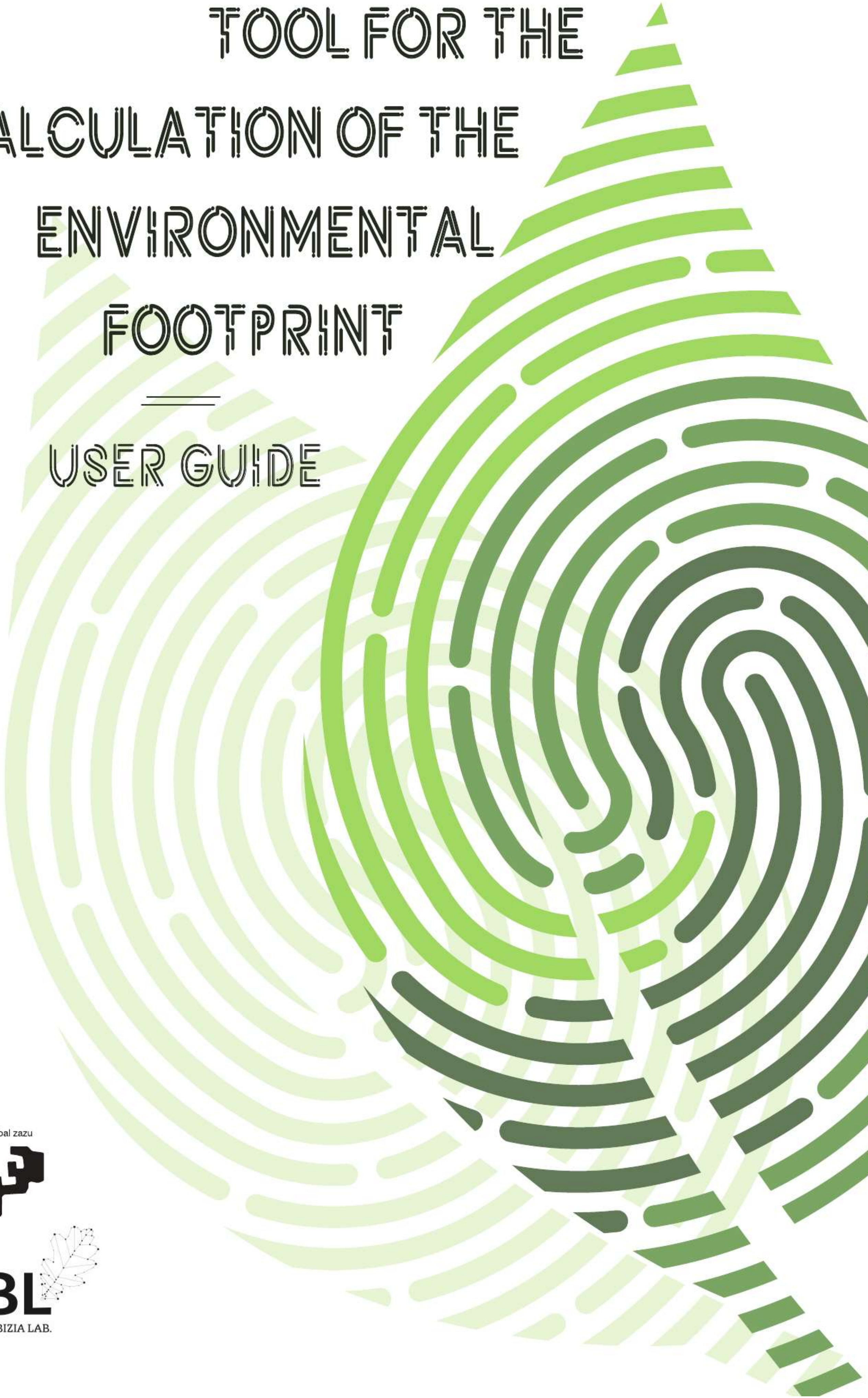
TOOL FOR THE CALCULATION OF THE ENVIRONMENTAL FOOTPRINT

USER GUIDE



eman ta zabal zazu

CBL
CAMPUS BIZIA LAB.

Project:

EHU-Aztarna / Scenario analysis and dissemination of results of the calculation of the environmental and social organizational footprint of the UPV/EHU.

Funded by:

- CBL Program
  (https://www.ehu.eus/es/web/iraunkortasuna/campus-bizia-lab);
  DIRECTORATE OF SUSTAINABILITY, VICE-RECTORATE OF INNOVATION, SOCIAL COMMITMENT AND CULTURAL ACTION, UPV/EHU.

Authors:

Bueno Viso, Ane

de Blas Martin, Maite

Bueno Mendieta, Gorka

de la Torre Pascual, Eduardo

Index

1. Introduction

Environmental protection is one of the most important challenges facing society. The solution must be global, and to this end it is absolutely necessary to promote a sustainable development model.

UPV/EHU aims to be an example of social transformation towards a more sustainable organizational model, and an example of this is the EHU-Aztarna project of the Campus Bizia Lab, promoted by the Directorate of Sustainability, in which the Environmental Footprint of the UPV/EHU has been calculated, using the Life Cycle Assessment (LCA) methodology, following the European Commission proposed methodological guide.

Within the framework of the EHU-Aztarna project, and based on the previously calculated UPV/EHU's environmental footprint, a tool has been designed so that UPV/EHU students can calculate, in an approximate way, the environmental footprint of their academic activity. In this way, students will be able to estimate the impact they generate during the time they are working on a specific academic activity, thus achieving a greater awareness of the impact it generates. The academic activities to be studied can be multiple: a student's Final Degree or Master's thesis, a complete course or term, or a project worked on in a subject.

1.1. Life Cycle Assessment (LCA)

Until recently, environmental improvement actions have focused on reducing pollution from very specific sources, such as emissions from industrial facilities into rivers and the atmosphere. Life cycle assessment addresses another, broader perspective. The life cycle approach aims to identify possible improvements in products and services, seeking lower environmental impacts and more efficient use of resources, throughout the entire life cycle of the products or services we use.

The life cycle of a product or service begins with the extraction of many raw materials and energy; followed by stages of transformation, manufacturing and distribution of these materials, up to the final product use or consumption stage. In the end-of-life stage of the product, materials are prepared for reuse, recycling or disposal, in some cases recovering energy.

The fundamental objective of the life cycle approach is to avoid shifting environmental burdens from one point in the life cycle to another. The life cycle perspective helps to reduce impacts in one life cycle stage, in one geographic region or in one impact category, but without increasing impacts elsewhere at the same time. The objective may be, for example, to achieve energy savings in the use stage of a product without increasing energy consumption and the amount of material required for its manufacture.

To continue, we will define in detail what the Life Cycle Assessment mentioned above is. The most concrete definition is the one expressed by ISO[1] in the ISO 14040 standard:

> *Life cycle assessment is a technique for determining the environmental aspects and potentials associated with a product by conducting an inventory of the significant inputs and outputs of the system, assessing the potential environmental impacts associated with those inputs and outputs, and interpreting the results of the inventory and impact phases in relation to the objectives of the study.*

1 ISO is an international standards-setting organization formed by standardization organizations from various states (162). It publishes standards/methodologies/standard tools to promote and improve the management of companies and institutions. The use of these standards facilitates the production of new, safe, reliable and high quality products and services.

2. Objectives

With the tool you have in your hands it will be possible to calculate the Environmental Footprint of Academic Activities. It is a simple tool that has been designed to be used by all UPV/EHU students. The objectives sought using this tool are:

2.1. Identification and quantification of the environmental impacts and processes related to the academic activity

This tool will make it possible to understand the processes related to the academic activity and quantify the associated environmental impacts, identifying the main sources of impact and determining the main possibilities for improvement.

The analysis will provide contrasted information on the impacts on the environment and will serve as an instrument to measure the university's environmental performance and control improvements. Thus, eco-efficiency will be increased, enabling a more responsible energy and material consumption of the UPV/EHU and promoting more environmentally sustainable manufacturing and transport processes.

2.2. Calculation of the environmental footprint of the academic activity

This tool is designed for students of different Undergraduate and Master's programmes to calculate the environmental footprint of their academic activity. In order to start the analysis, it is essential to define well the academic activity to be analyzed, in time and space. The academic activity can be multiple: a student's Final Degree or Master's Thesis, an activity linked to a complete course or term, or a project, or an activity worked on within a specific subject. The student, as he/she develops his/her academic activity, will make an inventory of the resources he/she consumes or uses, so he/she is able to know, using the tool, the environmental impact associated with such academic activity.

2.3. Preparation of the environmental footprint report of an academic activity

In view of the growing concern about environmental degradation and the effects of pollution, companies and institutions must be responsible for establishing mechanisms to support sustainable development and improve the quality of life of societies. To this end, information on the environmental performance of companies or organizations is an essential first step. In 2013 the European Union published the methodology for calculating the environmental footprint of products and organizations. Aligned with this methodology, this tool will allow university students to take the first step in the preparation of an environmental report of their academic activity. We hope that this experience will be useful for their future.

3. Footprint calculation tool

3.1. Design

The Ecoinvent database has been selected for the design of the tool. This database collects key data for conducting the LCA, is well documented -including information on data quality-, which is very useful for the inventoried data in this study (Ecoinvent, 2019). In addition, a food section has been added with help of the Agribalyse® database. This database collects information related to the environmental impacts of agricultural and food products. Regarding the software, openLCA (version 1.10.3) was used, it is a free software for LCA and sustainability assessment. The environmental impact assessment method selected for the calculation of the environmental footprint is the ReCiPe method; the midpoint[2] data format was used to interpret the results.

The tool is an application designed for students of any faculty, so it has a simple and easy to use operation. For this reason, a spreadsheet format has been used, which is an application that practically all university students have used or use on a regular basis. In addition, only a device compatible with the application (a computer) is needed and once the worksheet is downloaded, it is not even necessary to have an internet connection to work with it. The spreadsheet is available in three languages: English, Spanish and Basque. This section will detail the steps of use and information for the proper use of the tool.

3.2. Worksheet sections

The worksheet is divided into ten sections. Below is the information about what can be found in each section, including all the details the student should complete in each section (sections 3.2.1-8). In addition, an explanation of the results will be offered, explaining how to make an interpretation of these data (section 4).

2 This is the format for declaring environmental impact categories based on magnitudes related to the environmental impact emission or generation parameters analyzed. In the case of the ReCiPe methodology, a total of 18 impact categories are included, described in section 5.

- ### 3.2.1. Home tab

The home tab is what will appear when the worksheet is opened. Here you can distinguish the UPV/EHU logo from the Campus Bizia Lab (CBL) logo, as well as the title of the tool and the name of the authors of the application. Moreover, the student will be able to obtain additional information in the link mentioned in the references.

- ### 3.2.2. Student data

In this screen the student must fill in the following information:

Name	
Surname	
University	
Faculty	
Undergraduate or Master programme	
Activity (academic year / four-month term / project / ...)	
Time dedicated to the activity	

Table 1. Student data

It is very important to specify the time spent on the activity to be analyzed; this should be specified in **days** (for example: if a project of a subject has been carried out in three months, from March 1 to May 31, then we will enter 90 days, 3 months × 30 days/month). The determination of the time invested in the execution of the work will have a direct impact on the results, since a calculation of the daily impact will be made later, which will allow us to compare the impact of the activity with other references.

As shown in the table, the cells of **this color** determine where the student (the person using the tool) should enter the data. This format will be repeated throughout the application.

The concepts related to the academic activity and to be inventoried have been divided into five groups: direct energy consumption, materials' consumption (or use of material products), waste treatment, transportation needs and food consumption. Below is the list of these activities that can be found in each group and the data to be entered by the student.

- ### 3.2.3. Energy

This section includes some elements related to direct energy consumption, such as electricity consumption and heat supply. Regarding electricity consumption, two options are offered in this section: the electricity mix in Spain in 2018, and an only renewable origin electricity mix (excluding non-renewable from the 2018 mix).

For heating supply, two options are considered: 1) generated in a natural gas boiler and 2) generated in a fuel oil furnace. In this subsection it is essential to know the annual heat demand. The heat demand depends mainly on two elements: the climatology of the place where we work and the energy efficiency of the building. This value should be given in kWh/m^2. What is our heating requirement in our laboratory or office throughout the year? For reference, Table 3 shows the annual heating and cooling demand estimated by the IDAE in several Spanish capitals[3].

Process/Service/Product	Data to be entered by the student
Electricity consumption (electricity mix in Spain, 2018).	• Consumed kWh • Number of users
Only renewable origin electricity mix consumption	• Consumed kWh • Number of users
Heating, using a natural gas boiler	• Classroom/room/laboratory/office area, measured in m^2 • Number of users • Number of days the site has been used • Heat demand in the building, per year (see table 3)
Heating, using a fuel oil furnace	• Classroom/room/laboratory/office area, measured in m^2

[3] The data shown in Table 3 were obtained from the following sources (in Spanish):
Escala de calificación energética. Edificios de nueva construcción; IDAE, 2009
https://www.idae.es/uploads/documentos/documentos_CALENER_07_Escala_Calif_Energetica_A2009_A_5c0316ea.pdf (Tabla I.3. Valores de referencia para calefacción, refrigeración y demanda de ACS antes de considerar la contribución sola mínima de CTE-HE 4 en Bloques de viviendas).
Escala de calificación energética. Edificios existentes; IDAE, 2011
https://www.idae.es/uploads/documentos/documentos_11261_EscalaCalifEnerg_EdifExistentes_2011_accesible_c762988d.pdf (Tabla 3.2. Demanda de referencia para viviendas unifamiliares y bloques de viviendas).

	• Number of users • Number of days the site has been used • Heat demand in the building, per year (see table 3)

Table 2. "Energy" tab options list.

City	In buildings constructed before the year 2000		New buildings (more efficient)	
	Heating demand (kWh/m²)	Cooling demand (kWh/m²)	Heating demand (kWh/m²)	Cooling demand (kWh/m²)
Almería	36,5	33,7	10,8	19,1
Barcelona	87,4	14,6	28,3	8,0
Bilbao	106,1	-	40,0	-
Burgos	193,6	-	77,1	-
Cádiz	33,7	25,7	9,0	14,6
Granada	106,6	22,0	37,4	12,5
Madrid	121,2	19,1	43,2	10,8
Sevilla	52,9	41,2	16,6	23,4
Toledo	106,2	33,4	39,0	18,9
Valencia	64,5	22,3	21,3	12,6
Vitoria-Gasteiz	163,6	-	65,4	-
Zamora	148,4	9,7	56,3	5,3

Table 3. Annual heating and cooling demand in different Spanish capitals in block buildings (buildings constructed before 2000 and new buildings).

Important: the rows of the worksheet can be duplicated if several entries of the same concept with different amounts are to be made to collect more than one consumption.

As an example, the figure below combines the calculations of two different electricity consumptions. Line 5 shows the formula for the power consumption of a computer: a computer consuming 150 W (150 W / 1000 W × 1 kW) is switched on 7 hours a day (× 7 hours), during the operation of the project (× 90 days), from Monday to Friday (five days a week, × 5/7) (= 150/1000 × 7 × 90 × 5/7 = 67,5 kWh). Line 6 shows the consumption formula for a lighting system. The power of the lights is 500 W and they are turned on 8 hours a day (= 500/1000 × 8 × 90 × 5/7 = 257,1 kWh).

As can be seen, to record the electricity consumed, we will directly write down the amount (in kWh) in the cell, if the exact amount is known (for example, if we have extracted the consumption from an electric bill, or if we have measured it through a meter); otherwise, it is possible to apply a calculation formula in the cell itself to make an estimate using the available data.

	A	B	Y	Z
1	**Energy consumption**			
2				
3	Process	Functional Unit	Parameter 1	
4			Quantity 1	Unit 1
5	Electricity (computer)	1 kWh	=150/1000*7*90*5/7	kWh
6	Electricity (lighting system)	1 kWh	=500/1000*8*90*5/7	kWh

- ### 3.2.4. Materials

In the material consumption and use of products section, the options are as follows:

Process/Service/Product	Data to be entered by the student
Building use	• Built area in m^2 • Height of each floor in m • Regular users • Number of days of building use
Computer without screen (CPU)	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Laptop computer	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
17 " LCD screen	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)

17 ″ cathode ray screen	• Number of units (single user) • Days of use • Lifetime (estimate: 14 years)
Color laser printer	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Black and white printer	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Color printer toner	• Number of units (single user)
Black and white printer toner	• Number of units (single user)
Keyboard	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Mouse	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Router	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Telephone (smartphone)	• Number of units (single user) • Days of use • Lifetime (estimate: 4 years)
Tablet	• Number of units (single user) • Days of use • Lifetime (estimate: 4 years)
TV	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Hard Disk Drive (HDD, desktop)	• Number of units (single user) • Days of use • Lifetime (estimate: 7 years)
Hard Disk Drive (HDD, portable)	• Number of units (single user) • Days of use

	• Lifetime (estimate: 7 years)
Wood furniture (table, chair, wardrobes...)	• Weight of furniture (kg) • Days of use • Lifetime (estimate: 7 years)
Electronic equipment	• Weight of the equipment (kg) • Days of use • Lifetime (estimate: 20 years)
Heavy industrial machinery	• Weight of the equipment (kg) • Days of use • Lifetime (estimate: 20 years)
Recycled paper	• Number of sheets • Paper size (A4: 0,06237 m^2, A3: 0,12474 m^2) • Paper density (usually, 80 g/m^2)
Non-recycled paper	• Number of sheets • Paper size (A4: 0,06237 m^2, A3: 0,12474 m^2) • Paper density (usually, 80 g/m^2)
Tap water	• Liters per day • Consumption days

Table 4. "Materials" tab options list.

The tabs entitled "Electronic Equipment" and "Heavy Industrial Machinery" can be used to calculate the environmental impacts of the use of industrial and/or electronic infrastructure used in the laboratories.

Food for thought: if we manage to double the life span of a product (for example, by extending the life of a telephone from two to four years), we will reduce the environmental impact of the use of this product by half.

Important: the rows of the worksheet can be duplicated if several entries of the same concept with different amounts are to be made.

3.2.5. Waste treatment

The options available in the waste section are shown in the following table. In this section, the user should investigate the treatment of the residual fraction of the urban waste collected in his/her town or campus, which will most likely be incineration or landfill disposal.

Process/Service/Product	Data to be entered by the student
Wastewarer treatment	• Volume of wastewater generated, in liters per day (L/day) • Number of days
Municipal waste incineration (remainder waste)	• Amount of daily waste (kg/day) • Number of days
Landfill of urban waste (residual fraction)	• Amount of daily waste (kg/day) • Number of days
Anaerobic biowaste digestion	• Amount of daily waste (kg/day) • Number of days
Waste composting	• Amount of daily waste (kg/day) • Number of days
Toner recycling	• Consumed units, per month • Number of days
Hazardous waste incineration	• Amount of daily waste (kg/day) • Number of days
Landfill of hazardous waste	• Amount of daily waste (kg/day) • Number of days

Table 5. "Waste" tab options list.

Important: the rows of the worksheet can be duplicated if several entries of the same concept with different amounts are to be made.

- ### 3.2.6. Transport

The options available in the transport section are shown in the following table:

Process/Service/Product	Data to be entered by the student
Gasoline or diesel car transport (ICE[4])	• pkm (transport) [5] • Number of passengers in the vehicle (occupation)

4 Internal Combustion Engine (ICE), The internal combustion engine is the type of engine capable of supplying mechanical energy by causing an explosion mixing fuel with air. There are two main types of engines: gasoline engines and diesel engines.

5 pkm: passenger-km

Electric car transport (electricity mix in Spain, 2018)	• pkm (transport) • Number of passengers in the vehicle (occupation)
Electric car transport (only renewable electricity mix in Spain, 2018)	• pkm (transport) • Number of passengers in the vehicle (occupation)
Motorcycle transport	• pkm (transport) • Number of passengers in the vehicle (occupation)
Electric bicycle transportation (consuming electricity mix or only renewable sourced)	• pkm (transport)
Bus transport	• pkm (transport)
Tram transport	• pkm (transport)
Trolleybus transport	• pkm (transport)
Subway/regional train transport	• pkm (transport)
Long-distance train transport	• pkm (transport)
High-speed train transport	• pkm (transport)
Flights (airplane)	• pkm (transport)
Freight train transport	• pkm (transport)
Freight truck transport	• pkm (transport)
Freight ship transport	• pkm (transport)
Freight transport flights	• pkm (transport)
Transportation of goods by light commercial vehicle (LCV)	• pkm (transport)

Tabla 6. "Transport" tab options list.

Important: the rows of the worksheet can be duplicated if several entries of the same concept with different amounts are to be made.

- ### 3.2.7. Food

The user should collect the entire inventory of food consumed during the academic activity and enter in the tool the total number of portions for each of the foods. All portions should be calculated according to their approximate weight in grams and, for liquids, according to their volume, in milliliters. In addition, to facilitate the analysis, foods have been categorized into five main groups: dairy and similar; meat, fish and eggs; cereals, pulses and tubers; fruit, vegetables; other: fats, oils, sauces and sugars; and beverages. To calculate the number of servings, it is recommended to use the information in the following table, with examples as a guide. In case of not finding a product consumed in the list, it is recommended to use the most similar one.

List of foods		Examples of servings			Portion size	
Dairy products and analogues						
Milk/soy drink	One serving	- 1 cup	- 1 glass		200-250	ml
	Half serving	- Half a cup			100-125	ml
Yoghurt	One serving	- 2 plain yoghurts	- 1 large yoghurt (200-250 ml)		200-250	ml
	Half serving	- 1 plain yoghurt			100-125	ml
Cheese	One serving	- 1-2 small tubs - 2-3 slices	- 2-3 small cheeses - 2 slices of toast -	- 1 portion of cured cheese	80	g
	Half serving	- 1 tub - 1 slice	- 1 small cheese - 1 slice of toast		40-60	g
Meat, fish and eggs						
Chicken and hen, beef and pork meat	One serving	- 1 small chicken quarter - 1 small chicken breast - 1 hamburger	- 1 small veal steak - Half a plate of stewed meat - 1 T-bone steak	- 2-3 chops or ribs - 2-3 slices of pork loin	125-150	g
Ham (serrano or York)	One serving	- 2 slices			50-60	g
Fish	One serving	- 1 fillet, slice or individual portion - 3-4 slices			125-150	g
Hen's egg	One serving	- 1 egg			50-75	g
Potato omelette	One serving	- 1 pintxo of potato omelette			100-150	g
Cereals, pulses and tubers						
Bread	One serving	- 1 piece of 3 fingers of ciabatta - 1 small baguette	- 6 fingers of hollow loaf - 1 quarter baguette	- 4 rusks - 2 slices of tinned bread	40-60	g
	Half serving	- Half of what is described in the previous box			20-30	g

List of foods		Examples of servings	Portion size
Breakfast cereals / biscuits, wafers	One serving	- 1 cup breakfast cereal - Half a cup of muesli - 6-9 Maria biscuits - 4-6 digestive biscuits	30-40 g
Croissant / baklava	One serving	- 1 croissant - 3 mini croissants	90-100 g
	Half serving	- Half a croissant - 1-2 mini croissant - 1 baklava	45-50 g
Basque cake / rice pudding	One serving	- 1 small portion	100 g
Rice / Pasta	One serving	- 1 normal dish	170-240 g
	Half serving	- Half a regular dish	90-120 g
	A quarter of a serving	- A side dish, rice or pasta in salad (*)	60 g
Pulses	One serving	- 1 normal plate	140-210 g
	Half serving	- Half a normal plate - 1 garnish - Some in salad	70-105 g
Potato	One serving	- Half a normal plate - 1 large potato or 2 small potatoes - Half a regular mashed potato dish	150-200 g
	Half serving	- 1 normal quarter plate - Half a large or 1 small potato - Mashed potato garnish	75-100 g
Fruits, vegetables and greens			
Fresh fruit	One serving	- 1 medium piece of fruit - 2 tangerines - 1 pomegranate - 2 large or 3 small plums - 1 bowl of strawberries - 4 small apricots - 1 slice of pineapple	120-200 g
	Half serving	- Half a piece of fruit - 1 large plum - 1 mandarin orange - 4-6 strawberries - 2 small apricots	60-100 g
Tomato / Lettuce, endive, escarole	One serving	- 1 Medium tomato or 2 small tomatoes - 1 endive - 1 plate of salad	150-200 g
	Half serving	- Half a medium tomato or 1 small tomato - Half plate of salad	75-100 g
	A quarter of a serving	- Salad garnish	35-50 g
Olives	One serving	- 6-10 olives - 1 small handful of olives	25-35 g
Pepper / onion, spring onion	One serving	- 1 small pepper - Half a large pepper - 1 small onion - Half a small onion - 3-4 spring onions	100-120 g
	Half serving	- Half a small pepper - 8-10 padron peppers - 1-2 spring onions	50-60 g
Vegetable puree / Cooked carrot	One serving	- 1 normal plate of cooked or stewed vegetables - 1 normal plate of mashed or creamed vegetables	150-200 g
	Half serving	- Half a normal plate of cooked or stewed vegetables - Half a normal plate of mashed or creamed vegetables	75-100 g
	A quarter of a serving	- Garnish of boiled or stewed vegetables	32-50 g
Nuts	One serving	- 1 handful - 20-30 hazelnuts - 4-6 walnuts - 15-20 almonds	25 g
Others: fats, oils, sauces and sugars			
Olive oil	One serving	- 1 tablespoon	10 ml
Tomato sauce	One serving	- 2 large serving spoons	30 ml
White sugar / honey	One serving	- 1 dessert spoon of honey - 1 heaped dessert spoonful of sugar - 1 sugar sachet - 2 sugar lumps	8-10 g
Beverages			
Tap water	One serving	- 1 glass	250 ml
Bottled mineral water	Two portions	- 1 half-litre bottle (500 ml)	250 ml
	One serving	- 1 small bottle (200-250ml)	250 ml
Coffee with or without milk, tea, infusion	One serving	- 1 cup	80 ml

List of foods		Examples of servings			Portion size
Soft drink / Orange juice	One and a half portions	- 1 can			330 ml
	One serving	- 1 glass	- 1 glass botle		200-250 ml
Beer	One and a half serving	- 1 can	- 1 third		330 ml
	One serving	- 1 glass of beer	- 1 beer cane	- 1 small bottle (20 cl)	200-250 ml
	Half serving	- 1 small glass of beer			100 ml
Wine	One serving	- 1 glass of wine			100 ml

Table 7. List of options in the "Food" tab and servings guide

Important: rows of the spreadsheet may be duplicated if several entries of the same item with different amounts are to be made.

- ### 3.2.8. Supplementary information

In addition, the student can find more information in each section. Each activity (energy consumption, material consumption, waste treatment, transport of people or goods and food) is divided by rows and in the columns the following information is provided for each product/service: process, functional unit, ecoinvent or Agribalyse® database's reference process, process description, location, technology, impact category coefficients (hidden but visible if desired), parameters for the student to enter their values, and values of the impacts generated (through calculations, applying simple proportionality formulas (rule of three)).

4. Results

In the results tab, the student will find a summary of the tabs mentioned above, indicating the impact generated in each block, in each impact category. However, so that the user can qualitatively assess the impact of these values and measure the impact generated, the tool offers another reference: the average impact per person in 2010 worldwide[6]. The following table shows these normalized values:

Impact category	Value	Unit
Global warming	7.990,40765	kg CO_2 equivalent, in 2010
Stratospheric ozone depletion	0,06001	kg CFC-11 equivalent (trichlorofluoromethane) , in 2010
Ionizing radiation	479,91735	kBq Co-60, in 2010
Fine particulate matter formation	25,56959	kg $PM_{2.5}$ equivalent, in 2010
Ozone formation: human health	20,56746	kg NO_x, in 2010
Ozone formation: terrestrial ecosystems	17,74933	kg NO_x, in 2010
Terrestrial acidification	40,98051	kg SO_2 equivalent, in 2010
Freshwater eutrophication	0,64989	kg P equivalent to freshwater, in 2010
Marine eutrophication	4,61779	kg N equivalent to marine water, in 2010
Human carcinogenic toxicity	10,29831	kg 1,4-DCB equivalent (dichlorobenzene) to air, in 2010
Human non-carcinogenic toxicity	31.251,84226	kg 1,4-DCB equivalent (dichlorobenzene) to air, in 2010
Terrestrial ecotoxicity	15.200,31066	kg 1,4-DCB equivalent (dichlorobenzene) to industrial soil, in 2010
Freshwater ecotoxicity	25,17470	kg 1,4-DCB equivalent (dichlorobenzene) to freshwater, in 2010
Marine ecotoxicity	43,44284	kg 1,4-DCB equivalent (dichlorobenzene) al marine water, in 2010
Water consumption	266,63926	m^3 (cubic meters) water consumed, in 2010
Land use	6.167,48228	$m^2 \cdot yr$ ($m^2 \cdot$time in years), in 2010
Mineral resource scarcity	120.051,20955	kg Cu equivalent, in 2010
Fossil resource scarcity	983,27742	kg oil equivalent, in 2010

Table 8. Normalization values. Average impacts per person in the world, in 2010.
Source: ReCiPe 2016, *midpoint*, hierarchical perspective.

In order to see the results in a simpler way, the student also has the possibility to see two graphs. An example of each of them will be given below and will be explained based on how to interpret them.

6 ReCiPe 2016 normalization scores, year 2010, world average per capita, *midpoint*, hierarchical perspective.
The data can be obtained through the following link:
https://www.rivm.nl/sites/default/files/2020-07/Normalization%20scores%20ReCiPe%202016.xlsx

"A student carries out her Final Degree Project during the months of March, April and May (approximately 90 days).

She works in a 40 m² laboratory all day long, together with 3 other colleagues.

For 1 month, the heating is activated. The building has a natural gas boiler. The climate in the campus region is mild.

Electricity consumption has the following origins:

- *a laptop computer and a low-consumption screen (150 W, 5 working days per week, 7 h/day; a total of 67,5 kWh of electricity with a renewable and non-renewable mix);*
- *laboratory lighting (500 W of power, shared with 4 people, 5 working days per week, 8 h/day; a total of 64,3 kWh of electricity with a mix of renewable and non-renewable);*
- *in an industrial workshop, industrial machinery is used for testing for 20 hours in a given week (the machinery weighs 1000 kg and has an average consumption of 1 kW; the consumption is 20 kWh of electricity from renewable sources).*

During this time, the student uses a laptop computer, a low-power screen, a mouse, a color printer and two toner cartridges. Throughout the project she makes regular use of her cell phone (50%, the rest of the use is for personal matters) and her tablet (100%, exclusive use for the project). She consumes 1000 DIN-A4 sheets of recycled paper. Her daily water consumption is 10 liters per day, in the center's toilets.

As mentioned above, the student performs tests on an industrial machine weighing 1000 kg for 20 hours.

The student generates 0,5 kg of mixed waste per day (in the toilet, garbage cans, cafeteria). She knows that in her area 70% of this waste, after undergoing pre-treatment, is incinerated and the remaining 30% ends up in landfills.

The student commutes every day from her home to the campus, 15 km away (a total of 1930 km). She travels by subway. In addition, she has had to make sporadic trips by bus (200 km) and by car with another person (1000 km total)."

Her diet is varied, consuming products from all food groups, including meat products, desserts and alcoholic beverages. The student usually has five meals a day: breakfast, lunch, dinner and two snacks. However, during the academic activity she consumes only a proportion of these foods according to her project schedule, from Monday to Friday for seven hours a day. Table 9 describes in detail the food consumed in a typical week.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Breakfast	*1 fried egg 1 slice of bread 1 slice of cheese 5 strawberries*	*1 fried egg 1 slice of bread 1 slice of cheese*	*1 fried egg 1 slice of bread 1 slice of cheese*	*1 fried egg 1 slice of bread 1 slice of cheese*	*1 fried egg 1 slice of bread 1 slice of cheese*	*Bowl of cereal with milk*	*2 fried eggs 1 slice of bread 1 slice of cheese*
Snack	*Tea with milk*	*Tea with water 1 nectarine*	*Black coffee 1 banana 3 apricots*	*Infusion 1 plum*	*Infusion 1 nectarine*	*Black coffee Tortilla pintxo*	*2 mandarins 1 pomegranate*
Lunch	*1. Marmitako 2. Roast chicken with salad garnish (lettuce and tomato) and chips. Dessert: Apple*	*1. Macaroni and mushrooms 2. Anchovies with salad garnish (lettuce and tomato)*	*1. Salad: lettuce, tomato, carrot, olives and cheese. 2. Veal with garnish of bread and fries Dessert: Rice pudding*	*1. Vegetable puree 2. Battered fish with salad garnish (lettuce and tomato) and fries*	*1. Paella type rice 2. Potato omelette with fried tomato and salad garnish (lettuce and tomato). Dessert: 1 palm tree and 1 apple*	*Bottle of water Combined dish: chicken breast with garnish: white rice, chips, salad (lettuce and tomato) and carrot. Dessert: 2 baklava*	-
Snack	*Coke ® Black coffee*	*Honey infusion*	*Infusion*	*Apple*	*Coffee with milk Mixed sandwich pintxo*	*Black coffee*	*Infusion Ham sandwich 2 palmeras*
Dinner	*Cereal bowl with milk*	*Cereal bowl with milk*		*Cereal bowl with milk*	*2 beers (cane)*		*Sautéed vegetables with rice and almond garnish*

Table 9. Sample menu (one week).

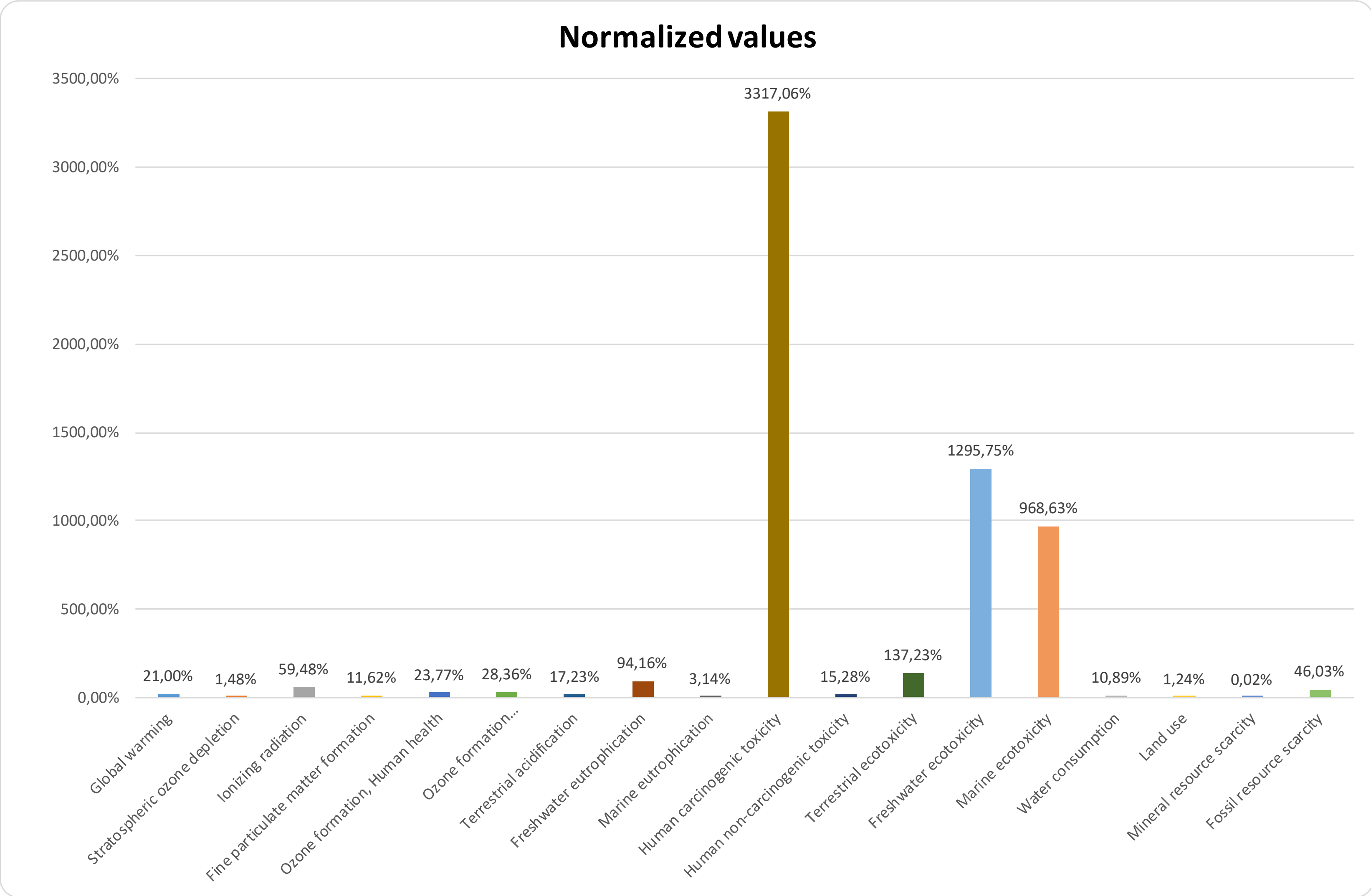
From the weekly model menu shown in table 10, the entire inventory is compiled and the total number of servings for each food item over a 90-day period is calculated.

Total # of appearances in the model menu		Equivalence of servings according to the table	Total number of servings divided by 7 days of the typical week and multiply by the 90 days	Comments
Dairy and analogues				
4	Milk	1	51,4	Refers to milk consumed with breakfast cereal
6,5	Cheese slice	0,5	41,8	Includes the cheese in the mixed sandwich
1	Cheese garnish	1	12,9	As an ingredient in Wednesday's salad course
Meat, fish and eggs				
2	Piece of chicken	1	25,7	
1	Beef	1	12,9	
1	Slice of serrano ham	0,5	6,4	
0,5	Slice of ham	0,5	3,2	As an ingredient in the mixed sandwich
3	Fish	1	38,6	Refers to anchovies, battered fish and seafood in paella
1	Tuna	1	12,9	Refers to the tuna in the marmitako (tuna stew)
7	Fried egg	1	90,0	
3	Tortilla and tortilla pintxo	1	38,6	Includes the omelette for Friday lunch (2) and the pintxo on Saturday (1)

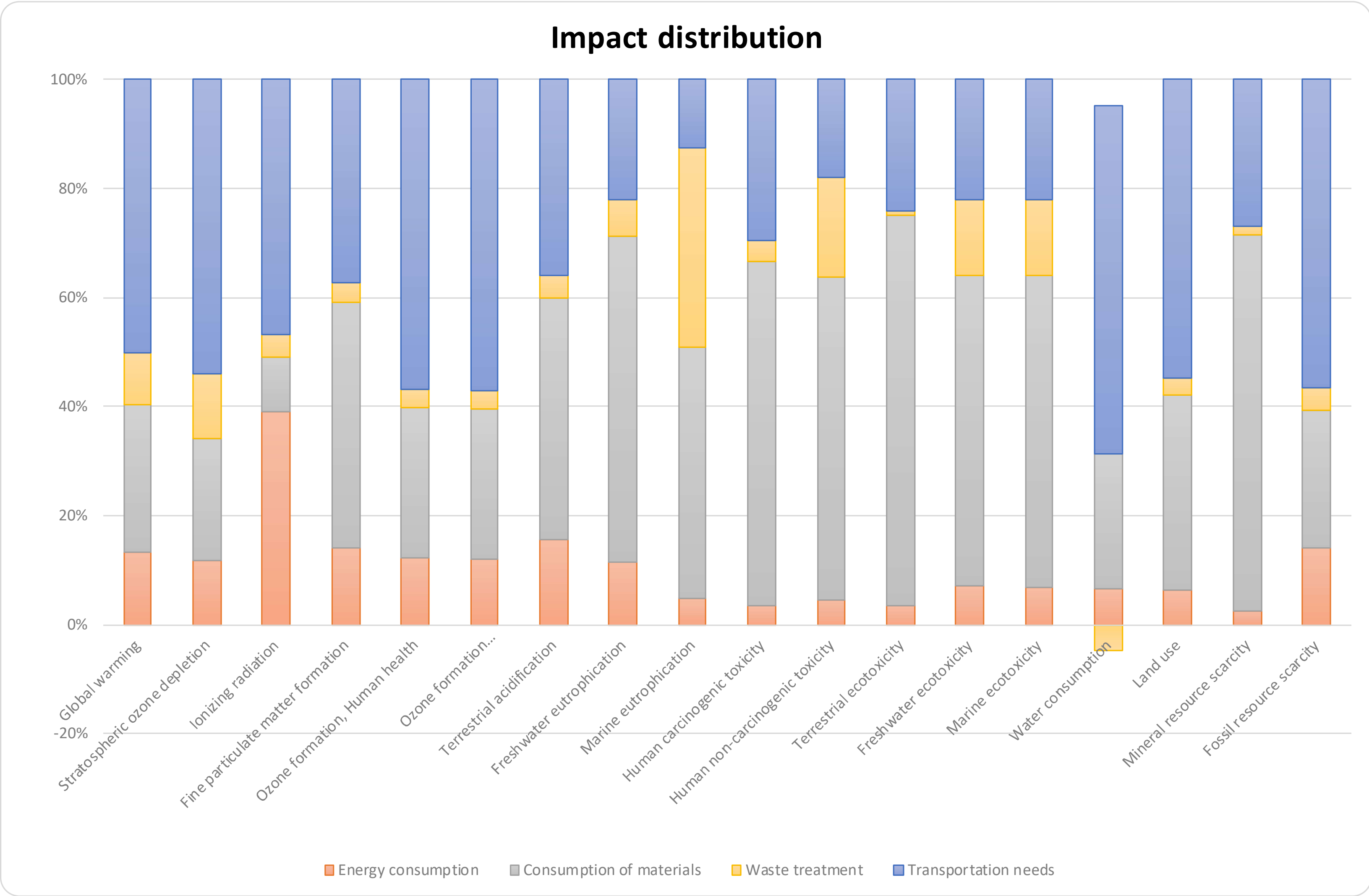
Total # of appearances in the model menu		Equivalence of servings according to the table	**Total number of servings** divided by 7 days of the typical week and multiply by the 90 days	Comments
Cereals, pulses and root vegetables				
3	Ciabatta bread garnish	1	38,6	
7	Sliced sliced bread	0,5	45,0	
1	Macaroni	0,5	6,4	
2	White rice	1	25,7	Refers to two side dishes and the rice in the paella.
4	Breakfast cereal	1,25	64,3	
2	Baklava	1	25,7	
1	Rice pudding	1	12,9	
3	Palms	0,5	19,3	Assigned to common biscuit
1	Potato	1	12,9	As an ingredient in marmitako
Fruit, vegetables and greens				
1	Handful of almonds	1	12,9	
1	Portion of strawberry	0,5	6,4	
4	Plum	0,5	25,7	In addition to plums, it also includes apricots and nectarines.
1	Banana	1	12,9	
1	Pomegranate	2	25,7	
1	Mandarin	1	12,9	Assigned to orange
3	Apple	1	38,6	
1	Olives	1	12,9	As part of the salad recipe
3	Carrot	0,25	9,6	As part of the salad recipe (2) and garnish (1)
5	Lettuce garnish	0,25	16,1	
1	Lettuce	1	12,9	As part of the salad recipe
7	Tomato	0,25	22,5	As part of the salad recipe
4	Garnish of French fries	0,5	25,7	
1	Onion	0,25	3,2	As an ingredient in the marmitako
2,5	Mashed vegetables	1	32,1	In addition to puree (1), includes sautéed vegetables (1), macaroni vegetables (0.25) and paella vegetables (0.25)
Others: fats, oils, sauces and sugars				
6	Olive oil	1	77,1	As salad dressing
1	Honey	1	12,9	Refers to the honey consumed with the ginger infusion
2	Tomato sauce	1	25,7	From Friday's meal (fried tomato) and the marmitako recipe
Beverages				
6	Tea / Infusion	1	77,1	
4	Black coffee	1	51,4	
2	Coffee with milk	1	25,7	
2	Beer (cane)	1	25,7	
1	Coca-Cola®	1	12,9	
1	Bottled water	1	12,9	
28	Tap water	1	360	Four glasses of water per day

Table 10. Food commodity inventory and total number of servings in 90 days

Finally, because the academic activity takes place only from Monday to Friday for seven hours a day, when entering the values in the tool, the proportional consumption has to be allocated by applying a factor. For example, in our inventory we have 51,4 servings of coffee in a 90-day period. To allocate *only the proportion that corresponds to the academic activity, we multiply by the factor of the number of hours per day (7/24) and by the factor of the number of days per week (5/7) (to be entered in the spreadsheet: 51,4 × 7/24 × 5/7). And so on with the whole list of foodstuffs".*



Graph 1. Percentage comparison of each impact category with respect to data from 2010



Graph 2. Percentage weight of each group of impacts (energy/materials/waste/transport/food) in the total impact of each category.

The graphs are interpreted as follows:

1. In the first graph, the impact generated by the student carrying out the activity is compared with the average impact per capita worldwide in 2010. To achieve this, as mentioned above, the tool divides the total impact by the time spent doing the activity, this way it is possible to calculate the average daily impact. This value is divided by the normalized values and shown as a percentage in the graph, for each environmental impact category. Therefore, the interpretation to be made in this graph is as follows: if the estimated percentage in an impact category is higher than 100%, then the impact generated in this impact category is higher than the 2010 average per person. For example: in academic activity the impact on global warming generated by the student during the day accounted for 29,6% of the global average per person in 2010; in freshwater eutrophication 107,03%, and in fossil resource depletion 58,75 %.

   If we analyze the example we have proposed, it is clear that the greatest impacts occur in the categories of human carcinogenic toxicity (3403,51%), terrestrial ecotoxicity (143,34%) and freshwater (1334,01%) and marine ecotoxicity (995,61%), compared to the available reference values. The graph is very useful for the student to know what the specific impact is. If the students want to know to which activities these impacts are related, it is necessary to analyze graph 2.

2. The second graph shows the impact of each group of activities (energy consumption, material consumption, waste treatment, transport needs and food) on each impact category. Each column (referring to each environmental impact category) is divided into 5 colors and each color reflects the contribution of a group of activities. In addition, by placing the pointer over each column, you can see exactly what effect the activity group has (the units of each impact category are shown in table 10 below). Analyzing the graph in the example, the activities that have the greatest influence on photochemical ozone formation are related to transport. On the other hand, in water consumption activities related to waste treatment reduce their impact: this is since in wastewater treatment, instead of consuming water, clean water is obtained. The consumption of materials influences all impact categories and, moreover, some in a very prominent way: mineral resources scarcity, marine ecotoxicity, human toxicities, freshwater eutrophication and terrestrial and freshwater toxicities. We can also see how food consumption influences all impact categories and in particular ozone depletion, marine eutrophication and land use.

In the two categories highlighted in Graph 1 (marine ecotoxicity and freshwater ecotoxicity), the most important contribution to the impacts is from the consumption of materials, where the use of buildings is the main source. In contrast, in carcinogenic human toxicity, the main source is the use of industrial machinery, followed by transportation needs, especially car travel.

5. Description of the Environmental Impact categories

Once the values required by the tool have been entered, the student will obtain the coefficients corresponding to the different impact categories. The correct cataloguing of these categories is essential for the user to know exactly the impact produced by his or her activity. The following sections will explain the Environmental Impact categories handled by the tool and the nature of the impacts.

This document contains the description of the 18 impact categories of the ReCiPe 2016 v.1.1 method (Huijbregts et al., 2017). Table 11 presents all impact categories together with their corresponding units. In the column "impact category", the categories described in this paper are grouped together.

DESCRIPTION OF THE 18 IMPACT CATEGORIES. Midpoint, ReCiPe 2016 v1.1

Table 11. 18 midpoint impact categories with their corresponding units. ReCiPe 2016 v.1.1 Methodology.

Impact Category		Unit
1.- Global warming		kg CO_2 equivalent
2.- Stratospheric ozone depletion		kg CFC-11 equivalent (trichlorofluoromethane)
3.- Ionizing ratiation		kBq Co-60
4.- Fine particulatte matter formation		kg $PM_{2.5}$ equivalent
5.- Ozone formation, Human health	Ozone formation	kg NO_x
6.- Ozone formation, Terrestrial ecosystems		kg NO_x
7.- Terrestrial acidification		kg SO_2 equivalent
8.- Freshwater eutrophication	Eutrophication	kg P equivalent to freshwater
9.- Marine eutrophication		kg N equivalent to marine water
10.- Human carcinogenic toxicity	Toxicity	kg 1,4-DCB equivalent (dichlorobenzene) to air
11.- Human non-carcinogenic toxicity		kg 1,4-DCB equivalent (dichlorobenzene) to air
12.- Terrestrial ecotoxicity	Ecotoxicity	kg 1,4-DCB equivalent (dichlorobenzene) to industrial soil
13.- Freshwater ecotoxicity		kg 1,4-DCB equivalent (dichlorobenzene) to freshwater
14.- Marine ecotoxicity		kg 1,4-DCB equivalent (dichlorobenzene) al marine water
15.- Water consumption		m^3 (cubic meters) water consumed
16.- Land use		$m^2 \cdot yr$ ($m^2 \cdot$time in years)
17.- Mineral resource scarcity	Resource scarcity	kg Cu equivalent
18.- Fossil resource scarcity		kg oil equivalent

More information in (see impact categories): https://lc-impact.eu/methodology.html

5.1. Global warming

Unit: kg CO_2 equivalent

This impact category measures greenhouse gas (GHG) emissions. These emissions result in an increase in the concentration of GHGs in the atmosphere, which, in turn, increases the radiative forcing capacity ($W \cdot m^{-2}$). Radiative forcing indicates the difference between the sunlight absorbed by the Earth and the energy radiated back into space.

An increase in radiative forcing implies an increase in global average temperature, resulting in several endpoint environmental impacts: damage to human health and damage to terrestrial and aquatic ecosystems (Figure 1).

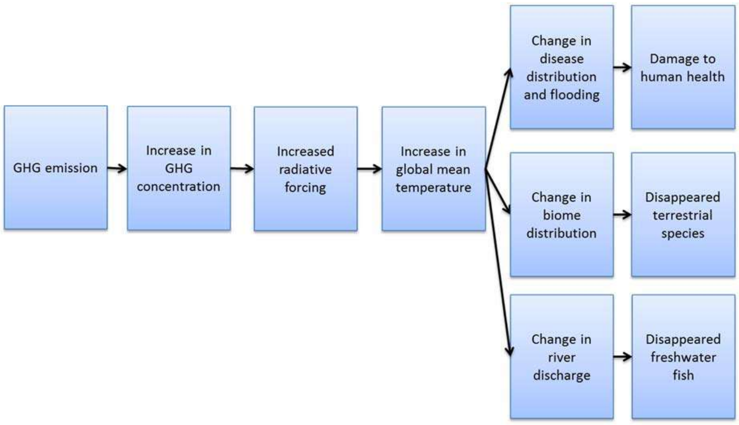


Figure 1. Cause-and-effect chain from GHG emissions to human health damage, loss of species in terrestrial and freshwater ecosystems. Source: ReCiPe, 2017

The capacity of a GHG to influence radiative forcing is expressed with respect to the reference substance, carbon dioxide (CO_2) and with respect to a time horizon of 20, 100 or 1000 years, according to the individualistic, hierarchical and egalitarian perspectives respectively.

Table 12 shows the Global Warming Potential (GWP) values of the main GHGs. The GWP indicates the additional radiative forcing integrated over time (20, 100 or 1000 years) caused by an emission of 1 kg of GHG relative to the integrated radiative forcing over the same time horizon caused by the emission of 1 kg of CO_2. GWPs of other GHGs can be consulted in the IPCC report (2013); among others, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, etc.

Table 12. Global Warming Potential (kg CO_2 eq/kg) of the main Greenhouse Gases for a time horizon of 2, 100 and 1000 years (Source: IPCC, 2013)

Compound	**Perspective**		
	Individualist (20 years)	**Hierarchist (100 years)**	**Egalitarian (1000 years)**
Carbon dioxide (CO_2)	1	1	1
Methane (CH_4)	84	34	4,9
Fossil methane (CH_4)	85	36	4,9
Nitric oxide (N_2O)	264	298	78,8

More information at (in Spanish): https://www.miteco.gob.es/es/cambio-limatico/temas/cumbre-cambio-climatico-cop21/el-cambio-climatico/

5.2. Stratospheric ozone depletion

Unit: kg CFC-11 equivalent (trichlorofluoromethane)

This impact category indicates emissions of Ozone Depleting Substances (ODS). Ozone depleting substances are very persistent and have chlorine or bromine groups in their molecules that interact with and destroy ozone, mostly in the stratosphere (given their long lifetime they can reach the stratosphere). Stratospheric ozone absorbs ultraviolet-B (UVB) radiation. As a consequence of the decrease in ozone concentration in the stratosphere, there is an increase in UVB radiation reaching the earth's surface. Figure 2 shows the cause-effect chain of emissions of ozone-depleting substances, which results in negative effects on human health, such as an increase in the incidence of skin cancer and cataracts.

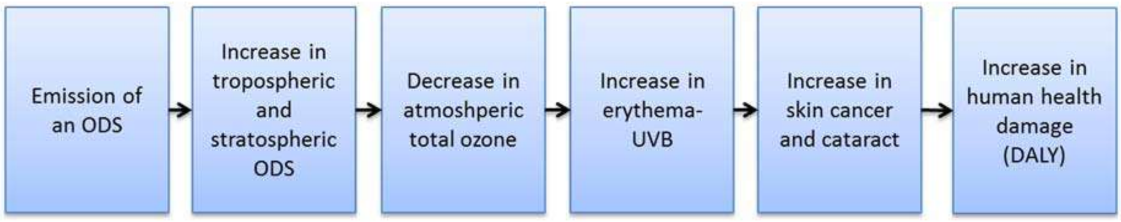


Figure 2. Cause-and-effect chain from emissions of Ozone Depleting Substances (ODS) resulting in damage to human health. Source ReCiPe, 2017

For the calculation of the characterization factors in this impact category, CFC-11: trichlorofluoromethane (CCl_3F) is used as a reference, which is assigned a characterization factor of 1.

More information at (in Spanish): https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/capadeozonorecuperacion_tcm30-505597.pdf

5.3. Ionizing radiation

Unit: kBq Co-60

This impact category indicates damage to human health due to radioactive discharges. Ionizing radiation is a type of energy released by atoms in the form of electromagnetic waves (gamma rays or X-rays) or particles (alpha and beta particles or neutrons). The spontaneous disintegration of atoms is called radioactivity and the excess energy emitted is a form of ionizing radiation. Unstable elements that disintegrate and emit ionizing radiation are called radionuclides. Activity, used as a measure of the amount of a radionuclide, is expressed in becquerel (Bq), which corresponds to one disintegration per second (WHO, 2016).

Figure 3 shows how radionuclide emissions result in human health damage: as an increased risk of cancer and as severe hereditary effects.

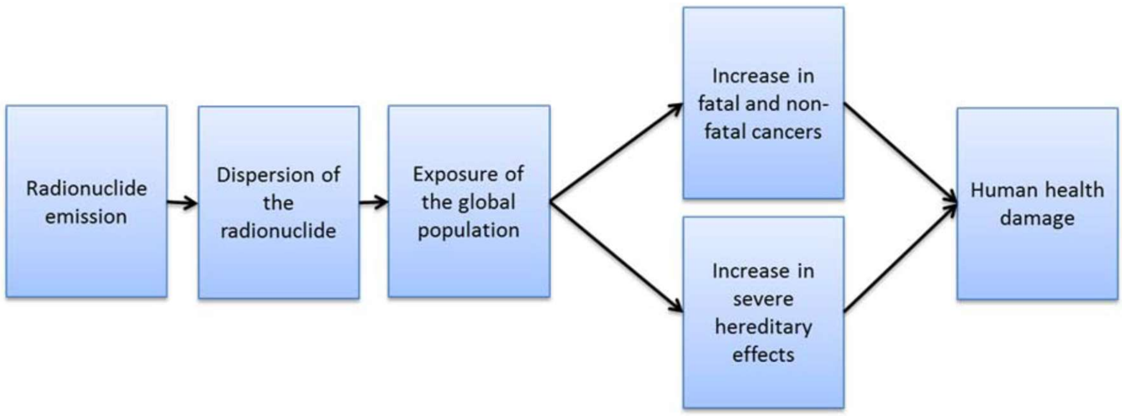


Figure 3. Cause-and-effect chain, from radionuclide airborne or waterborne emission e to damage to human health. Source: ReCiPe, 2017

The reference unit is calculated in kBq Co-60. That is, with respect to Cobalt-60 (60Co), a synthetic radioactive isotope of cobalt, which has a half-life of 5,27 years.

More information at:https://www.who.int/es/news-room/fact-sheets/detail/ionizing-radiation-health-effects-and-protective-measures

5.4. Fine particulate matter formation

Unit: kg $PM_{2.5}$ equivalent

This impact category indicates the damage to human health caused by the emission of primary particles and the formation of secondary particles in the atmosphere. Fine particulate matter ($PM_{2.5}$: particles with a diameter of less than 2,5 μm) represents a complex mixture of organic and inorganic pollutants. Figure 4 shows the sequence of emissions of fine particulate precursor pollutants (NO_x, NH_3, SO_2) and the emission of primary particulate matter ($PM_{2.5}$), which can be inhaled and reach the upper respiratory tract and lungs. Chronic exposure to fine particulate matter results in increased mortality (damage to human health).

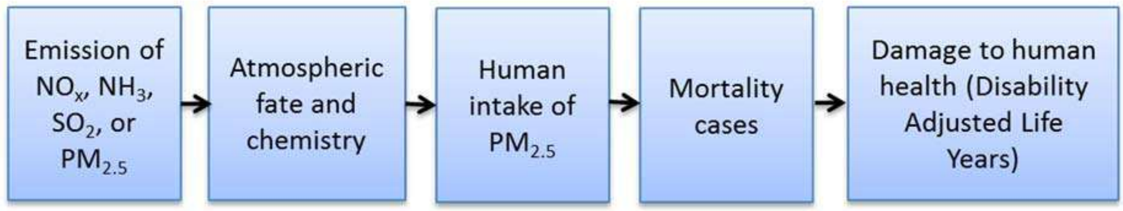


Figure 4. Cause-and-effect chain from fine particulate emissions that result in damage to human health. Source ReCiPe, 2017.

The unit is referred to fine particulate matter ($PM_{2.5}$), since according to the World Health Organization the effects on mortality are more related to the fine fraction ($PM_{2.5}$) than to the coarser one ($PM_{2.5-10}$, particles with a diameter between 2,5 and 10 μm), since exposure to the latter is more related to respiratory morbidity (WHO, 2006).

More information at (Particulate Matter, PM, section): https://www.who.int/es/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

5.5. Ozone formation: human health

5.6. Ozone formation: terrestrial ecosystems

Unit: kg NO_x

The impact category "Ozone formation" measures the photochemical ozone formation capacity whose precursors are nitrogen oxides (NO_X) and NMVOCs (Non-Methane Volatile Organic Compounds). Both human health effects and terrestrial ecosystem damage are considered in this impact category.

Ozone is a substance that is not directly emitted into the atmosphere, since it is formed from its main precursors, NO_x and NMVOCs, a process that is intensified in summer due to increased solar radiation. It should be noted that ozone formation process is not linear, as it depends on the concentration of its precursors and meteorological conditions (solar radiation).

As it is shown in Figure 5, ozone affects human health by aggravating diseases such as asthma and other chronic respiratory diseases, for example Chronic Obstructive Pulmonary Disease (COPD). In addition, ozone can affect vegetation, altering its natural processes of growth and seed production. Ozone can also damage materials.

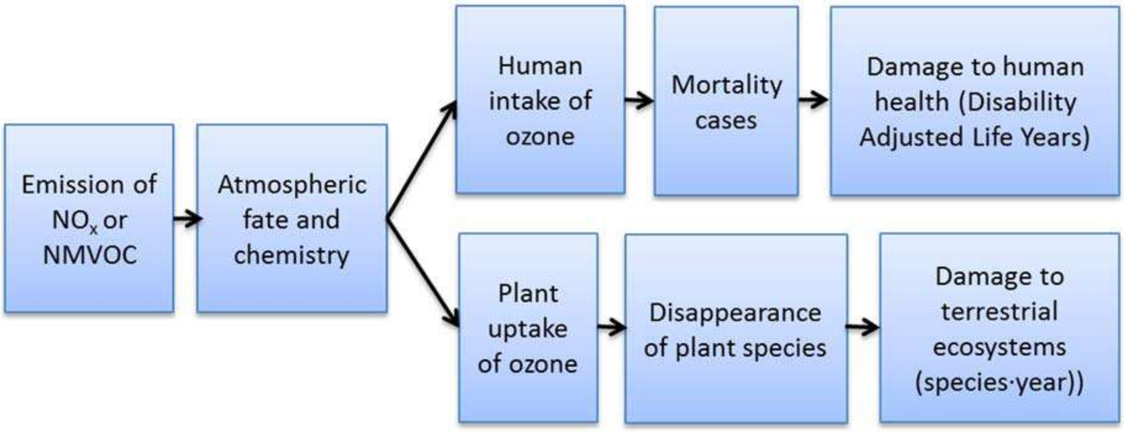


Figure 5. Cause-and-effect chain, from ozone formatting emissions to human health and ecosystems damage. Source: ReCiPe, 2017

The unit of measurement for this impact category is due to one of the precursors of ozone, nitrogen oxides (NO_x). The term NO_x refers to the sum of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_2 is the compound formed in the greatest quantities in combustion processes occurring at high temperatures (PRTR, 2021).

More information at (see Box 5.1): https://www.eea.europa.eu/es/publications/92-828-3351-8/page005.html

5.7. Terrestrial acidification

Unit: kg SO_2 equivalent (sulfur dioxide)

This impact category indicates the effect of the deposition of inorganic substances in soils, such as sulfates (SO_4^{2-}), nitrates (NO_3^-) and phosphates (PO_4^{3-}), as they modify soil acidity.

The main precursors of acidifying substances are NO_X, NH_3 and SO_2 which, after being emitted into the atmosphere, can undergo physicochemical transformations to give rise to

NO_3^- and SO_4^{2-}. These ions can be deposited in the soil, altering its acidity. For all plant species, there is an optimum level of acidity which, if altered, could cause damage to certain plant species.

Figure 6 shows the cause-effect chain of gas emissions that are precursors of acidifying substances for the soil and harmful to vegetation.

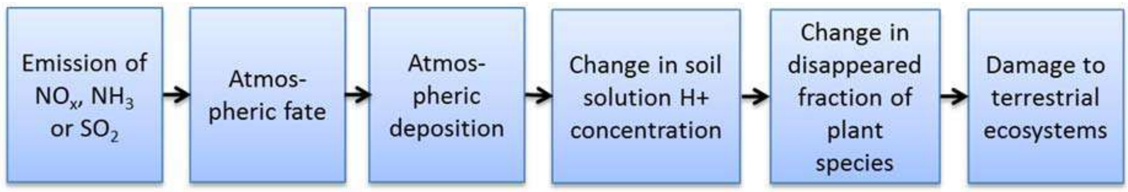


Figure 6. Cause-and-effect chain from acidifying emissions that result in relative species loss in terrestrial ecosystems. Source ReCiPe, 2017

The unit of measurement for this impact category is due to sulfur dioxide (SO_2).

More information at (see box 4.1): https://www.eea.europa.eu/es/publications/92-828-3351-8/page004.html

5.8. Freshwater eutrophication

Unit: kg P equivalent to freshwater

Freshwater eutrophication occurs due to the discharge of nutrients (phosphorus and nitrogen) into the soil or directly into freshwater. The rise in nutrients levels (freshwater, is especially affected by phosphorus), there is an increased uptake of nutrients by autotrophic organisms such as cyanobacteria and algae, but also by heterotrophic species such as fish and invertebrates. The excessive growth of aquatic plants prevents the entry of light for photosynthesis. When plants die, a large amount of oxygen is needed for the degradation of the dead biomass. This oxygen deficit can endanger the subsistence of aquatic animal species and, in extreme cases, can even cause their death.

Figure 7 shows the cause-and-effect chain of phosphorus discharges to freshwater and soils, which concludes with damage to freshwater ecosystems.

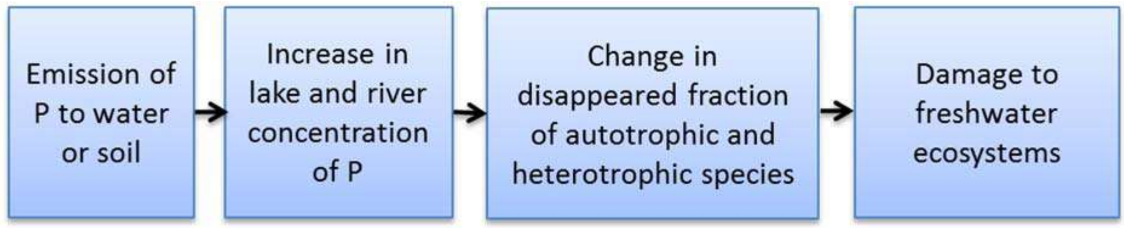


Figure 7. Cause-and-effect chain for phosphorus emissions causing damage to freshwater ecosystems. Source: ReCiPe, 2017

The unit for calculating this impact category refers to phosphorus, since it is the nutrient that most affects freshwater.

More information at:

General: https://www.britannica.com/science/eutrophication

Freshwater eutrophication, surface water (in Spanish): https://www.miteco.gob.es/va/agua/temas/estado-y-calidad-de-las-aguas/proteccion-nitratos-pesticidas/impacto-calidad-agua/

5.9. Marine eutrophication

Unit: kg N equivalent to marine water

Marine eutrophication is caused by runoff and leaching of nutrients from the soil which, through discharge, eventually end up in the sea. This results in an increase of nutrients, phosphorus and nitrogen in marine systems, which accelerates the growth of algae and other aquatic vegetation. This is mainly due to an increase in the amount of dissolved inorganic nitrogen (DIN). When aquatic plants die, the oxygen available for the degradation of the dead biomass is consumed. Dissolved oxygen (DO) deficiency can lead to the disappearance of marine species.

Figure 8 shows the cause-and-effect chain of nutrient discharges to rivers and coastal waters, which end up in the sea, resulting in increasing levels of dissolved inorganic nitrogen (DIN) and ultimately damaging marine ecosystems.

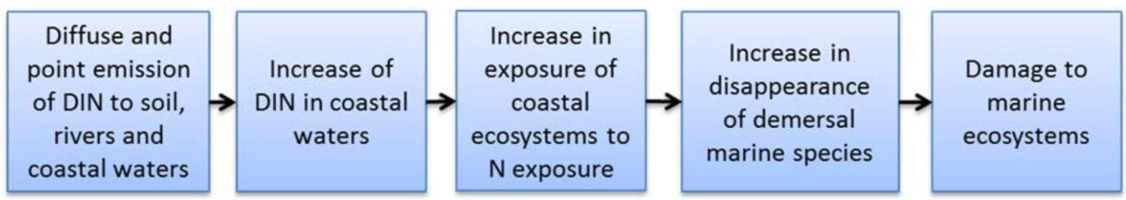


Figure 8. Cause-and-effect chain for dissolved inorganic nitrogen (DIN) emissions, causing damage to marine ecosystems. Source: ReCiPe, 2017

The unit for calculating this impact category refers to nitrogen, as it is the limiting nutrient in marine ecosystems.

More information at:

General: https://www.britannica.com/science/eutrophication

Marine eutrophication: https://www.encyclopedie-environnement.org/en/water/phosphorus-and-eutrophication/

Toxicity

5.10. Human toxicity (carcinogenic)

5.11. Human toxicity (non-carcinogenic)

5.12. Terrestrial ecotoxicity

5.13. Freshwater ecotoxicity

5.14. Marine ecotoxicity

Unit: kg 1,4-DCB equivalent (dichlorobenzene) to air / to industrial soil / to freshwater / to marine water

The description of this impact category includes human toxicity effects, both for effects related to cancer risk (5.10.) and those related to other health effects (5.11.). Ecotoxicity of the terrestrial (5.12.), freshwater (5.13.) and marine environment (5.14.) are also included.

Figure 9 summarizes the cause-and-effect chain, from the emission of a chemical into the environment to the subsequent increase of its concentration which results in:

1.- Damage to terrestrial, freshwater and marine ecosystems, caused by the entry or release of chemicals with a direct effect on the health of each of the ecosystems.

2.- Damage to human health, which occurs as a consequence of the absorption of toxic substances through inhalation of air, ingestion of food or water, penetration through the skin, etc.

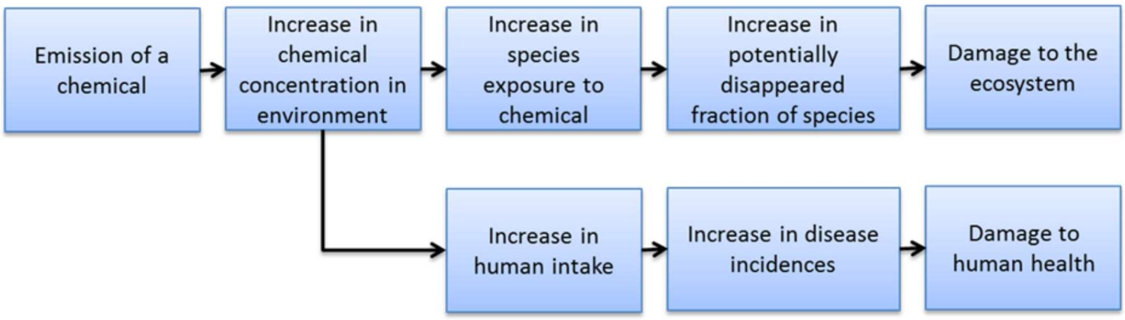


Figure 9. Cause-and-effect chain, from toxic chemical emissions to damage to the ecosystems and damage to human health. Source: ReCiPe, 2017

The unit to calculate this category refers to 1,4-dichlorobenzene (1,4-DCB or para-dichlorobenzene, molecular formula $C_6H_4C_{l2}$), substance classified as a possible human carcinogen, group 2B (IARC, 2021). In addition, exposure to high concentrations of 1,4-DCB may cause other adverse health effects such as irritation of the eyes and nose, shortness of breath and stomach upset. Extremely high concentrations may cause dizziness, headaches and liver problems (ATSDR, 2006).

More information at:

Toxicology and toxicity:
https://www.atsdr.cdc.gov/es/training/toxicology_curriculum/modules/1/es_lecturenotes.html

Ecotoxicity (definition): https://www.informea.org/en/terms/ecotoxicity

5.15. Water consumption

Unit: m^3 (cubic meters) water consumed

This impact category refers to water use or consumption, which implies a reduction in the availability of freshwater. Water consumption includes evaporated water, water incorporated into products, water transferred to other watersheds or discharged into the sea.

Figure 10 shows the cause-and-effect chain of water use, which results in damage to human health and the disappearance of terrestrial and freshwater aquatic species.

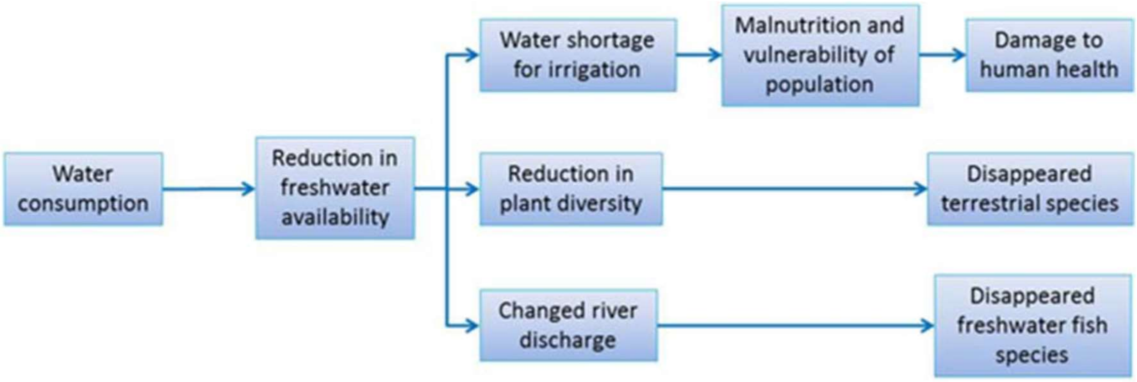


Figure 10. Cause-and-effect chain from water consumption, leading to damage to human health, disappearance of terrestrial and freshwater species. Source ReCiPe, 2017

The unit of measurement refers to freshwater consumption expressed in volume units (m^3). This impact category has led to the development of the concept of the Water Footprint (More information at: https://waterfootprint.org/en/).

More information at:

Water footprint: https://waterfootprint.org/en/water-footprint/what-is-water-footprint/

5.16. Land use

Unit: m^2·yr (m^2 ·time in years) of crop land

This impact category indicates the relative loss of species due to local use, occupation and land use transformation. It is based on the comparison of natural land use (reference) with anthropogenic land use, considering activities such as agriculture and urban land use (roads, housing, mining, etc.). Figure 11 brings together the cause-and-effect chain of land use, up to the end-point impact, i.e., damage to the ecosystem.

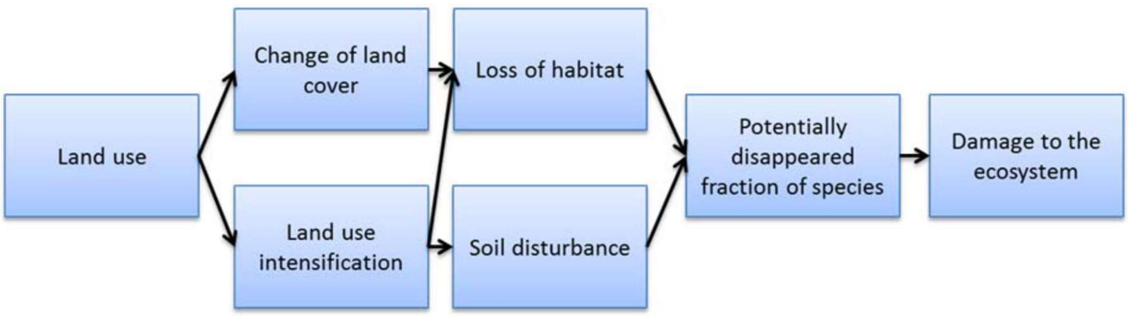


Figure 11. Cause-and-effect chain of land use, leading to damage to the ecosystems. Source ReCiPe, 2017

The unit of measurement refers to the occupied area (m^2) times the duration of land occupation (years). (Explanation: 10 m^2a can be interpreted as the use of a land area of 10 m^2 for 1 year, or the use of a land area of 1 m^2 for 10 years; the product of area times time will be 10 m^2a.)

More information at:

Land use: https://www.eea.europa.eu/es/themes/landuse/about-land-use

5.17. Mineral resource scarcity

Unit: kg Cu equivalent (copper)

This impact category refers to the depletion of mineral resources, such as metals. Metals are obtained from ores extracted from mines. Ore includes both ore (the mineral containing the desired metal) and gangue (other unwanted minerals). The grade of a metal refers to the concentration of a metal in the ore extracted from the mine. Normally, ores with higher grades of the desired metals are mined first (higher concentration, lower gangue). As the grade of the metal in the ore decreases, more ore must be mined to obtain the same amount of metal.

Figure 12 summarizes the cause-and-effect chain in this impact category. The extraction of the ore leads to a decrease in the concentration of the metal sought in the ore extracted. This increases the extraction of the ore. Considering also the future ore extraction, the Surplus Ore Potential (our midpoint indicator) is calculated, which in turn leads to the potential increase in the extraction cost (Surplus Cost Potential, endpoint indicator).

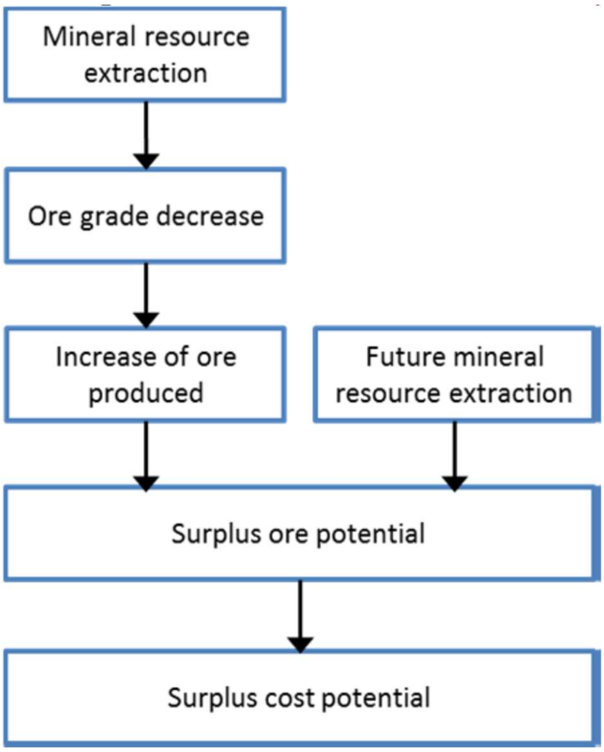


Figure 12. Cause-and-effect chain from mineral resource extraction to natural resource scarcity. Source ReCiPe, 2017

The unit of measurement for this category refers to the amount of copper (mass expressed in kg) of copper, a mineral resource that is assigned a value of "1" in this impact category. In other words, this category measures the impact of mineral extraction taking as a reference the estimated impact for the extraction of 1 kg of copper. This indicator considers not only the scarcity of the material, but also the concentration of available resources.

More information at:

Good practices for the extraction of mineral resources:

https://www.undp.org/content/dam/undp/library/Sustainable%20Development/Environmental-Governance-Project/UNDP-MINING%20Summary%20Report%20ES.pdf

5.18. Fossil resource scarcity

Unit: kg oil equivalent

This impact category refers to the scarcity of fossil resources, from oil, natural gas or coal.

Figure 14 summarizes the cause-effect chain in this environmental category. As occurred with mineral resources, the extraction of a fossil resource makes it increasingly expensive to extract the remaining resources. This results in an increase in extraction costs, characterized by the surplus cost potential (SCP, endpoint indicator). In this category, the midpoint indicator is the energy content of the resource, taking the energy density of oil as a reference.

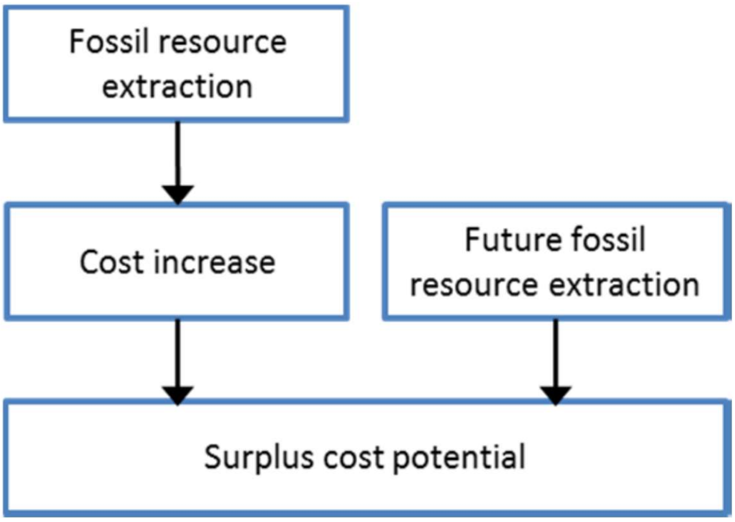


Figure 14. Cause-and-effect chain from fossil resource extraction to fossil resource scarcity. Source ReCiPe, 2017

The unit of measurement for this category refers to the amount of energy contained in crude oil (expressed in kg oil equivalent).

More information at:

Definition, fossil fuel: https://www.britannica.com/science/fossil-fuel

6. References

ATSDR, 2006. Agency for Toxic Substances and Disease Registry U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES. DICHLOROBENZENES. Available from: https://www.atsdr.cdc.gov/toxfaqs/tfacts10.pdf Last accessed: December 2021.

IARC, 2021, International Agency of Research on Cancer. Agents Classified by the IARC Monographs, Volumes 1–130 Available from: https://monographs.iarc.who.int/list-of-classifications Last accessed: December 2021.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Huijbregts, M. A., Steinmann, Z. J., Elshout, P. M., Stam, G., Verones, F., Vieira, M. D. M., Hollander, A., van Zelm, R. (2017). ReCiPe 2016 v1.1. A harmonized life cycle impact assessment method at midpoint and endpoint level. report I: Characterization; RIVM Report 2016-0104. National Institute for Human Health and the Environment, Bilthoven. Available from: https://pre-sustainability.com/legacy/download/Report_ReCiPe_2017.pdf Last accessed: December 2021.

PRTR-España (2021). Registro Estatal de Emisiones y Fuentes Contaminantes. NOx Óxidos de nitrógeno. Available from: https://prtr-es.es/NOx-oxidos-de-nitrogeno,15595,11,2007.html Last accessed: December 2021.

WHO, World Health Organization (2016). Radiaciones ionizantes: efectos en la salud y medidas de protección. Available from: https://www.who.int/es/news-room/fact-sheets/detail/ionizing-radiation-health-effects-and-protective-measures Last accessed: December 2021.

WHO, World Health Organization (2006). Health risks of particulate matter from long-range transboundary air pollution. World Health Organization, Copenhagen, Denmark. Available from: https://www.euro.who.int/__data/assets/pdf_file/0006/78657/E88189.pdf Last accessed: December 2021.