16 Environmental Impact Categories of PEF

- and how to obtain a PEF single score through normalization and weighting

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Introduction

The PEF (Product Environmental Footprint) LCA (Life Cycle Assessment) method introduces 16 environmental impact categories where climate change is one of them. These are all approaches in which manufacturing and production of goods and services harm the environment.
When measuring a product's influence on the impact categories, the whole life cycle is considered.
Furthermore, three endpoint categories are defined, also called Areas of Protection. As the name indicates, the endpoints aim to represent values that are considered important to society in a broader scope:

Human Health
Ecosystem Quality
Natural Resources

To assess the impact of a product on these endpoints**,** each individual impact category is analyzed, and it is assessed how it affects the endpoint.

The Unit for human health damage is DALYs (disability adjusted life years) and represents the years that are lost or that a person is disabled due to a disease or accident. E.g., people working in wood burning factories are exposed to a high level of particulate matter – how many years will they on average lose because they die earlier or become sick.

The unit for measuring ecosystem quality is the local relative species loss in terrestrial, freshwater, and marine ecosystems. E.g., how many species (not individual animals) are lost globally because of a water depletion somewhere locally.

The unit for natural resources is dollars ($), which represents the extra costs involved for future mineral and fossil resource extraction. E.g., if you use a lot of minerals now, it will become much more expensive to extract minerals in the future.*

Reading guide

In this document, all 16 categories will be briefly explained. Each impact category is presented with:

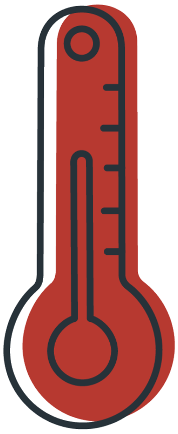
- **Simplified:** A simplified explanation and description of the most common emitters contributing to the effect
- **Unit ():** The unit in which it is measured
- **The weighted impact:** Its weighting factor, which refers to its assigned significance in relation to the other impact categories
- **The endpoint(s)** which it impacts and whether the impact categories have a global, a regional or a local effect on the endpoints.

Because the various impact categories are measured in different units, the result in each category needs to be normalized and weighted, so that they can be compared to each other. The normalized and weighted results can be summed up to a single score that reflects the overall environmental performance of a product. Read more about normalization, weighting, and single score on page 12.

A short note on biodiversity as a potential future impact category finalizes this document.

* Source: Hauschild, Michael Z., Ralph K. Rosenbaum, and Stig Irving Olsen. Life cycle assessment. Springer International Publishing, Cham. https://doi. org/10.1007/978-3-319-56475-3 Book, 2018, page 181-182.

Climate change
- global warming potential



Endpoint effects of this impact category

Human health and ecosystem quality globally

Unit (CO2eq)

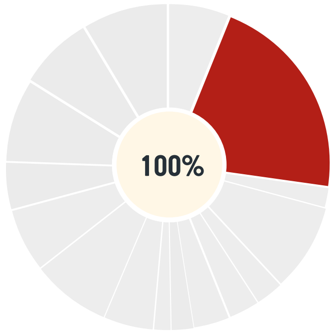
The global warming potential of all greenhouse gas emissions is measured in kilos of CO_2eq, meaning that all GHG are compared to the amount of the global warming potential of 1 kg of CO_2.

Simplified

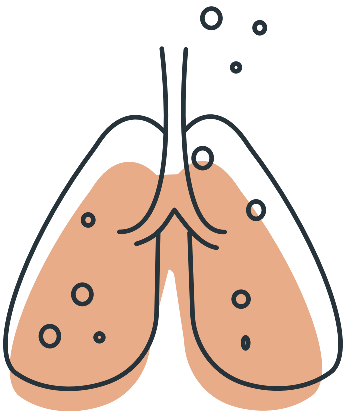
How the product adds to global warming and the planet getting hotter. This category measures the impact of the product on climate change by assessing its emissions of greenhouse gases (GHG), like carbon dioxide(CO_2), methane(CH_4), nitrous oxide(N_2O), and other climate effects like deforestation. It is expressed as CO_2 equivalents.

The weighted impact

21.06%



Particulate matter formation



Endpoint effects of this impact category

Human health regionally

Simplified

How many tiny harmful particles are released into the air in connection to the product.

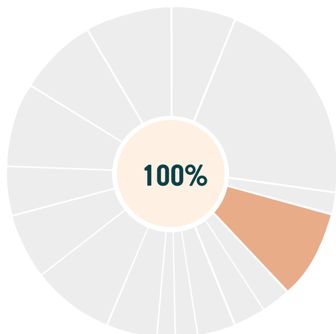
This category is about the product's contribution to the formation of particulate pollution, consisting of particles of different sizes. They affect air quality and human health. The smaller the particles are, the deeper they can go into the lungs and blood system. These emissions primarily originate from combustion processes (the burning of both fossil and biofuels), and industrial activities. These combustion processes are currently needed for providing electricity, heat, and mobility for vehicles, ships, and airplanes.

Unit (kg of PM2.5)

Disease incidences per kg of PM2.5 emitted (2.5 refers to the size of the particle in micrometers). The potential impact is measured as the change in human deaths caused by particulate matter (PM).

The weighted impact

8.96%



Water use

Unit [m³]

The potential impact is expressed in cubic meters [m^3] of water being deprived in an area. The number relates to the local scarcity of water and not only the consumed amount of water. In other words, how much water is missing after water has been used in relation to a product.

Simplified

Assesses the deprivation of fresh-water resources associated with a product.

Assessment of the product's water resource consumption, which is relevant in areas facing water scarcity. The impact category considers the availability or scarcity of water in the regions where the activity takes place if this information is known. Some materials and products commonly associated with high water use impacts include:

1. Cotton is a water-intensive crop used extensively in the textile industry. The production of cotton textiles often requires substantial irrigation, leading to significant water use.

2. The production of electronic devices, such as smartphones, laptops, and other gadgets involves a complex supply chain that consumes a considerable amount of water. The mining of minerals and metals, the manufacturing processes, and the cooling of electronic components all contribute to the water footprint of these products.

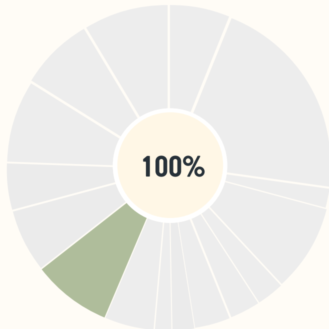
3. The production of beef has a large water footprint. It involves the direct water consumption by cattle and the water required for growing crops fed to the animals.

Endpoint effects of this impact category

Ecosystem quality and natural resources locally

The weighted impact

8.51%



Resource use
- fossils

Endpoint effects of this impact category

Ecosystem quality and natural resources globally

Unit [MJ]

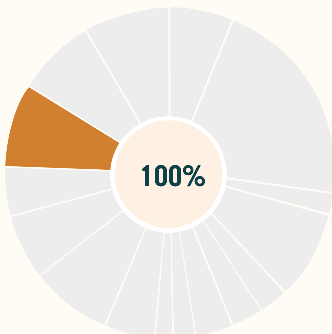
The number of materials contributing to resource use, fossils, are converted into megajoule, which is an inherent energy in fossil fuels [oil, gas, etc.].

Simplified

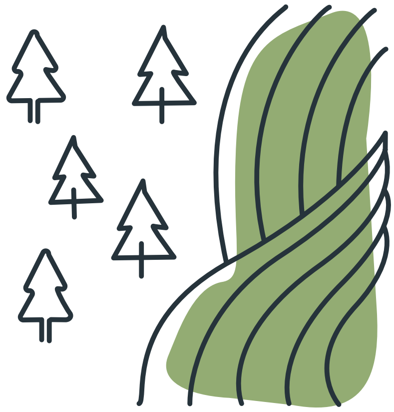
Depletion of non-renewable resources like fossil fuels deprives future generations of this important resource.
Here, the product's consumption of fossil fuels is evaluated. The idea behind this impact category is to extract less of the finite number of non-renewable resources, such as coal, oil, and gas from the earth.

The weighted impact

8.32%



Land use



Unit [Pts]

This is a composite indicator measuring impacts on four soil properties (biotic production, erosion resistance, groundwater regeneration, and mechanical filtration), expressed in points.

Biotic production is the capacity of ecosystems to produce and sustain biomass in the long term. **Erosion resistance** is the capacity of ecosystems to stabilize soils and prevent sediment accumulation downstream. **Groundwater regeneration** is the capacity to recharge and maintain the groundwater to natural levels. **Mechanical filtration** is the capacity of ecosystems to absorb, bind, or remove pollutants from water.

Endpoint effects of this impact category

Ecosystem quality and natural resources regionally

Simplified

Soil quality loss measures the amount of land and soil used, blocked, ruined, affected, or changed in negative ways by the manufacturing and use of a product.

The land use impact depends on various factors, including the scale and location of activities, land management practices, and efforts to reduce environmental harm through sustainable land use planning and conservation initiatives. Some of the primary factors impacting this environmental category include:

1. Agricultural activities, especially large-scale monoculture farming, and deforestation for agricultural expansion, can lead to habitat destruction and soil degradation.

2. Commercial logging and unsustainable forestry practices can result in deforestation and degradation of forested lands, affecting biodiversity and ecosystem services.

3. The expansion of cities and the construction of infrastructure can lead to the conversion of natural landscapes, land fragmentation, and habitat loss.

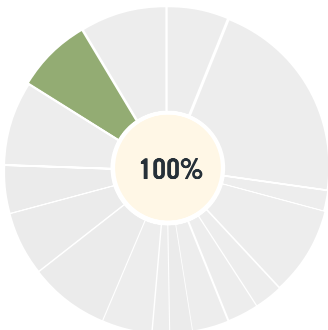
4. Mining operations can change the landscape and lead to land degradation, habitat destruction, and disruption of ecosystems.

5. The development of infrastructure for energy production, such as hydropower dams, wind farms, and solar installations, can require substantial land use changes, impacting natural ecosystems.

6. The disposal of waste in landfills and the establishment of waste management facilities can result in land use changes and potential contamination of soil and groundwater.

The weighted impact

7.94%



Resource use
- minerals and metals

Endpoint effects of this impact category

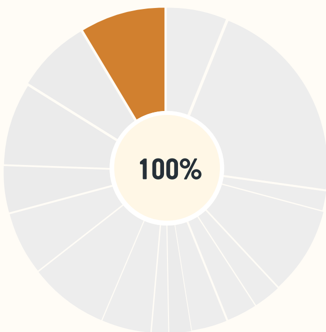
Ecosystem quality and natural resources globally

Unit (kg Sbeq)

The number of materials contributing to resource depletion is converted into equivalents of kilograms of antimony. It is the ratio between the annual production of the resource and the known global reserve that is considered in this measurement.

The weighted impact

7.55%

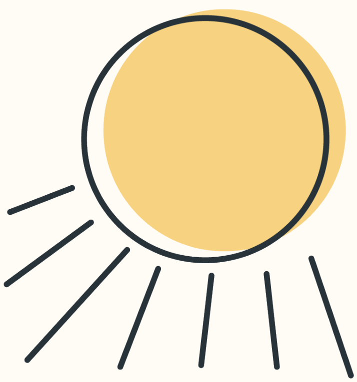


Simplified

Extracting a high amount of resources today will force future generations to extract lower concentrations or lower value resources. Use resources wisely.

Consumption of various finite and non-renewable rare minerals and metals is critical for various technological advancements which have applications in industries such as renewable energy like solar panels, electronics, aerospace, and healthcare. Ensuring a stable supply of these is vital for the global economy and sustainable development.

Ozone depletion potential



Endpoint effects of this impact category

Human health and ecosystem quality globally

Simplified

Whether the product harms the protective ozone layer around earth.

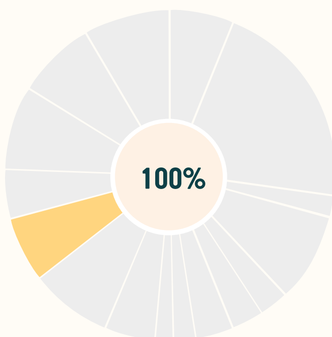
The stratospheric ozone (O_3) layer serves as a crucial shield, safeguarding both humanity and the environment against the harmful effects of ultraviolet radiation (UV-B). The gradual thinning of this ozone layer has been directly linked to a rise in skin cancer incidences among humans and significant harm to plant life. Ozone depletion is primarily caused by polystyrene foam packaging materials using fluoride gasses, and chloride and bromine chemicals found in fire retardants used in electronics, textiles, and fire extinguishers. The most harmful substances are now banned but effects of the disposal of old products still cause ozone depletion.

Unit (kg CFC-11eq)

The potential impacts of all relevant substances for ozone depletion are converted to their equivalent of kilos of trichlorofluoromethane, also called Freon-11 and R-11.

The weighted impact

6.31%



Acidification

Unit (mol H+eq)

The potential impact of substances contributing to acidification is converted to the equivalent of moles of hydron concentration.

Simplified

Indicator of the potential acidification (turning sour) of soils and water.

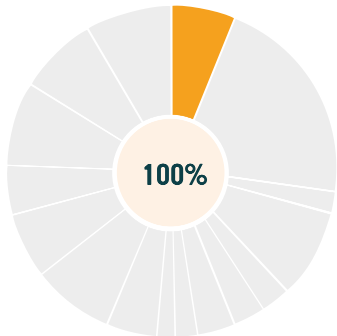
This category is about the product's contribution to environmental acidity in the air, water, and soil, which can have harmful effects on ecosystems and aquatic organisms. The main contributors are combustion processes, especially when containing a high amount of sulphur, in transport, heating production, and electricity. Futhermore, some of the excess CO2 in the atmosphere is absorbed by the oceans to regulate the earth's temperature, leading to a decrease in pH levels and the formation of carbonic acid in the water. This is the largest contributing factor to ocean acidification, which affects the entire food chain to an extent that is yet to be discovered. It also causes the destruction of coral reefs and sandstone monuments, altering the living conditions of sea life.

Endpoint effects of this impact category

Ecosystem quality regionally

The weighted impact

6.31%



Ionizing radiation

Endpoint effects of this impact category

Human health locally

Simplified

Assesses whether the product causes humans to be exposed to any radioactive substances.

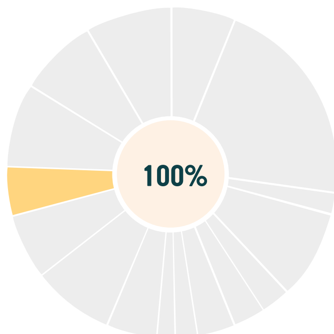
This category is about how exposure to ionizing radiation (e.g., radioactive rays) can impact human health and the normal functioning of living organisms. Manmade ionizing radiation is mostly caused by nuclear power plant fuels, and its waste, nuclear weapon testing, and other uses of radioactive materials in scanning equipment like X-rays. Notably, the most ionizing radiation occurs naturally when humans are subjected to radon gas from nature or cosmic radiation when flying at high altitudes.

Unit (kgU_{235}eq)

The potential impact on human health of different ionizing radiations is converted to the equivalent of kilograms of Uranium-235.

The weighted impact

5.01%



Photochemical ozone formation

Unit (kg NMVOCeq)

The potential impact of substances contributing to photochemical ozone formation is converted into the equivalent of kilograms of Non-Methane Volatile Organic Compounds.

Simplified

Measures the amount of toxic ozone that a product causes to be released in the lower atmosphere.

The product's impact on the formation of photochemical ozone is assessed because it influences air quality negatively e.g., causing smog incidents. As opposed to the protective effect of the ozone layer located in the earth's stratosphere (12-50 km above the surface), the presence of ozone close to the earth (in the troposphere) is a big health risk. It is toxic when inhaled and can have immediate and serious harmful effects on human health. The main manmade drivers of photochemical ozone formation are:

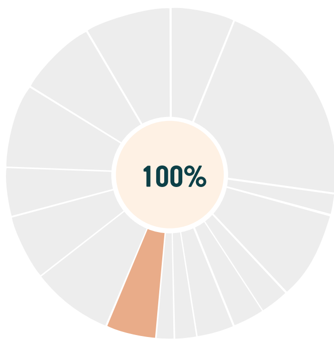
1. Transportation (mainly cars, trucks, and buses) is responsible for roughly 25-50% of photochemical ozone formation.

2. Manufacturing, energy production, chemical manufacturing, and solvent use are responsible for 10-30% of total emissions.

3. Nitrogen-based fertilizers used in agriculture are estimated to contribute with 5-20%.

The weighted impact

4.78%



Endpoint effects of this impact category

Human health regionally

Eutrophication

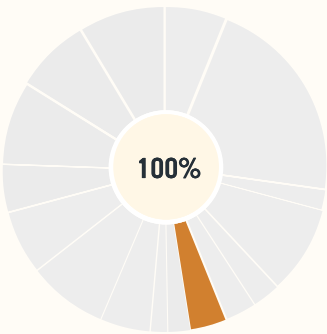
- terrestrial, freshwater and marine

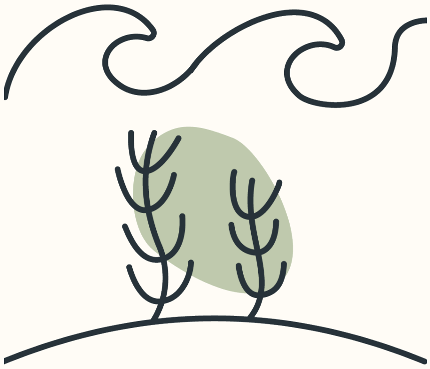
Unit (mol Neq)

The potential impact of the concentration of substances contributing to terrestrial eutrophication is converted to the equivalent of moles of nitrogen.

The weighted impact

3.71%



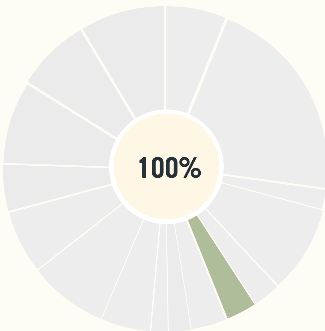


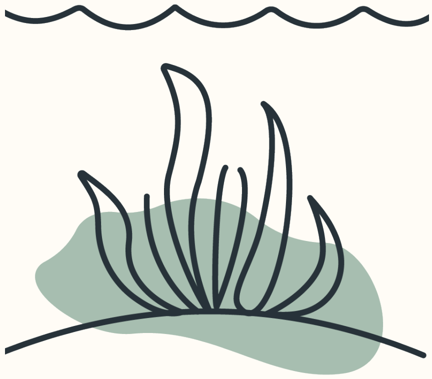
Unit (kg Neq)

The potential impact of substances contributing to marine eutrophication is converted to the equivalent of kilograms of nitrogen.

The weighted impact

2.96%



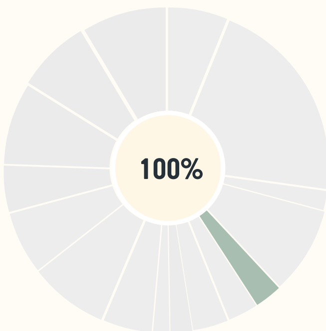


Unit (kg Peq)

The potential impact of substances contributing to freshwater eutrophication is converted to the equivalent of kilograms of phosphorus.

The weighted impact

2.80%



Simplified

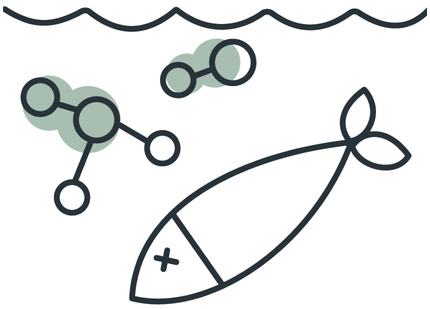
Overfertilization (caused by human activities) of the soil, freshwater, or marine resulting in an excessive amount of nutrients pushing the ecosystem out of balance due to too much plant/algae growth which can suffocate other wildlife in the ecosystem.

The evaluation of a product's contribution to eutrophication, especially nitrogen (N) and phosphorus (P), can cause excessive growth of specific plants and limit growth in the original ecosystem. E.g., algae blooms in freshwater and marine can cause oxygen depletion killing fish and other living organisms. Nitrogen emissions into terrestrial and aquatic environments are caused largely by fertilizers used in agriculture, but also by combustion processes (the burning of fuels).

Endpoint effects of this impact category

Ecosystem quality regionally

Ecotoxicity
- freshwater



Unit (CTUe)

The Comparative Toxic Unit for ecosystems is the estimate of the potentially affected fraction of species (PAF) integrated over time and volume, per unit mass of a chemical emitted.

Endpoint effects of this impact category

Ecosystem quality regionally

Simplified

The direct impact of toxic substances on freshwater ecosystems, including lakes, rivers, groundwater reserves, etc.

Here, the product's toxic effects on freshwater organisms, including plants and animals, are assessed.

Chemicals that contribute significantly to this impact category often include:

1. Many agricultural pesticides are designed to be toxic to specific organisms that can harm crops. When these pesticides run off into freshwater systems, they can have harmful effects on aquatic organisms.

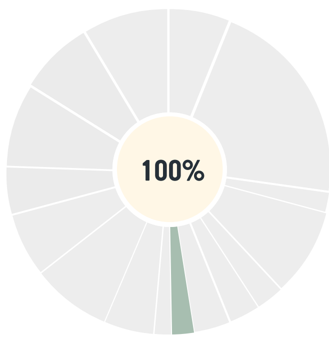
2. Heavy metals may enter water bodies through industrial discharges, mining activities, or atmospheric deposition and can have severe ecotoxic effects on plant and animal life.

3. Pharmaceuticals and Personal Care Products (PPCPs) often contain harmful chemicals that can enter freshwater systems through sewage and wastewater.

4. Various industrial chemicals, such as solvents, dyes, and surfactants, can be toxic to aquatic life when they are released into freshwater systems without proper treatment.

The weighted impact

1.92%



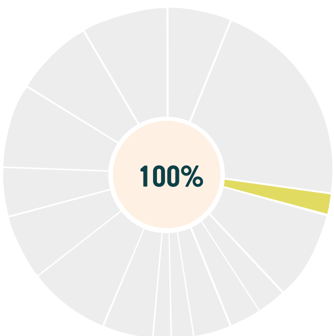
Human toxicity
cancer and non-cancer

Endpoint effects of this impact category

Human health locally

The weighted impact

2.13%

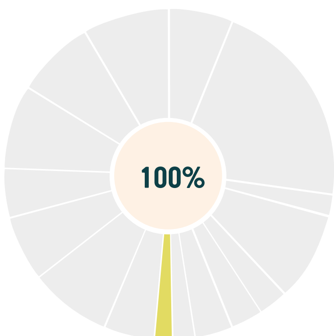


Unit (CTUh)

Comparative Toxic Unit for humans. The measurement considers the estimated increase in mortality in the total human population per unit mass of different chemicals emitted.

The weighted impact

1.84%



Simplified

Impact on human health caused by absorbing substances through the air, water, and soil.

These categories assess the potential harm to human health from exposure to chemicals and substances that may increase the risk of cancer and that may cause non-cancerous health effects. The release of toxic chemicals into the environment through industrial processes, emissions from products containing harmful chemicals, emissions from vehicles, the use of pesticides in agriculture and landscaping and other sources can lead to human toxicity. Direct effects of products on humans are not measured. Instead, toxicity of products is measured indirectly in labs.

Normalization

Normalization in the context of PEF impact categories means that we convert different kinds of environmental impacts (such as carbon emissions, water use, toxicities, etc.) into a common language, so we can compare them more easily.

Thought experiment
Imagine you are baking a cake. The recipe contains ingredients measured in different units, such as kilograms, liters, tablespoons, and pieces. You are on a budget and want to know which ingredients constitute the largest share of the price for the whole cake.

To figure this out, you normalize the units (kilograms, liters, tablespoons, etc.) by converting them into the same reference unit, namely price. If you used two eggs for the cake and you paid 5 euros for 10 eggs, then the eggs in the cake cost (5/10*2) 1 euro. Maybe you also paid 5 euros for a bag of vanilla sugar with 100 grams but only used 5 grams for the cake – that's only 0.25 euros. You continue this method with all the ingredients. Let's say you find out that the cake has a total price of 10 euros. Then the eggs make up 10% of the total costs, while the vanilla sugar constitutes 2.5%.

This enables you to compare the different ingredients and see which is the most expensive ingredient in your cake.

Common reference system
In the context of life cycle assessment (LCA) and environmental impact assessment, normalization is a step we use to provide context and perspective to the results of the environmental impact categories.

Normalization involves comparing the environmental impacts of a product or process to a reference or baseline. This reference can be a specific benchmark, an industry average, or some other meaningful standard. Normalization aims to help us, and you to understand the relative significance of the environmental impacts of the various impact categories.

The reference system of PEF
The common reference in the PEF LCA framework is **a global average person's emissions in 1 year**. So, the result of each environmental impact category must be converted into what it corresponds to in relation to an average global person's yearly emissions.
For example, in an LCA using the PEF methodology, we express the environmental impact of a product in 16 different categories. These are all measured in different units.
The climate impact is measured in carbon dioxide equivalents (CO_2eq) emissions, and ozone depletion potential is measured in trichlorofluoromethane equivalents (kg CFC-11eq).
To be able to know which impact is greatest, we must convert the two numbers into the same unit. We do this by comparing the results to the yearly emissions of an average global person, which is the common reference unit.

Normalization is an important step and valuable tool in LCA because it provides us with a way to compare the impact of different categories measured in different units. It makes it possible to see which categories impact the environment the most.

Weighting

Think of the weighting of PEF impact categories like assigning importance to different aspects of a product's impact on the environment and evaluating how much you can trust the figures.

Thought experiment

Imagine you're judging a cooking competition with three categories: taste, presentation, and creativity.
You decide that taste is the most important, so you give it a higher score, let's say 50%, while presentation and creativity are less critical, so you give them lower scores, e.g., 25% each.

Different levels of significance
In the context of PEF impact categories, weighting is a process we use to assign different levels of importance to the various environmental impacts. Scientists, researchers, and the EU have assigned a specific weight to each of the categories. They have based their weighting on the overall importance, urgency, impact scale, and

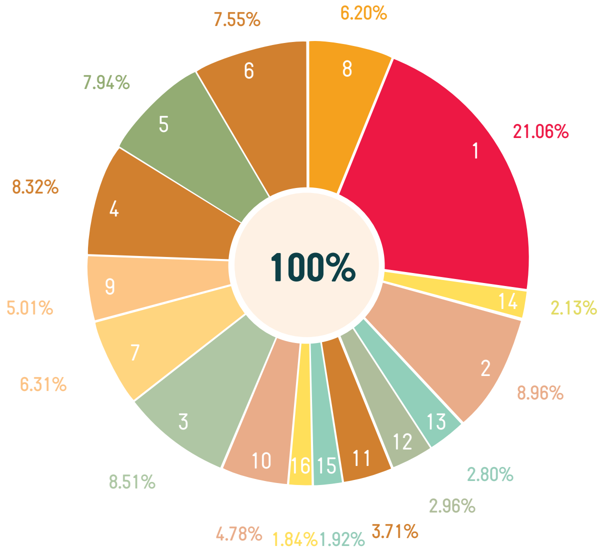


Figure 1

https://eplca.jrc.ec.europa.eu/EFtransition.html

calculation accuracy (robustness) of each category. The weight is called the weighting factor (Figure 1). Weighting is a valuable step when we work with so many different types of environmental impacts. It allows us to prioritize and focus our efforts on the most significant environmental impact categories, helping decision-makers identify which environmental categories are most important to reduce first. Usually, climate change in terms of global warming has the highest score in a normalized and weighted set of environmental parameters calculated according to PEF rules, but for some materials or production processes, other environmental effects might be more harmful.

The weighting of PEF impact categories
In PEF, different aspects of a product's impact on the environment (like climate emissions, water use, and resource depletion) are like the cooking competition categories. Weighting means deciding how much each of these environmental aspects counts toward the overall environmental performance. EU has decided on the weighting of all the impact categories as shown in figure 1.

PEF single score

A PEF single score in this context refers to a product's overall environmental assessment. The PEF single score is a sum of all the normalized and weighted numbers that a product has scored in each of the impact categories.

So, building on top of all the individual calculations from each impact category, we are able to obtain one figure that expresses the overall environmental impact of a product. This means that we can compare the total environmental impact of different products. Ultimately, it allows us as consumers to make more responsible purchasing decisions. Due to the PEF single score, for the first time, we have a scientific method that allows for comparing and evaluating easily the total environmental performance of two products. The potential effects of this are huge and can be a massive driver for a more environmentally sustainable lifestyle.

Biodiversity

The PEF method does not yet include a designated impact category called biodiversity. This is because there is no international consensus on a life cycle impact assessment method capturing that impact.

However, the PEF method includes at least 8 impact categories that influence biodiversity:
Climate impact, **Eutrophication marine**, **Eutrophication freshwater**, **Eutrophication terrestrial**, **Acidification**, **Water use**, **Land use** & **Ecotoxicity freshwater**.

Land use and climate change are responsible for the largest share of the damage in terms of biodiversity loss caused by consumption in the EU*.

It is important to highlight, that the uncertainty of modelling (calculating in a scientific manner) biodiversity loss is high and there are still many research gaps as to how the 8 relevant impact categories affect biodiversity. We will continue following the suggestions and updates from the EU on this matter and add this category to our tool as soon as the PEF rules on biodiversity are defined and implemented.

* Source: https://publications.jrc.ec.europa.eu/repository/handle/JRC128571

THE JOURNEY FROM 16 IMPACT CA

Impact Categories

16 environmental impact categories describe how humans harm the planet through production and construction.

Normalization

The impact categories are measured in different uni compare them to each other, results from each cate into a common reference unit. This process is called The common reference unit in PEF LCA is the environ **an average global person over one year.**

1	2587.449781	kg CO_2eq
2	0.000321	Disease incidence
3	1829.474203	M^3 world eq
4	65561.667349	MJ
5	573.633041	Dimensionless
6	0.014854	kg Sb eq
7	0.000021	kg CFC-11 eq
8	18.124273	Mol H+eq
9	34.671085	Kbq U-235 eq
10	13.124030	kg NMVOC eq
11	45.446968	Mol N eq
12	4.756349	kg N eq
13	0.173241	kg P eq
14	0.000002	CTUh
15	45037.101032	CTUe
16	0.000020	CTUh

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PEF single score

The single score reflects the overall environmental performance of a product. The single score is obtained by adding up all the weighted results.

* Scientists have weighted the categories based on urgency, impact scale, accuracy of measuring method.
Numbers are based on calculations of 1 tonne of Polypropylene (PP) pellets GLO. Numbers are subject to changes.

ATEGORIES TO ONE SINGLE SCORE

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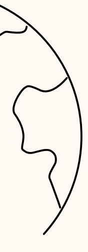
Weighting

Not all impact categories are considered equally important. To get the weighted results, the normalized results are multiplied by their weighting factor*.
Now, the product's impact on the environmental categories is comparable.



1 0.342569
2 0.539089
3 0.159519
4 1.008575
5 0.000700
6 0.233469
7 0.000394
8 0.326155
9 0.008216
10 0.321201
11 0.257118
12 0.243352
13 0.107814
14 0.100438
15 0.794073
16 0.158473

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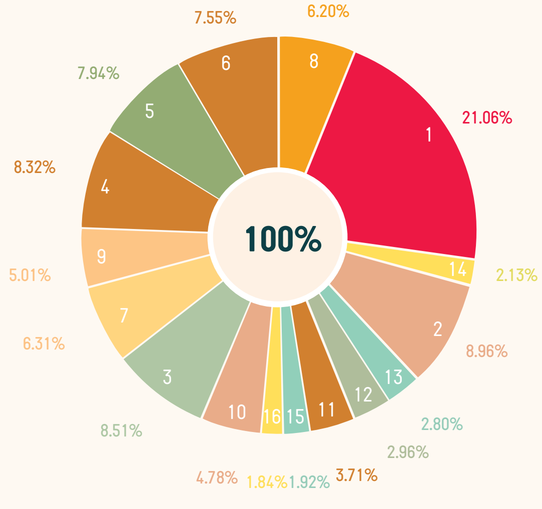

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1 0.072145
2 0.048302
3 0.013575
4 0.083913
5 0.000056
6 0.017627
7 0.000025
8 0.020222
9 0.000412
10 0.015353
11 0.009539
12 0.007203
13 0.003019
14 0.002139
15 0.015246
16 0.002916

0.311692 PEF single score

e = 0.311692

MÅLBAR

THE JOURNEY FROM 16 IMPACT CATEGORIES TO ONE SINGLE SCORE

Impact Categories

16 environmental impact categories describe how humans harm the planet through production and construction.

Normalization

The impact categories are measured in different units. To be able to compare them to each other, results from each category are converted into a common reference unit. This process is called normalization. The common reference unit in PEF LCA is the environmental impacts of **an average global person over one year.**

1	2587.449781	kg CO_2eq
2	0.000321	Disease incidence
3	1829.474203	M^3 world eq
4	65561.667349	MJ
5	573.633041	Dimensionless
6	0.014854	kg Sb eq
7	0.000021	kg CFC-11 eq
8	18.124273	Mol H+eq
9	34.671085	Kbq U-235 eq
10	13.124030	kg NMVOC eq
11	45.446968	Mol N eq
12	4.756349	kg N eq
13	0.173241	kg P eq
14	0.000002	CTUh
15	45037.101032	CTUe
16	0.000020	CTUh

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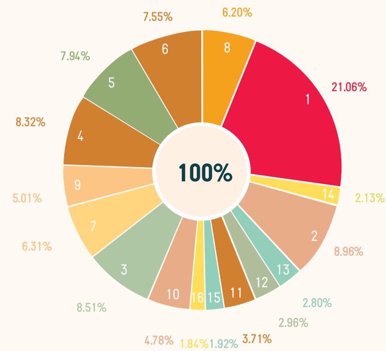

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0.311692 PEF single score

PEF single score = 0.311692

The single score reflects the overall environmental performance of a product.
The single score is obtained by adding up all the weighted results.

* Scientists have weighted the categories based on urgency, impact scale, accuracy of measuring method.
Numbers are based on calculations of 1 tonne of Polypropylene (PP) pellets GLO. Numbers are subject to changes.

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