Tetis Institute Srl
TEchniques for The Impact on Sustainability

Università degli Studi di Genova

Energy from different carriers emission factor evaluation

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1 Environmental impacts

In the journey toward sustainable development, one of the key priorities is to measure and minimize the environmental impact of various products and processes. Two crucial concepts that guide this measurement are the Global Warming Potential (GWP) and Ecopoints.

1.1 Global Warming Potential (GWP)

The Global Warming Potential, or GWP, is a metric used to compare the impact of various greenhouse gases on global warming. Not all greenhouse gases contribute equally to the greenhouse effect; some have a much higher heat-trapping capability than others. GWP measures this effect over a specific period, usually 100 years, and assigns each gas a value relative to carbon dioxide (CO_2), the baseline gas with a GWP value equal to 1.
As an example, methane (CH_4) has a GWP of about 25, meaning it is 25 times more effective at trapping heat than CO_2 over the same timeframe while nitrous oxide (N_2O) has a GWP of around 298, indicating an even greater effect on global warming. The GWP unit of measurement is then set in relation to the carbon dioxide value, and it is expressed in terms of mass of CO_2 equivalent.
The GWP values help policymakers, scientists, and companies evaluate and compare the impact of different gases, especially when deciding on targets for emissions reduction. In practical terms, GWP provides insight into how much more potent one gas is than another in contributing to climate change. Consequently, products and processes that release gases with high GWP values are seen as having a higher impact on global warming, guiding choices in product design, energy production, and industry regulations to minimize emissions.

1.2 Ecopoints

Ecopoints are a distinct but complementary tool used in environmental impact assessment. While GWP focuses specifically on greenhouse gases and their role in global warming, ecopoints provide a more comprehensive measure of a product or process's overall environmental impact. Developed as part of life cycle assessment (LCA) frameworks, ecopoints evaluate various environmental effects, from resource depletion and pollution to waste generation and water consumption.

The ecopoints system assigns numerical values to these impacts, summing them into a single score that represents the total environmental burden. Higher ecopoints indicate a greater negative impact on the environment, and lower ecopoints suggest a more sustainable outcome. This measure allows manufacturers, consumers, and regulators to compare products or services from an environmental standpoint. The detailed evaluation process is explained in chapter 2.

2 Evaluation method

This chapter describes the process of calculating the environmental impacts expressed in Ecopoints according to the recipe 2016 calculation method: Midpoint impact categories, that correspond mainly to common environmental impact indicators, are first evaluated, then through the Damage Pathways and appropriate factors are evaluated the Endpoint areas of protection, finally the single score (Ecopoints) is obtained through a normalization and weighing process.
The calculation process has been divided and will be presented in three different steps for simplicity.

Step 1 – Midpoint impact categories evaluation
The Midpoint impact categories are the following:

- Global warming [kg CO_2 eq]
- Stratospheric ozone depletion [kg CFC11 eq]
- Ionizing radiation [kBq Co-60 eq]
- Ozone formation [kg NO_x eq]
- Fine particulate matter formation [kg PM2.5 eq]
- Terrestrial acidification [kg SO_2 eq]
- Freshwater eutrophication [kg P eq]
- Marine eutrophication [kg N eq]
- Terrestrial ecotoxicity [kg 1,4-DCB]
- Freshwater ecotoxicity [kg 1,4-DCB]
- Marine ecotoxicity [kg 1,4-DCB]
- Human carcinogenic toxicity [kg 1,4-DCB]
- Human non-carcinogenic toxicity [kg 1,4-DCB]
- Land use [m2a crop eq]
- Mineral resource scarcity [kg Cu eq]
- Fossil resource scarcity [kg oil eq]
- Water consumption [m^3]

The impact on each of the Midpoint impact categories is evaluated through an LCA approach considering all the analysed processes related to the product, good or process.

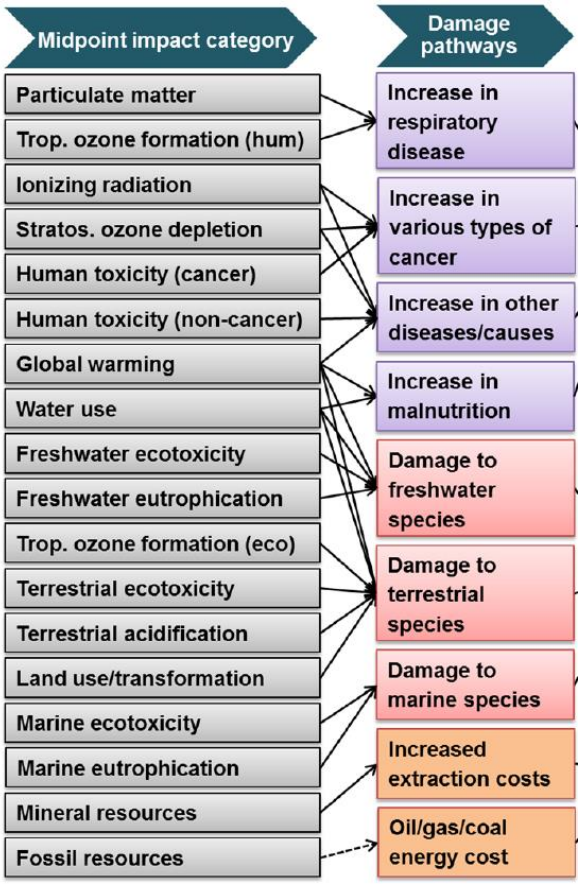
Step 2 – From Midpoint impact categories to Endpoint areas of protection

Each Midpoint impact category is assigned one or more Damage pathways according to the damage that this category can generate. The Damage pathways are the following:

- Increase in respiratory disease;
- Increase in various types of cancer
- Increase in other disease/causes;
- Increase in malnutrition;
- Damage to freshwater species;
- Damage to terrestrial species;
- Damage to marine species
- Increased extraction costs
- Oil/gas/coal energy cost

For example, the generation of particulate matter has negative effects that result in an increase in respiratory disease, while the use of water results in increased malnutrition, damage to freshwater species and damage to terrestrial species.

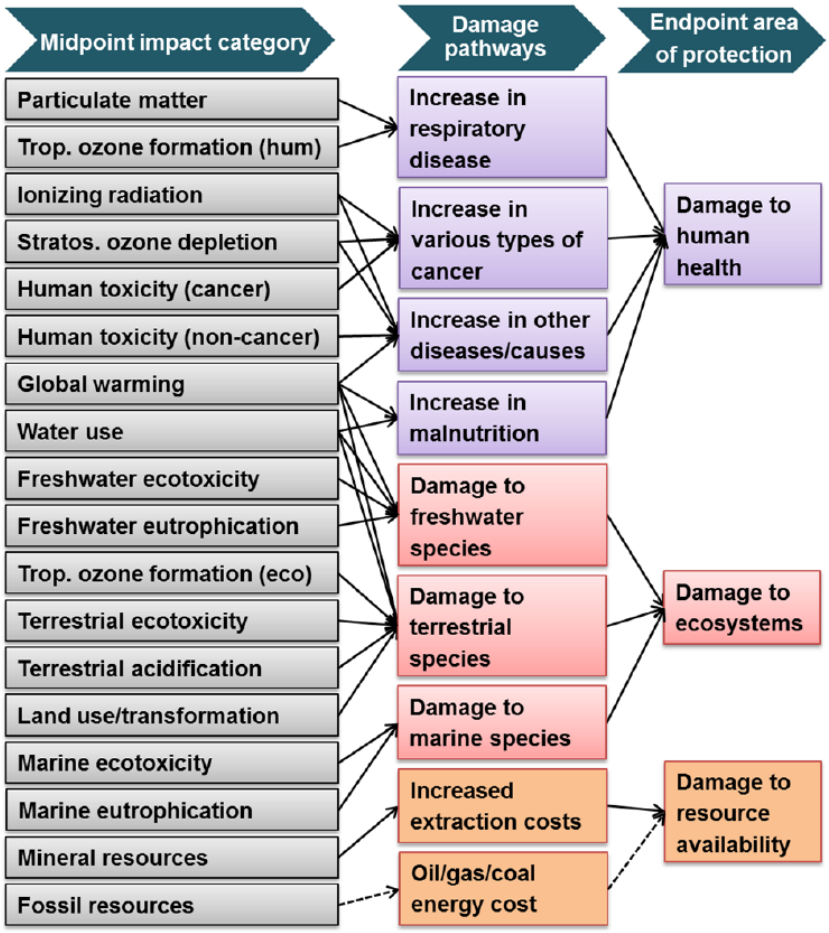
Below is a descriptive diagram of all the relationships between Midpoint impact categories and Damage Pathways.



Then the nine Damage pathways are merged into three Endpoints area of protection based on which natural element suffers the damage:

- Damage to human health;
- Damage to ecosystems;
- Damage to resource availability.

The relationship between Midpoint impact categories, Damage pathways and Endpoint area of protection is expressed in the following diagram.



Each Endpoint area of protection has its own unit of measurement, namely:

- Damage to human health: disability adjusted loss of life years (DALY), expressed in years;
- Damage to ecosystems: time integrated species loss, expressed in species per year;
- Damage to resource availability: surplus cost, expressed in 2013 US dollars.

Through appropriate emission factors (reported in appendix A), the impact of each Midpoint impact category is transformed into impact reported to the appropriate Endpoint area of protection.

Step 3 - From Endpoint areas of protection to Single score (Ecopoint)

Eco-points will be shown as a single score through weighting, allowing for easy comparison of the environmental impact of various products. This method simplifies decision making because it is evident whether a product's environmental impact is greater, lesser, or similar to that of other items.

After calculating the total impact on the three Endpoint areas of protection, a process of normalisation of the impacts obtained is carried out according to specific factors, which are shown in the following table.

Endpoint area of protection	Normalizing factor
Damage to human health	41.7
Damage to ecosystems	676
Damage to resource availability	3.57E-5

When the impacts are normalised according to the above mentioned factors, they are further multiplied by weight factors, which are shown in the following table.

Endpoint area of protection	Weighting factor
Damage to human health	400
Damage to ecosystems	400
Damage to resource availability	200

Once the weighing process has been carried out, the environmental impacts for the three Endpoint areas of protection are expressed in Ecopoints: therefore, the sum of the Ecopoints obtained for each endpoint area of protection is the overall score expressed in Ecopoint associated with this process.

3 Results obtained

3.1 Direct emission factors

Document: Direct emission factors evaluation v.14-10-2024

			FU	Ecoinvent 3.9.1 (January 2023)	
				Ecopoint [Pt]	GWP [kgCO_2eq]
OUTPUT (DIRECT EMISSIONS)	AIRBORNE EMISSIONS	Ammonia	1 kg	2.63E+00	0
		Carbon dioxide, fossil	1 kg	1.62E-02	1
		Carbon monoxide, fossil	1 kg	0.00E+00	0
		Heat, waste	1 MJ	0.00E+00	0
		Hydrocarbons, aliphatic, alkanes, cyclic	1 kg	7.75E-03	0
		Hydrocarbons, aromatic	1 kg	2.41E-02	0
		Methane, fossil	1 kg	5.84E-01	36
		Nitrogen oxides	1 kg	1.22E+00	0
		NMVOC, non-methane volatile organic compounds, unspecified origin	1 kg	1.28E-02	0
		PAH, polycyclic aromatic hydrocarbons	1 kg	1.89E+00	0
		Particulates, < 10 um	1 kg	0.00E+00	0
		Particulates, < 2.5 um	1 kg	1.05E+01	0
		Sulfur oxides	1 kg	3.09E+00	0
	WATERBORNE EMISSIONS	Hydrocarbons, unspecified	1 kg	0.00E+00	0
		Nitrogen oxides	1 kg	4.14E-05	0

3.2 Diesel upstream emission factor

Document: Diesel emission factors evaluation v.14-10-2024

	kgCO_2eq/kg	Pt/kg
Diesel upstream	1,03E+00	3,49E-02

3.3 Shore power with weighing on frequency of visited marinas

Document: Preliminary report for YETI Project v.21-10-2024

Geographical framework	Country	Ecoinvent 3.9.1 (January 2023) GWP [kgCO_2eq/MWh]	Ecoinvent 3.9.1 (January 2023) Ecopoints [Pt/MWh]	Visiting frequencies
MEDIT	Albania	145,32	9,15	253
	Croatia	451,26	27,80	2078
	France	89,78	5,28	4477
	Gibraltar	953,85	33,83	839
	Greece	684,81	36,73	4681
	Israel	765,71	28,04	-
	Italy	393,10	13,41	7030
	Malta	462,73	13,01	297
	Montenegro	773,35	85,28	767
	Morocco	1054,73	50,48	-
	Principality of Monaco	89,78	5,28	2275
	Spain	284,55	12,03	2100
	Tunisia	758,25	17,30	-
	Turkey	622,14	72,72	664
WEIGHTED MEDITERRANEAN COUNTRY AVERAGE		**396,34**	**20,94**	**-**
CARRIBEAN	Colombia	272,55	12,85	-
	Cuba	1208,65	46,28	583
	Curaçao	857,89	34,79	583
	Dominican Republic	978,88	37,13	875
	Jamaica	1001,67	35,89	-
	Panama	381,04	14,56	221
	Trinidad and Tobago	716,69	16,36	-
	USA - Florida	529,63	19,70	3186
WEIGHTED CARRIBEAN COUNTRY AVERAGE		**703,54**	**26,75**	**-**
WEIGHTED GLOBAL AVERAGE		**450,49**	**21,96**	**-**

3.4 Urea

40.94 Pt/ton

3.5 HVO upstream emission factor

Document: HVO production impacts assessment v.05-10-2023

Environmental Indicator	Unit	Transport to the treatment plant	Pre-treament process	Production process	TOTAL
Global warming potential (GWP)	kgCO_2eq	46.72	92.05	524.69	**663.46**
Ecopoints	Pt	1.52	2.83	11.84	**16.20**

3.6 Methanol from CC upstream emission factor

Document: Methanol from CC production impacts assessment v.31-10-2023

Environmental Indicator	Unit	Production process	TOTAL
Global warming potential (GWP)	$kgCO_2eq$	944.3	**944.3**
Ecopoints	Pt	26.2	**26.2**

3.7 Hydrogen from electrolysis (300 bar compression) upstream emission factor

Document: Hydrogen from hydrolysis (300 bar compression) production impacts assessment v.30-11-2023

GWP unit	Process	RER	PV	WIND
Global warming [$kgCO_2eq/Nm^3$]	Electrolysis	1.81E+00	4.46E-01	2.16E-01
	Compression	6.52E-02	1.48E-02	6.34E-03
	Total	**1.87E+00**	**4.61E-01**	**2.22E-01**

GWP unit	Process	RER	PV	WIND
Global warming [$kgCO_2eq/kg$]	Electrolysis	2.01E+01	4.96E+00	2.40E+00
	Compression	7.25E-01	1.65E-01	7.05E-02
	Total	**2.09E+01**	**5.13E+00**	**2.47E+00**

Ecopoints unit	Process	RER	PV	WIND
Global warming [Pt/Nm^3]	Electrolysis	6.40E+01	2.41E+01	1.41E+01
	Compression	2.33E+00	8.56E-01	4.86E-01
	Total	**6.63E+01**	**2.50E+01**	**1.46E+01**

Ecopoints unit	Process	RER	PV	WIND
Global warming [Pt/kg]	Electrolysis	7.12E+02	2.68E+02	1.57E+02
	Compression	2.59E+01	9.53E+00	5.41E+00
	Total	**7.38E+02**	**2.78E+02**	**1.62E+02**

3.8 Hydrogen from electrolysis (cryogenic storage) upstream emission factor

Document: Hydrogen from hydrolysis (cryogenic storage) production impacts assessment v.29-11-2023

GWP unit	Process	RER	PV	WIND
Global warming [$kgCO_2eq/Nm^3$]	Electrolysis	1.81E+00	4.46E-01	2.16E-01
	Compression	4.49E-01	4.37E-02	4.37E-02
	Total	**2.26E+00**	**4.90E-01**	**2.59E-01**

GWP unit	Process	RER	PV	WIND
Global warming [$kgCO_2eq/kg$]	Electrolysis	2.01E+01	4.96E+00	2.40E+00
	Compression	4.99E+00	4.86E-01	4.86E-01
	Total	**2.51E+01**	**5.45E+00**	**2.89E+00**

Appendix A

	Unit[1,2]	H
Human health		
climate change	yr/kg CO_2 to air	9.3E-07
ozone depletion	yr/kg CFC11 to air	5.3E-04
ionizing radiation	yr//kBq Co-60 to air	8.5E-09
fine particulate matter formation	yr/kg PM2.5 to air	6.3E-04
photochemical ozone formation	yr/kg NOx to air	9.1E-07
cancer toxicity	yr/kg 1,4-DCB to air	3.3E-06
non-cancer toxicity	yr/kg 1,4-DCB to air	6.7E-09
water use	yr/m^3 water	2.2E-06
Ecosystem quality: terrestrial		
climate change	species.yr/kg CO_2 to air	2.8E-09
photochemical ozone formation	species.yr/kg NO_x to air	1.3E-07
acidification	species.yr/kg SO_2 to air	2.1E-07
toxicity	species.yr/kg 1,4-DCB to industrial soil	5.4E-08
water use	species.yr/m^3 water consumed	1.4E-08
land use	species/m^2 annual crop land	8.9E-09
Ecosystem quality: fresh water		
climate change	species.yr/kg CO_2	7.7E-14
eutrophication	species.yr/kg P to fresh water	6.1E-07
toxicity	species.yr/kg 1,4-DCB to fresh water	7.0E-10
water use	species.yr/m^3 water consumed	6.0E-13
Ecosystem quality: marine		
toxicity	species.yr/kg 1,4-DCB	1.1E-10
eutrophication	species.yr/kg N to marine water	1.7E-09
Resource scarcity		
minerals	US_{2013} $/kg Cu	0.23
fossils[3]	US_{2013} $/kg crude oil	0.46
	US_{2013} $/kg hard coal	0.03
	US_{2013} $/$Nm^3$ natural gas	0.30

1 The unit for human health damage refers to the disability adjusted life years lo
human population; 2 the units for ecosystem damage refer to the number of spe
integrated over time; 3 fossil resource scarcity is the only midpoint category whi
have a constant midpoint to endpoint factor.