species), but then the PDF values need to be normalized against the total global PDF.

Weighting factors for material processes

Monetary values for impacts on environmental goods can also be determined for material processes. In many situations it is more practical to use such estimations.

Monetary values of impacts on environmental goods from land use

Land use is often treated as an elementary flow with the dimension of m2year, but a more correct characterization would be to regard it as a process, resulting in impacts on environmental goods.

As much of the concern for environmental impacts from land use relates to biodiversity, the IUCNs land use categories are used. These allows quantifying threats to red-listed species.

Besides threats to biodiversity, land use also has impacts on climate, ecosystem services and availability of drinking water.

Table 12 shows monetary values of environmental impacts on environmental goods from land use activities in cities with more than half a million inhabitants.

Table 12 Monetary values of environmental impacts from residential & commercial developments in cities > 0.5 million inhabitants

Land use activity	**Unit**	**Environmental impact factors**						
		YLL/unit	**Working capacity (p-yr/unit)**	**Crop (kg/unit)**	**Wood (m3/unit)**	**Drinking water (m3)**	**Share of threat to red-listed species (dimension-less)**	**Impact value (€/m2year)**
Housing and urban areas on arable land	m2year	1.10E-06	3.21E-01	6.00E-01		3.08E-01	2.60E-13	9.57E+00
Housing and urban areas on forestland	m2year	1.10E-06	3.21E-01		6.00E-04	3.08E-01	2.60E-13	9.45E+00
Housing and urban areas on impediment	m2year	1.10E-06	3.21E-01			3.08E-01	2.60E-13	9.41E+00
Commercial & industrial areas on arable lanc	m2year	1.10E-06	3.21E-01	6.00E-01		3.08E-01	1.30E-13	9.56E+00
Commercial & industrial areas on forestland	m2year	1.10E-06	3.21E-01		6.00E-04	3.08E-01	1.30E-13	9.44E+00
Commercial & industrial areas om impedime	m2year	1.10E-06	3.21E-01			3.08E-01	1.30E-13	9.40E+00
Tourism & recreational areas	m2year	1.10E-06					9.25E-14	1.14E-01

The largest contribution to the impact values is caused by the heat island changing the local climate. The values are global averages. In colder regions the impact is less and in warmer the impact is larger. The heat islands are less pronounced in smaller cities (table 13) and in rural areas (table 14).

Table 13 Monetary values of environmental impacts from residential & commercial developments in cities < 0.5 million inhabitants

Land use activity	**Unit**	**Environmental impact factors**						
		YLL/unit	**Working capacity (p-yr/unit)**	**Crop (kg/unit)**	**Wood (m3/unit)**	**Drinking water (m3)**	**Share of threat to red-listed species (dimension-less)**	**Impact value (€/m2year)**
Housing and urban areas on arable land	m2year	7.35E-07	2.14E-01	6.00E-01		3.08E-01	2.60E-13	6.61E+00
Housing and urban areas on forestland	m2year	7.35E-07	2.14E-01		6.00E-04	3.08E-01	2.60E-13	6.49E+00
Housing and urban areas on impediment	m2year	7.35E-07	2.14E-01			3.08E-01	2.60E-13	6.45E+00
Commercial & industrial areas on arable lanc	m2year	7.35E-07	2.14E-01	6.00E-01		3.08E-01	1.30E-13	6.60E+00
Commercial & industrial areas on forestland	m2year	7.35E-07	2.14E-01		6.00E-04	3.08E-01	1.30E-13	6.48E+00
Commercial & industrial areas on impedimer	m2year	7.35E-07	2.14E-01			3.08E-01	1.30E-13	6.44E+00
Tourism & recreational areas	m2year	7.35E-07					9.25E-14	7.80E-02

Table 14 Monetary values of environmental impacts from land use in rural areas

Land use activity	**Unit**	**Environmental impact factors**						
		YLL/unit	**Working capacity (p-yr/unit)**	**Crop (kg/unit)**	**Wood (m3/unit)**	**Drinking water (m3)**	**Share of threat to red-listed species (dimension-less)**	**Impact value (€/m2year)**
Agriculture and Aquaculture								
Annual&perennial non-timber crops	m2year						1.07E-14	7.42E-04
Wood & pulp plantations	m2year						2.00E-14	1.38E-03
Livestock farming and ranching	m2year						3.33E-15	2.31E-04
Marine and freshwater aquaculture	kg produced						6.27E-14	4.34E-03
Energy production and mining								
Oil and gas drilling	kg produced						4.99E-16	3.45E-05
Mining and quarrying	m2year				6.00E-04	3.08E-01	6.86E-14	5.68E-01
Renewable energy	m2year						2.95E-15	2.04E-04
Transportation and service corridors								
Roads and railroads	m2year			6.00E-01		3.08E-01	4.01E-12	9.59E-01
Utility and service lines	m2year				6.00E-04		1.71E-15	3.94E-02
Biological resource use								
Logging and wood harvesting	m2year						3.76E-15	2.60E-04

Monetary values of impacts on environmental goods from manufacturing and waste management of materials

Product related decisions are seldom based on full LCA. Most decisions-makers do not have LCA training or enough time for performing an LCA. But they are used to economic considerations. The price of the product materials and components, its maintenance costs and sometimes end-of-life costs are common to include in an overall calculation of product economics. Monetary values of environmental impacts on environmental goods from materials, processes and components may be used in a similar way. LCI data from production and various end-of-life processes may be used to calculate environmental impact costs for materials and components. Below (table 15), is an example of such data for polymers, metals, silicate materials, and energy production.

Table 15 example of damage costs for polymers, metals, silicate materials, and energy production.

Material or process	**Unit**	**Monetary impact cost, €/unit**						
		Production	Incineration	Energy recovery	Material recycling	Composting	Landfill, municipal	Landfill, (C&D)
Glass&minerals								
Cement	kg	0.276	0	0	0	0	0	0
Glass	kg	0.418	0	0	-0.335	0	0	0
Glass wool	kg	1	0	0	-0.4	0	0	0
Gypsum	kg	0.131	0	-0.0206	-0.105	0.000235	2.05	-0.0000555
Limestone	kg	0.0102	0	0	-0.00817	0	0	0
Metals								
Steel coil (steel sheet)	kg	2.16	0	0	-0.9	0	0	0
Stainless steel	kg	14.1	0	0	-11.2	0	0	0
Aluminium	kg	3.27	0	0	-2.62	0	0	0
Zinc	kg	77.2	0	0	-61.7	0	0	0
Copper wire	kg	277	0	0	-221	0	0	0
Brass	kg	27.5	0	0	-22	0	0	0
Magnesium	kg	16.8	0	0	-13.4	0	0	0
Packaging materials								
Corrugated board	kg	0.352	0.0003	-0.412	-0.106	0.0047	1.33	1.33
Polymers								
Acrylonitrile butadiene styrene (ABS)	kg	1.95	0.385	-0.678	-1.56	0.00901	0.0261	0.0261
Polyamide 6 (PA 6)	kg	2.42	-0.292	-1.15	-1.94	0.00673	-0.0192	-0.0192
Polycarbinate, PC	kg	2.33	0.786	-0.0157	-1.86	0.00785	0.04954	0.04954
Polyethylene, PE	kg	1.37	0.905	-0.373	-1.1	0.045	0.363	0.363
Polymethylmethacrylate, PMMA	kg	5.57	0.634	-0.0578	-4.46	0.00634	0.0419	0.0419
Polypropylene, PP	kg	1.37	0.905	-0.373	-1.05	0.00905	0.0726	0.0726
Polyurethane foam, PU	kg	3.47	-0.00808	-0.691	0	0.00693	-0.0076	-0.0076
Polyvinyl Butyral, PVB	kg	3.55	0.7142	-0.151	0	0	0	0
Polyvinyl chloride, PVC	kg	1.23	-3.54	-4	-0.984	0.00409	0.0304	0.0304
Styrene-butadiene rubber, SBR	kg	1.96	-2.98	-4.11	-0.981	0.00967	0.06743	0.06743
Textiles								
Cotton&Polyester, 50/50	kg	2.96	0.565	0.0692	-0.888	0.155	1.76	1.76
Transports								
Heavy truck transport	ton km	0.0579						
Ship	ton km	-0.000716						
Light duty vehicle	ton km	0.271						
Wood								
Wood, average		0.318	-0.0664	-0.00954	-0.0953	0.00465	0.541	0.541

Example of applications

Comparing fossil and renewable ethylene production routes

A case study was made in order to determine the environmental damage cost of different ethylene production routes (both fossil and renewable) and the major cost drivers in the different ethylene production routes. Ethanol from wheat was compared to ethanol from naphtha.

A traditional LCI was made and the elementary flows determined were multiplied by their monetary impact values. The results, which were recalculated with LCI data from (Gunnarsson 2020) are shown in figure 2.

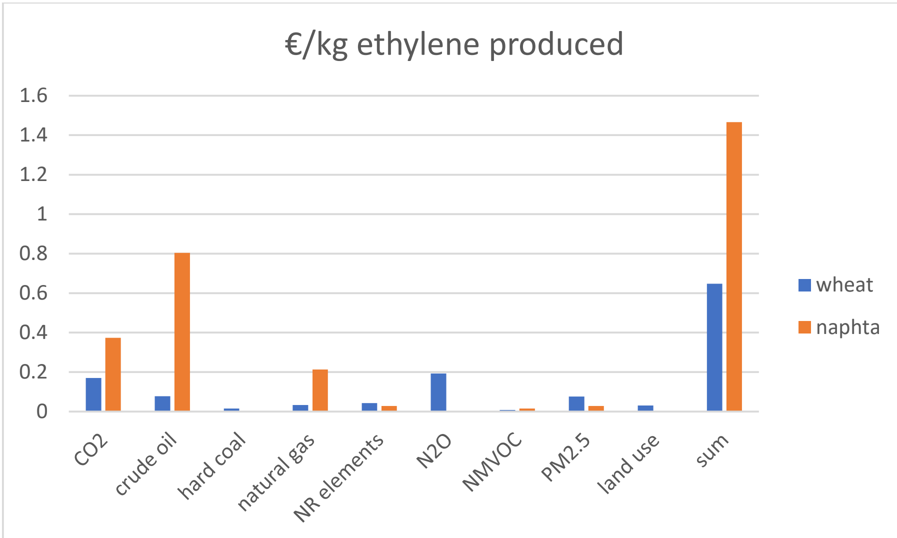

Figure 2 Environmental impact costs from alternative ways of ethylene production.

As might be expected, the wheat-based alternative has lower environmental impact costs. In comparison with the current price of ethylene, about 1.1 €/kg, the impact costs are quite high. There are good reasons to try to decrease the impact costs. In the naphtha case, the dominating impacts come from the use of fossil resources and fossil CO_2, and there is not much options for improvement, except carbon sequestration. In the wheat case fossil CO_2 and N_2O from fertilizing may be controlled better.

Choice between tool sheds

A tool shed should be purchased. There were two options: one made of steel sheet and one made of wood. The weight of the steel alternative was 360 kg and the weight of the wood alternative was 935 kg.

From table 13 we find that the environmental impact cost for production of steel sheet is 2.16 €/kg, which means that the environmental impact cost of the tool shed production is 2.16*360 = 778 €.

The environmental cost to produce the wooden toolshed will be 0.318*935 kg = 297 €

If the steel shed is recycled as steel scrap when not used any longer, there will be a benefit of 0.9*360 = 324 €. The net life cycle environmental impact cost will be 778 – 324 = 454 €.

If the wood of the wooden shed is recycled, there is a benefit of 0.0953*935 = 89 €. The net life cycle environmental impact cost will be 297 – 89 = 208 €.

The wooden shed is thus to prefer, but if the wood of the wooden shed is deposited in a landfill (household or construction & demolition type), methane is produced, and the damage cost is 0.541 €/kg and 0.541*935 = 506 €. The steel shed now becomes the best alternative.

These types of calculations can be made relatively fast, even if there are more than one material. A simple spreadsheet template for such calculations can be used. Such an Excel tool is available at https://www.lifecyclecenter.se/tools/ .

Global annual damage cost

The monetary damage cost values can also be used on national and global levels. In table 16 the ten highest monetary values for global emissions and resource extraction are shown. They contribute with 73 % of the total damage costs from all emissions and resource extractions. This is more than the global GNP (110%). However, a direct comparison of the EPS 2020d damage costs with the global GDP is misleading. When the damage costs on human health was calculated, the average salary of an OECD inhabitant was used for all affected people, globally and disability was accounted for all waken hours. In order to get a comparable value, we need to adjust the global GDP to the OECD salary level and to all waken hours. The adjusted GDP would then be equal to the value of a YLL times the global population, i.e. 9.73 E+04 * 7.2 E+09 = 7.01E+14, which is about 10 times higher and result in a monetary environmental impact value of 11% of such an adjusted GDP.

About half of the monetary environmental impact costs are from emissions and cost for disability of the present generations. The other half is an annual decrease of the long-term natural capital, such as depletion of mineral resources.

Table 16 Selected global flows and global damage costs values

Flow	**Unit**	**Value/unit €/unit**	**Global flow**	**Global cost, €**
CO2	kg	2.88E-01	3.26E+13	9.39E+12
PM2.5	kg	2.44E+02	3.80E+10	9.26E+12
Au	kg	2.91E+06	2.60E+06	7.56E+12
Rh	kg	2.91E+08	2.50E+04	7.27E+12
Urban land use >0.5 million	m2yr	9.55E+00	4.68E+11	4.47E+12
Sb	kg	2.62E+04	1.63E+08	4.27E+12
CH4	kg	9.18E+00	3.33E+11	3.06E+12
Urban land use <0.5 million	m2yr	6.55E+00	4.68E+11	3.06E+12
Fe - resource	kg	1.00E+00	3.00E+12	3.00E+12
Oil - resource	kg	7.27E-01	4.01E+12	2.92E+12
			sum	5.43E+13
Other flows				2.91E+13
			global total	8.34E+13

Discussion

The environmental impact cost data given above are global averages, useful as defaults when assessing environmental impacts from products and services. Global averages are meaningful to use for two reasons. One is that supply chains and markets often are global. Another is that the highest environmental damage costs mostly come from climate gases and natural resources traded on a global market. But sometimes, like in agriculture and some industrial plants, local impacts may cause the highest damage costs. Although seldom used, uncertainty measures and Monte Carlo simulations may help to identify those data that are critical to the decision at hand (Steen 1997).

Two future developments are in the pipeline. One the addition of more data for processing of materials (table 13). Another is the sixth IPCC Assessment report, scheduled to 2022. This may lead to some updates of the weighting factors for climate gases. Of particular interest is the issue of natural versus human caused climate change.

References.

1987. Our Common Future. UN.

Gunnarsson, J. 2020. Case study on fossil and renewable ethylene production routes, Focus on Environmental Priority Strategies (EPS) calculations, 2020-04-28, , Göteborg. IVL Swedish Environmental Research Institute, Göteborg, Sweden.

ISO. 2019. Monetary valuation of environmental impacts and related environmental aspects. ISO, Geneva.

Steen, B. 1997. On uncertainty and sensitivity of LCA-based priority setting. Journal of Cleaner Production **5**:255-262.

Steen, B. 2016. Calculation of Monetary Values of Environmental Impacts from Emissions and Resource Use. The Case of Using the EPS 2015d Impact Assessment Method. Journal of Sustainable Development **9**:18.

Steen, B. 2019. Monetary Valuation of Environmental Impacts. Models and Data. CRC Press, Taylor & Francis Group, Boca Raton, FL USA.

UNEP/SETAC. 2016. Global Guidance for Life Cycle Impact Assessment Indicators. UNEP/SETAC life cycle initiative.

UNEP/SETAC. 2019. Global Guidance for Life Cycle Impact Assessment Indicators. UNEP/SETAC Life cycle initiative.