Supplementary materials

Specific assumptions

In rice straw exploitation process, its density is considered equal to 18 kg/m^3 [66] and injection molding time is approximated to one hour.

In wheat straw exploitation processes, wheat straw density is assumed to be 50.46 kg/m^3 [67]. In graphene production, during alkali hydrothermal treatment it is assumed a 90% recycle of potassium hydroxide and 80 °C drying time is considered equal to 12 h, similar to an equivalent treatment in the same process; in pyrolysis step, it is hypothesised a hydrochloric acid recycle by 90% for the washing treatment. In the exploitation process of wheat straw to lignin, residue: solvent ratio during extraction is considered 1:10 and extraction time 5 h, as in a similar study [68]. In the purification step the time to concentrate the solution from 70 mL to 50 mL in oven at 60 °C is assumed one hour, since it is not specified elsewhere.

In tomato pomace exploitation process, the residue density is assumed to be equal to the tomato density, 0.47 g/cm^3 [69]. During pre-treatment, residue: solvent ratio to remove waxes is considered 1:10, similar to another study [18] and the time is set to 8 h [70]; in this same step, overnight drying is equal to 12 h. Finally, in filtration step, centrifugation time is assumed 15 min [71].

In orange peel exploitation process, dried orange peel density is assumed to be 0.40 g/cm^3 [72] and 80 °C thermal treatment time realized during pre-treatment, not mentioned in the article, is considered 24 h, based on a similar process [73]. In crosslinking step, to assess its share during characterization, the occasional stirring is considered continuous, assuring conservative conditions; moreover, the epichlorohydrine quantity has been compared to the quantity of another similar study [49], since it is not mentioned in the article. In polymerization step, ceric ammonium nitrate quantity is calculated starting from the initial nitric acid solution to whom the salt is added later, because the real reference volume is not specified in the article; ethanol is considered as the quinone solvent [74]. In purification step, 60 °C thermal treatment is considered 48 h long, in relation to another similar treatment of humidity reduction [75] and residue: acetone ratio for Soxhlet extraction is assumed 1:20 [76]. Furthermore, during post-treatment, 80 °C vacuum thermal treatment is assumed to last 12 h, based on a similar study [23].

To carry out inventory analysis and classification, characterisation, normalisation and weighing, thinkstep Gabi software 9.5, Database for Life Cycle Engineering, Sphera, Chicago, USA is used to collect data. However, some information were not in the database, therefore substitutions are made; Table S1 shows them.

Table S1. Specific assumptions: comparable raw materials chosen to substitute the raw materials missing in the database.

Needed Reagent	Substitute Reagent
Orange peel exploitation-adsorbent polymer	
Epichlorohydrine	DE: Propylene oxide (Chlorohydrin process with $Ca(OH)_2$) ts
Ceric ammonium nitrate	EU-28: Urea ammonium nitrate (UAN, 30% N) Fertilizers Europe
Quinone	IT: Cumene (isopropylbenzene) (C_9H_{12}) ts
Wheat straw exploitation-graphene production	
Potassium hydroxide	EU-28: Sodium hydroxide (caustic soda) mix (100%) ts
Tomato pomace exploitation-polyester film production	
Hexane	RER: Pentane Plastics Europe
Methanol	Ethanol ts
Rice straw exploitation-composite panel production	
Lignin bioplastic Arboform®	Kraft lignin [52]

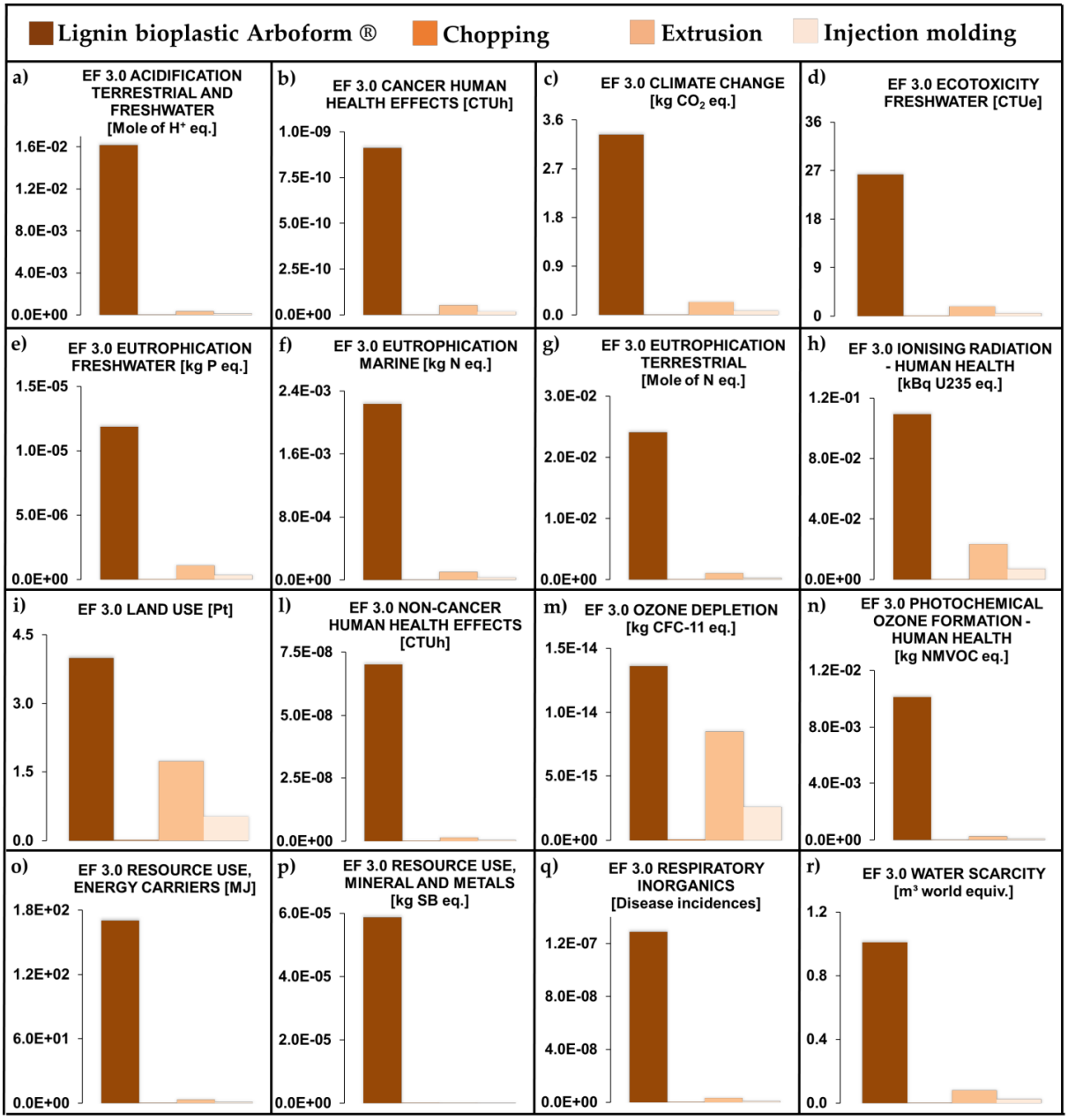

Figure S1. Classification and characterization graphics of rice straw exploitation process for the considered impact categories (**a**)–(**r**). Functional unit: 1 kg of organic residue.

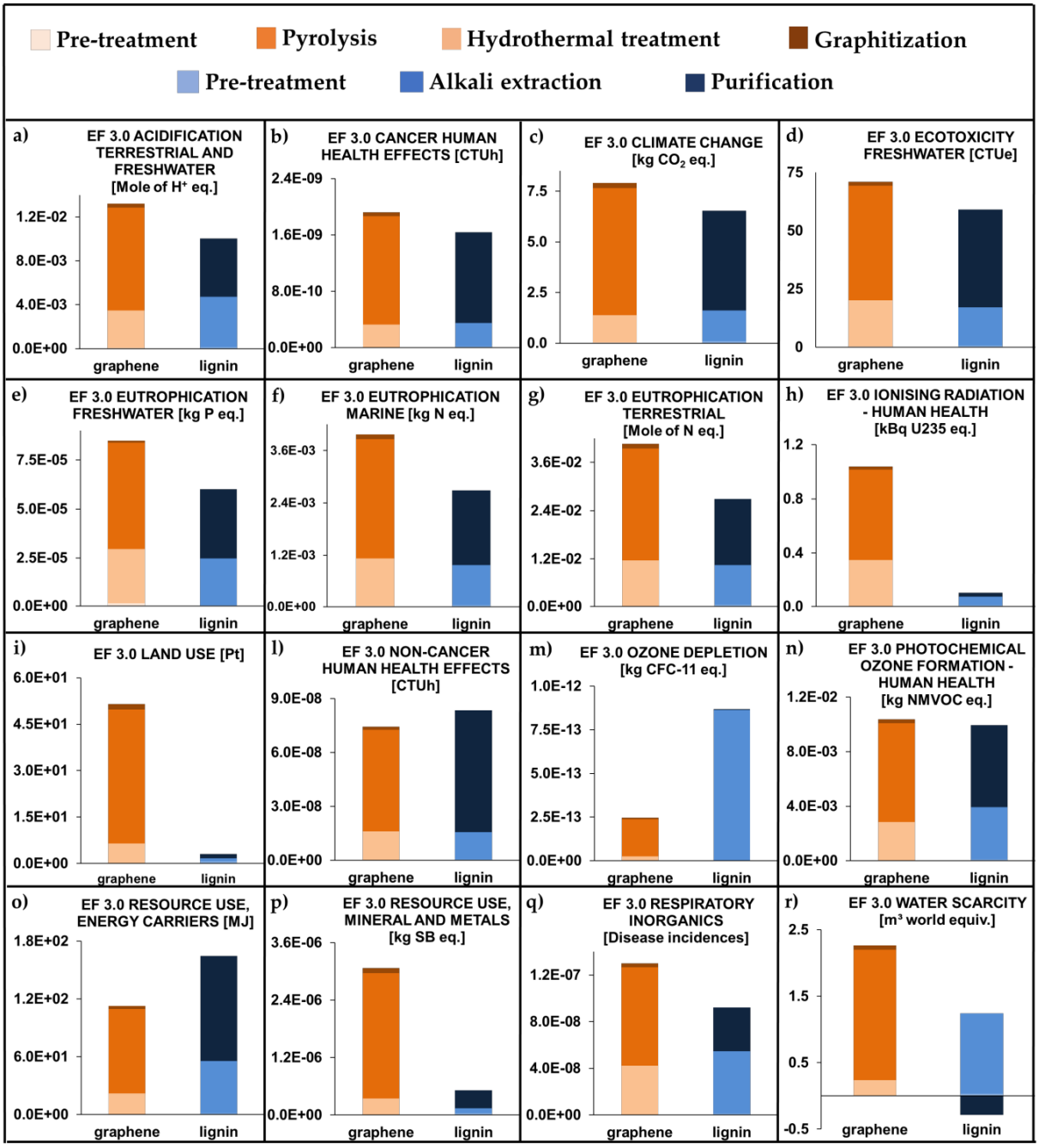

Figure S2. Classification and characterization graphics of two wheat straw exploitation processes for the considered impact categories (**a**)–(**r**). Functional unit: 1 kg of organic residue.

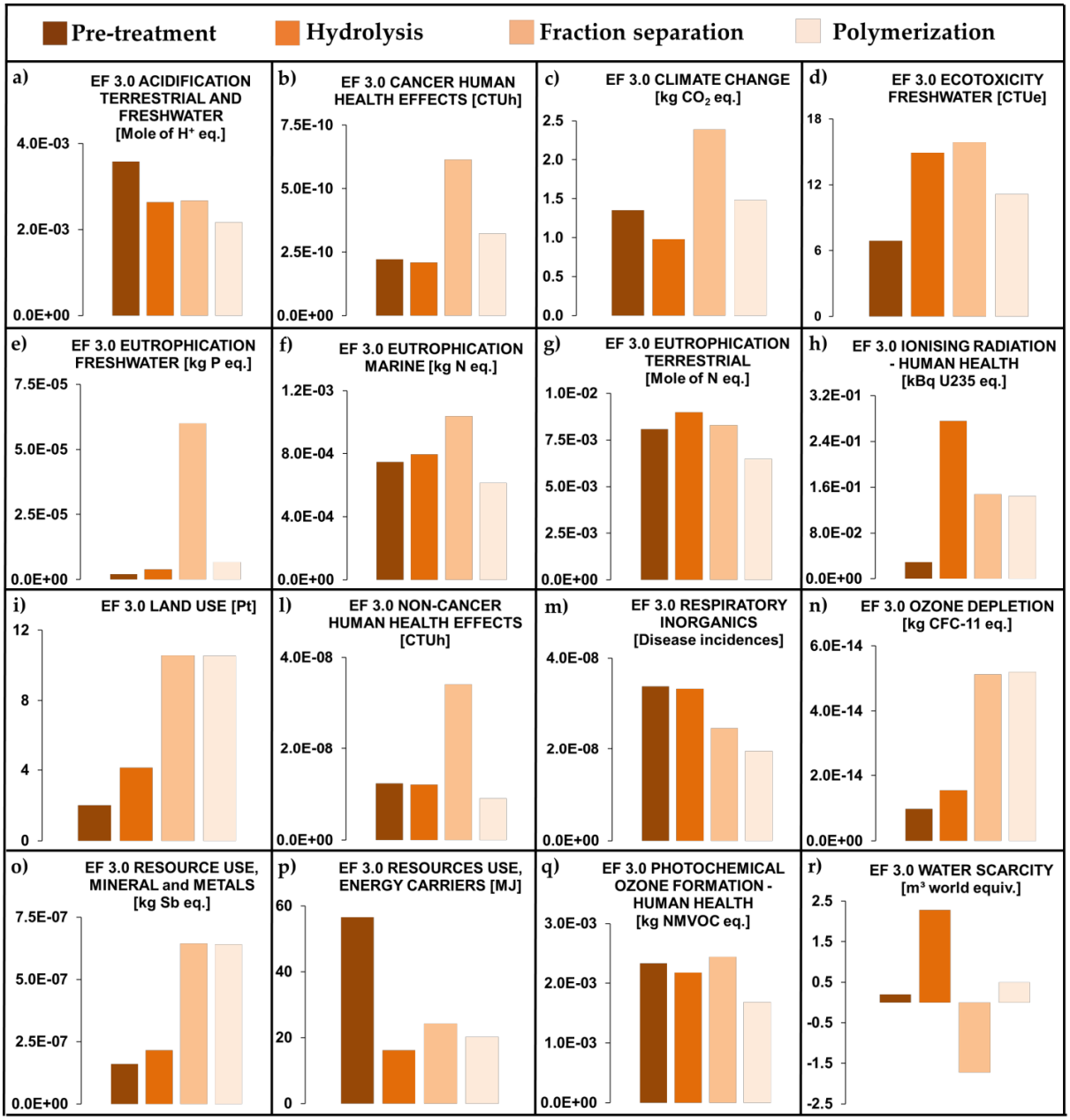

Figure S3. Classification and characterization graphics of tomato pomace exploitation process for the considered impact categories (**a**)–(**r**). Functional unit: 1 kg of organic residue.

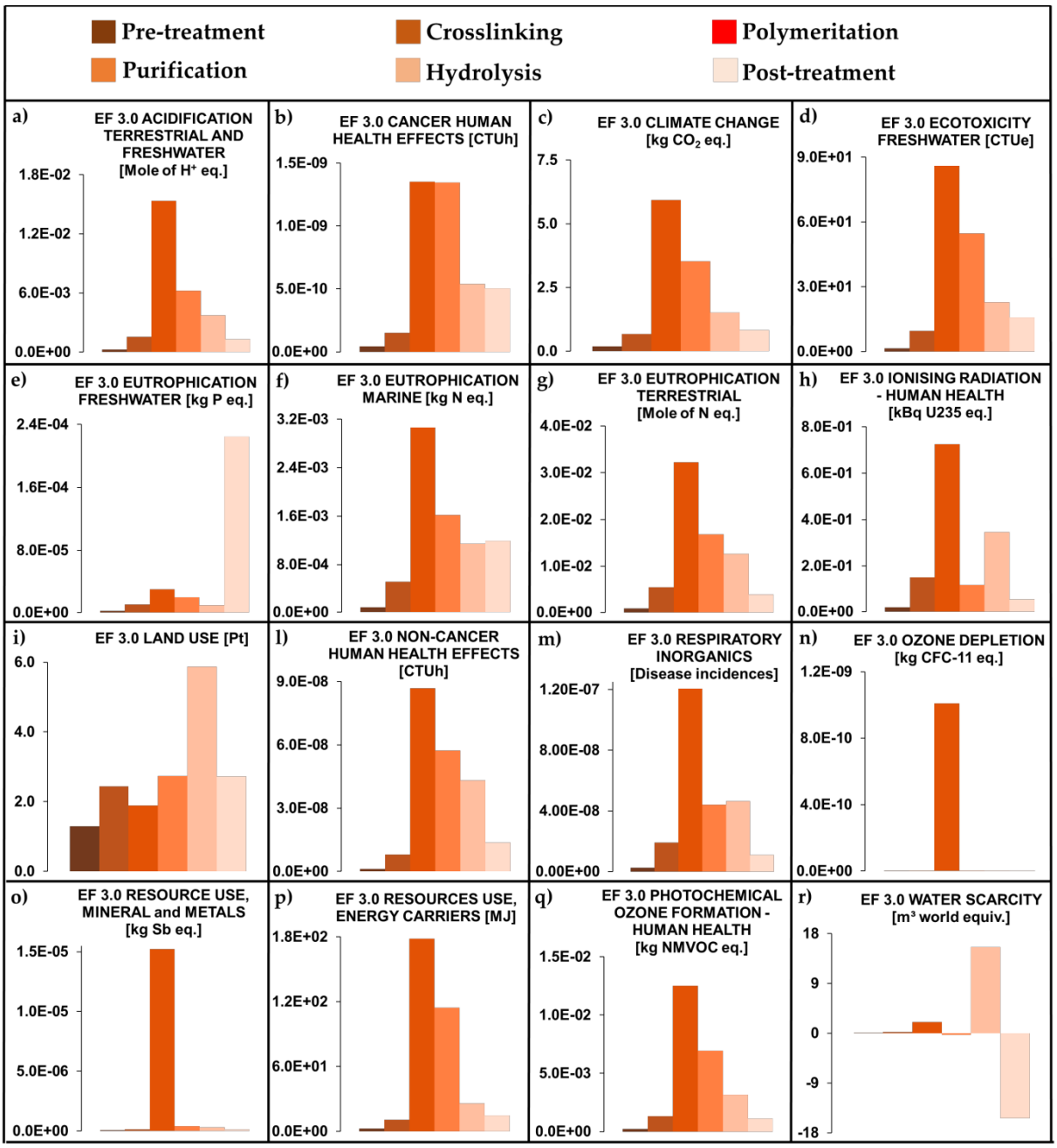

Figure S4. Classification and characterization graphics of orange peel exploitation process for the considered impact categories (a)-(r). Functional unit: 1 kg of organic residue.

Table 2. Weight of each impact category on the normalization and weighing results. Functional unit: 1 kg of organic residue.

Impact Category	Composite Panel			Graphene			Lignin			Polyester Film			Metal-Adsorbent Polymer		
	BBP	BBP–Renewable Energy	Traditional Product	BBP	BBP–Renewable Energy	Traditional Product	BBP	BBP–Renewable Energy	Traditional Product	BBP	BBP–Renewable Energy	Traditional Product	BBP	BBP–Renewable Energy	Traditional Product
EPI (p.e.)	$5.3x10^{-2}$	$5.0x10^{-2}$	$7.1x10^{-2}$	$8.5x10^{-2}$	$3.7x10^{-2}$	$5.8x10^{-3}$	$4.8x10^{-2}$	$4.8x10^{-2}$	$4.5x10^{-3}$	$6.0x10^{-2}$	$3.6x10^{-2}$	$7.6x10^{-3}$	$1.6x10^{-1}$	$1.5x10^{-1}$	$5.9x10^{-2}$
Acidification terrestrial and freshwater	3.5%	3.6%	2.5%	1.7%	2.1%	1.1%	2.3%	2.3%	1.7%	2.0%	2.4%	2.0%	2.0%	2.1%	1.6%
Cancer human health effects	0.2%	0.2%	0.5%	0.3%	0.3%	0.1%	0.4%	0.4%	0.3%	0.3%	0.3%	0.4%	0.3%	0.3%	0.1%
Climate Change	18.1%	17.5%	22.7%	24.3%	16.5%	12.3%	30.7%	30.6%	25.9%	24.0%	19.8%	32.6%	21.2%	20.9%	14.6%
Ecotoxicity freshwater	2.4%	2.4%	5.6%	3.8%	3.3%	2.2%	5.4%	5.4%	3.4%	3.6%	3.3%	7.0%	5.5%	5.5%	3.6%
Eutrophication freshwater	0.0%	0.0%	0.0%	0.2%	0.3%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.1%	0.3%	0.3%	0.0%
Eutrophication marine	0.7%	0.7%	1.2%	0.7%	0.8%	0.5%	0.8%	0.8%	0.7%	0.8%	0.8%	0.7%	0.7%	0.7%	0.7%
Eutrophication terrestrial	1.0%	1.0%	1.5%	1.0%	1.1%	0.7%	1.1%	1.1%	1.0%	1.1%	1.2%	1.1%	1.0%	1.0%	1.0%
Ionising radiation-human health	9.6%	8.2%	22.6%	44.1%	48.5%	28.9%	7.6%	7.1%	38.3%	35.8%	32.6%	8.5%	32.8%	32.5%	55.2%
Land Use	0.0%	0.0%	0.0%	0.2%	0.1%	0.1%	0.0%	0.0%	0.2%	0.2%	0.1%	0.1%	0.0%	0.0%	0.1%
Non-cancer human health effects	1.1%	1.1%	1.8%	0.7%	1.2%	0.4%	1.3%	1.3%	0.5%	0.9%	1.2%	2.3%	1.1%	1.1%	0.5%
Ozone depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Photochemical ozone formation-human health	2.3%	2.4%	4.0%	1.4%	1.7%	1.0%	2.3%	2.3%	1.4%	1.6%	1.8%	2.7%	1.9%	1.9%	1.4%
Resource use, energy carriers	42.3%	43.4%	31.5%	16.9%	12.4%	8.9%	43.7%	43.8%	17.8%	25.0%	28.0%	40.0%	28.5%	28.8%	11.6%
Resource use, mineral and metals	13.2%	14.1%	0.2%	0.4%	7.8%	0.1%	0.1%	0.3%	0.5%	0.3%	4.1%	0.2%	1.2%	1.5%	0.2%
Respiratory inorganics	3.8%	3.9%	4.3%	2.3%	3.4%	1.9%	2.8%	2.8%	2.1%	2.7%	3.6%	2.0%	2.4%	2.4%	2.7%
Water scarcity	1.6%	1.5%	1.4%	2.0%	0.6%	41.8%	1.5%	1.7%	6.2%	1.5%	0.6%	0.3%	1.0%	1.0%	6.7%