



**Sustainability in Energy and
Buildings**

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Product environmental footprint applied to the food sector in Sicily: a case study of pasta production

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The AGROPEF project

This research was conducted as part of the AGROPEF project, developed by the Center for Sustainability and Ecological Transition (CSTE), funded by the Italian Ministry of Universities and Research (MUR) within the program for technical-scientific university hubs in Southern Italy. The project aims to support SMEs in their transition towards a more sustainable economy through the adoption of the Product Environmental Footprint (PEF) methodology.

The initiative includes two pilot studies, in a pasta factory and a winery, to test and optimize production processes.

The project explores barriers and opportunities for PEF adoption in Southern Italian SMEs, developing practical solutions to facilitate its implementation.

<https://www.unipa.it/Progetto-AGROPEF/>



agröpef



Greenhouse gas emissions

Responsible for 21–37% of global anthropogenic GHG emissions

- ✓ 6.2 GtCO₂eq/year from livestock and animal product supply chain
- ✓ 4.3±2.6 GtCO₂/year from land use change and deforestation
- ✓ 4.4 GtCO₂eq/year from food waste – 8–10% of total emissions

Deforestation and biodiversity loss

- ✓ 90% of global deforestation driven by agriculture
- ✓ 13 million hectares of forest lost per year

Water scarcity

- ✓ Agriculture = 70%
- ✓ Livestock = 41% of agricultural water use

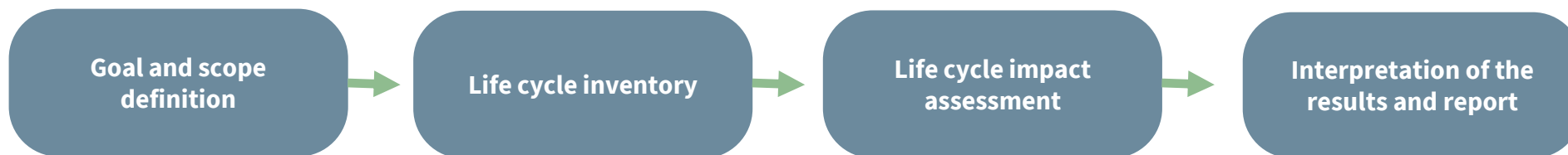
Food waste

- ✓ 1.05 billion tons wasted globally in 2022 → 132 kg per capita EU



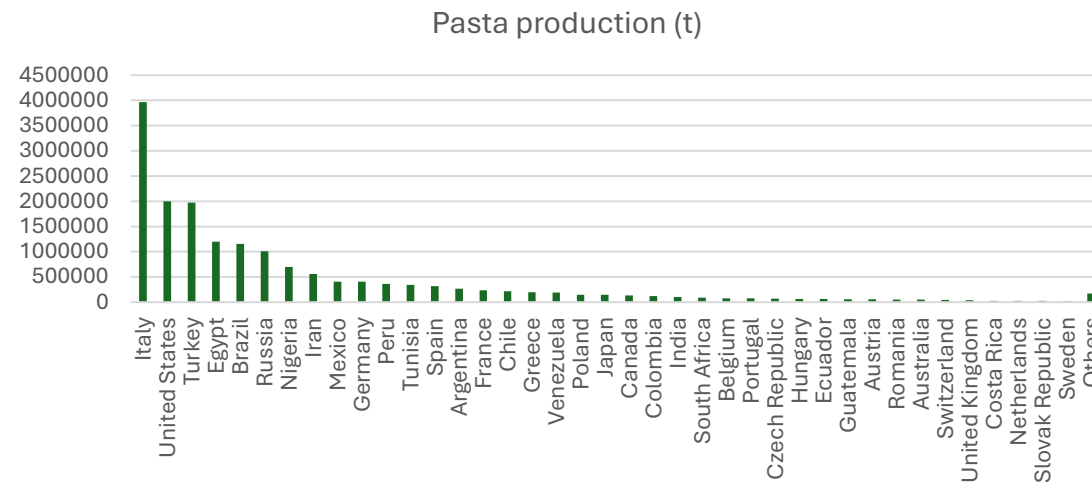
PRODUCT ENVIRONMENTAL FOOTPRINT
ORGANIZATION ENVIRONMENTAL FOOTPRINT

Steps in a PEF study





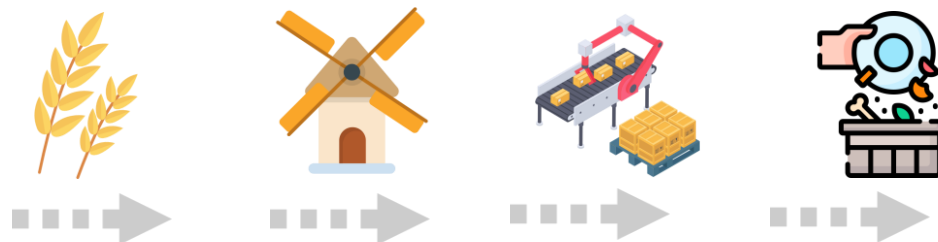
- ✓ Global pasta production: 17.1 million tons
- ✓ Italy is the leading producer (4 million tons) and top exporter (2.1 million tons, 43%)
- ✓ Durum wheat production in Italy: 3.8 million tons (12% of global total), but not self-sufficient



Source: Union of the Organizations of Manufacturers of Pasta Product in the E.U., October 2024



- ✓ 36% of Italian mills
- ✓ Rich cereal biodiversity: Timilia, Russello, Perciasacchi, Senatore Cappelli, Maiorca
- ✓ Local varieties adapted to arid climates, often grown under organic or integrated systems



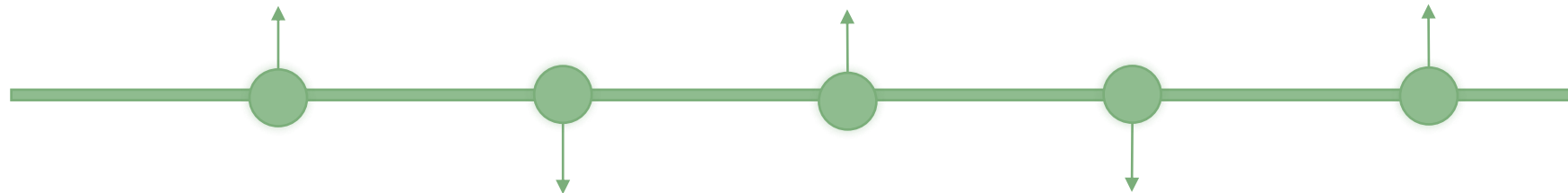
Apply the **Product Environmental Footprint** to a real case: Penne rigate n. 59, a durum wheat semolina pasta format produced in Sicily by Pastificio Gallo S.r.l., based in Mazara del Vallo (TP), marketed under the brand name “Primeluci.”

Product Environmental Footprint Category Rules for Dry pasta



Develop operational recommendations to support SMEs in using PEF.

Identify hotspots and suggest actions for impact reduction.



Assess environmental impacts in 16 categories, comparing with EU benchmarks.

Critical assessment of the applicability of PEF method to SMEs



Word cloud containing environmental impact categories: RADIATION, WATER USE, TOXICITY, ACIDIFICATION, PHOTOCHEMICAL, OZONE, MINERALS, LAND USE, ECOTOXICITY, FRESHWATER, RESOURCE USE, FOSSIL FORMATION, CLIMATE CHANGE, PARTICULATE MATTER, OZONE DEPLETION, HUMAN HEALTH, CANCER, RESOURCE IONISING, USE METALS, EUTROPHICATION.

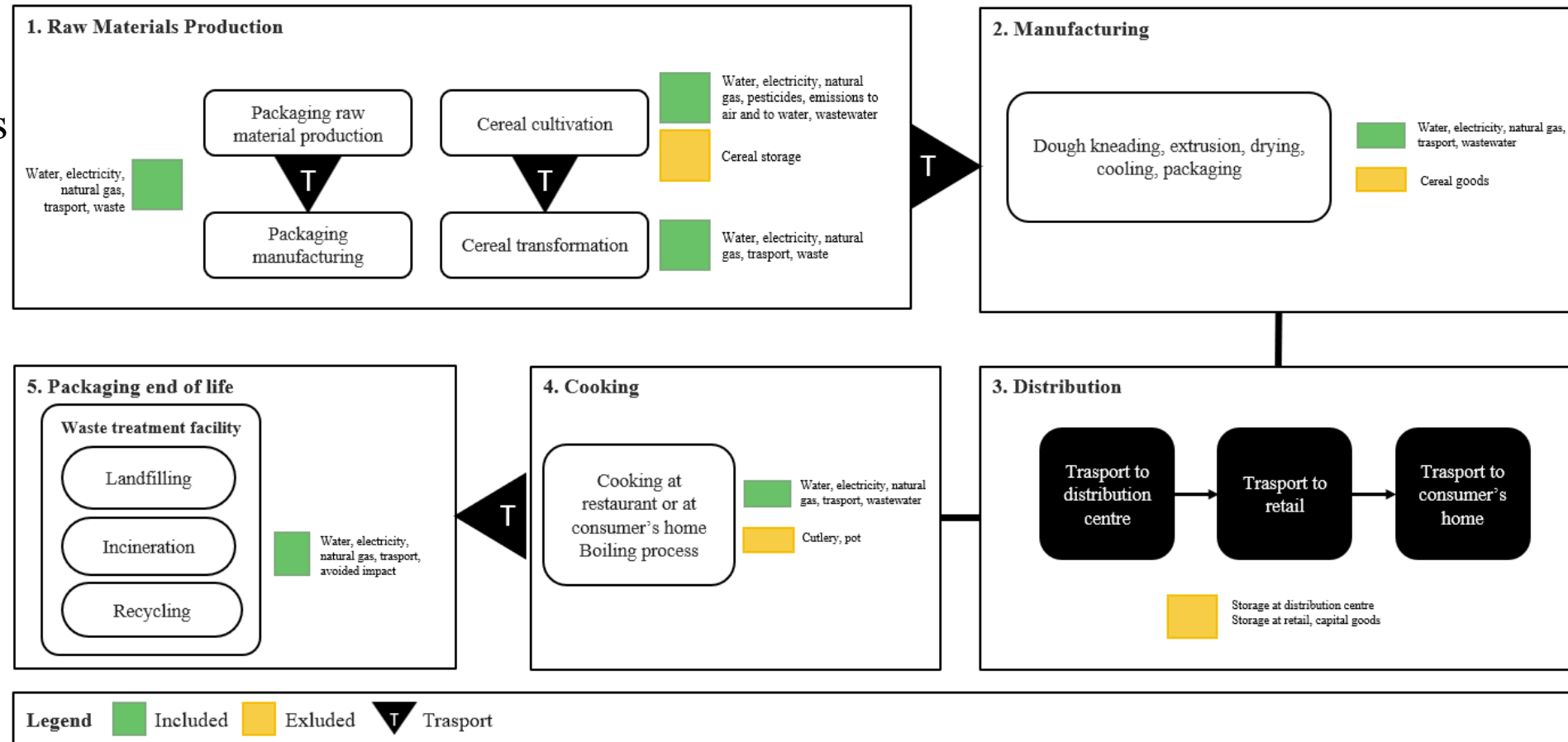


What?	Dry pasta, packaged, bought at the retail and cooked for the time suggested by the producer
How much?	1 kg of dry pasta.
How well?	<u>Not defined</u>
How long?	1 year

Scope of the study

1 Functional unit: 1 kg of durum wheat dry pasta ready to be cooked at home or at restaurant, packaging weight is not included.

2 System boundaries



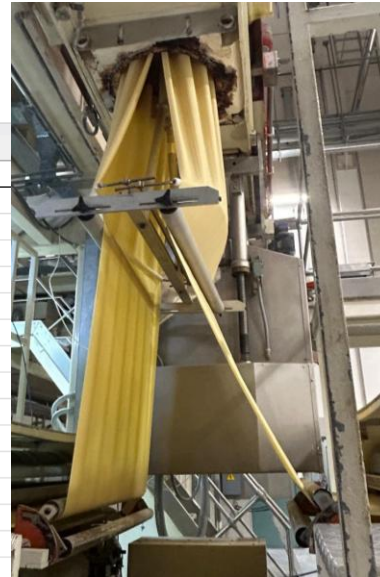


CONTEXT AND MOTIVATION OF THE STUDY
OBJECTIVES OF THE STUDY
METHODS
RESULTS
CONCLUSIONS

METHOD
GOAL AND SCOPE DEFINITION
INVENTORY ANALYSIS
IMPACT ASSESSMENT

Data collection

	A	B
1	GENERAL INFORMATION	
2	Reference year	2024
3	Pasta factory name	Pastificio Gallo
4	Contact person	Giuseppe Gilante
5	Total annual production (kg/year)	15.135.000
6	PRODUCT	
7	Product name	Penne Rigate n.59
8	Reference year	2024
9	Package weight (kg)	1
10	Number of packages/year	912.200
11	Durum wheat semolina purchased (kg/year)	15.932.000
12	Semolina for this product (kg/year)	960.235.90
13	Other ingredients	NO
14	Total pasta production (kg/year)	15.135.000
15	Pasta waste (kg/year)	19.600
16	PASTA FACTORY	
17	Packaging waste (kg/year)	5.350
18	Semolina transport distance (km)	141–169 km (by tanker truck)
19	Durum wheat semolina (type - kg)	Sicilian durum wheat - 15.932.000
20	Water consumption (kg/year)	8.600.000
21	Lubricant oil (L/year)	525 (from Catania)
22	Electricity consumption (kWh/year)	2.670.000
23	Gas consumption (m3/year)	969.557
24	Wastewater produced (kg)	3.832.475
25	Pasta waste (kg)	19.600
26	Primary packaging	Polypropylene (PP) - SIRACUSA - 0.35 micron
27	Secondary packaging	Polyethylene (PE) – shrink film for 12 kg
28	Tertiary packaging	Polyethylene (PE) – stretch film for 42×12 kg
29	HOUSEHOLD	
30	Tap water (L)	10
31	Salt (kg)	0.1
32	Cooking time (min)	10

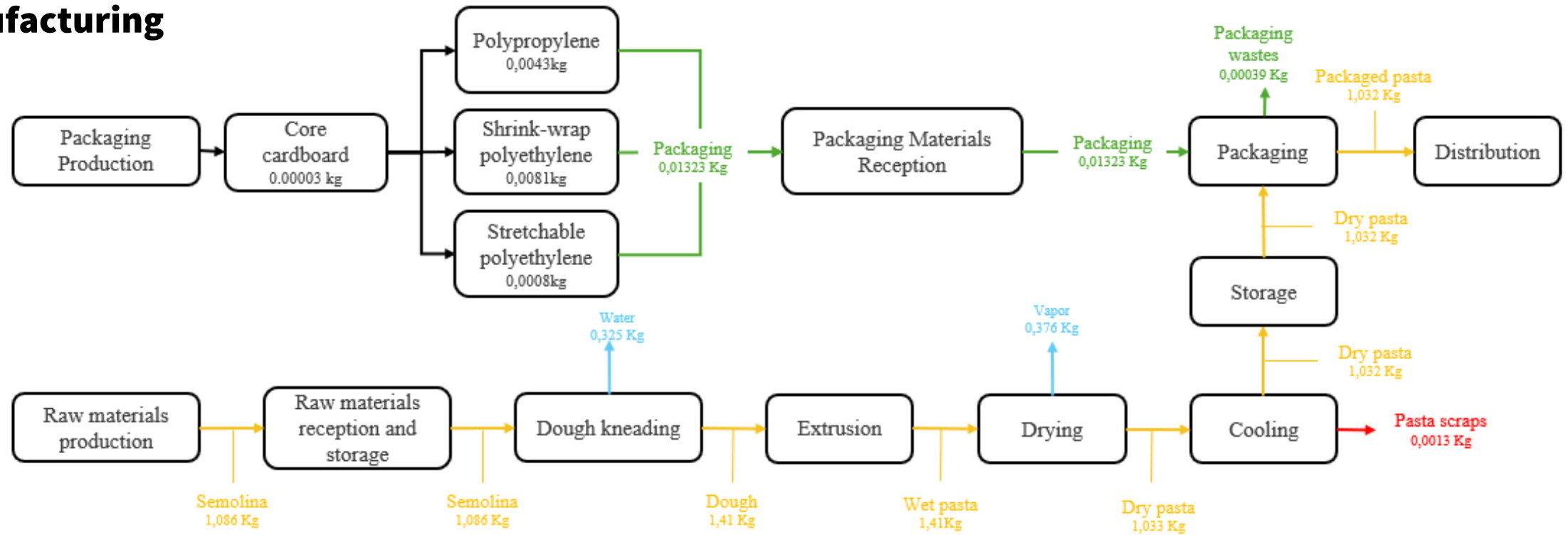


Questionario

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Manufacturing



Distribution



Product losses (1%)
9122 kg/year

4561 kg
50% Landfill

2280.5 kg
25% Methanization

2280.5 kg
25% Composting

9122 kg
50% Landfill

Use phase



Product losses (2%)
18.244 kg/year

4561 kg
25% Methanization

4561 kg
25% Composting

End of life of packaging



Plastic wastes
322.449 kg/year

125.755 kg
39% Landfill

103.181 kg
32% Incineration

93.51 kg
29% recycling



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A Life Cycle Impact Assessment (LCIA) was carried out to translate the inventory data into environmental impacts.

Characterized results

Impact categories	Units	Packaging production	Raw materials acquisition and pre-processing	Pasta manufacturing	Distribution	Use phase	End of life
Acidification	mol H+ eq	1.04E+02	4.87E+02	3.19E+01	3.18E+02	8.55E+01	-3.48E-01
Climate change	kg CO2 eq	4.14E+04	6.73E+04	2.49E+04	2.98E+04	7.10E+04	6.11E+02
Climate change - Biogenic	kg CO2 eq	8.60E+01	3.85E+02	2.63E+01	3.94E+02	1.55E+03	1.45E-01
Climate change - Fossil	kg CO2 eq	4.13E+04	6.16E+04	2.48E+04	2.93E+04	6.94E+04	6.11E+02
Climate change - Land use and LU change	kg CO2 eq	1.91E+01	5.32E+03	3.43E+00	3.74E+01	3.14E+01	7.40E-02
Ecotoxicity, freshwater - part 1	CTUe	7.75E+05	8.77E+06	1.96E+04	4.12E+05	6.85E+04	-4.69E+02
Ecotoxicity, freshwater - part 2	CTUe	4.51E+04	1.27E+07	1.36E+04	1.48E+04	1.51E+05	-1.57E+01
Ecotoxicity, freshwater - inorganics	CTUe	8.12E+05	2.70E+05	3.00E+04	4.15E+05	2.15E+05	-6.46E+02
Ecotoxicity, freshwater - organics - p.1	CTUe	5.90E+02	8.57E+06	2.73E+03	4.17E+02	1.08E+03	1.59E+02
Ecotoxicity, freshwater - organics - p.2	CTUe	6.93E+03	1.26E+07	4.80E+02	1.10E+04	3.62E+03	2.00E+00
Particulate matter	disease inc.	7.80E-04	1.04E-02	2.61E-04	3.36E-03	6.69E-04	-4.12E-06
Eutrophication, marine	kg N eq	2.52E+01	1.22E+03	7.93E+00	1.24E+02	2.91E+01	-1.14E-02
Eutrophication, freshwater	kg P eq	2.98E-01	2.68E+01	8.89E-01	1.33E-01	2.47E+00	3.46E-03
Eutrophication, terrestrial	mol N eq	2.62E+02	4.17E+03	8.44E+01	1.37E+03	2.36E+02	2.28E-01
Human toxicity, cancer	CTUh	1.95E-05	3.44E-05	1.48E-05	9.18E-06	1.56E-05	-5.33E-08
Human toxicity, cancer - inorganics	CTUh	1.42E-05	2.68E-05	9.98E-07	6.64E-06	7.06E-06	-1.92E-09
Human toxicity, cancer - organics	CTUh	5.36E-06	7.64E-06	1.38E-05	2.54E-06	8.57E-06	-5.13E-08
Human toxicity, non-cancer	CTUh	5.03E-04	5.39E-03	8.56E-05	1.19E-04	2.09E-04	3.82E-07
Human toxicity, non-cancer - inorganics	CTUh	4.93E-04	4.51E-03	7.92E-05	1.16E-04	1.94E-04	4.18E-07
Human toxicity, non-cancer - organics	CTUh	1.08E-05	8.77E-04	6.41E-06	3.30E-06	1.56E-05	-3.57E-08
Ionising radiation	kBq U-235 eq	4.25E+03	1.09E+03	5.26E+02	1.61E+02	2.73E+03	2.59E+00
Land use	Pt	5.48E+04	1.90E+07	8.80E+03	6.26E+04	4.63E+04	5.23E+02
Ozone depletion	kg CFC11 eq	3.71E-06	1.66E-04	9.46E-05	2.05E-08	1.92E-05	2.28E-08
Photochemical ozone formation	kg NMVOC eq	1.01E+02	2.48E+02	2.79E+01	2.65E+02	7.58E+01	-1.66E-01
Resource use, fossils	MJ	1.54E+06	5.21E+05	3.76E+05	3.97E+05	1.07E+06	-5.64E+03
Resource use, minerals and metals	kg Sb eq	6.97E-03	1.73E-02	9.71E-02	5.37E-02	5.87E-02	-1.43E-04
Water use	m3 depriv.	4.35E+03	7.35E+04	1.72E+03	2.00E+03	1.39E+04	4.71E+01

Normalized results

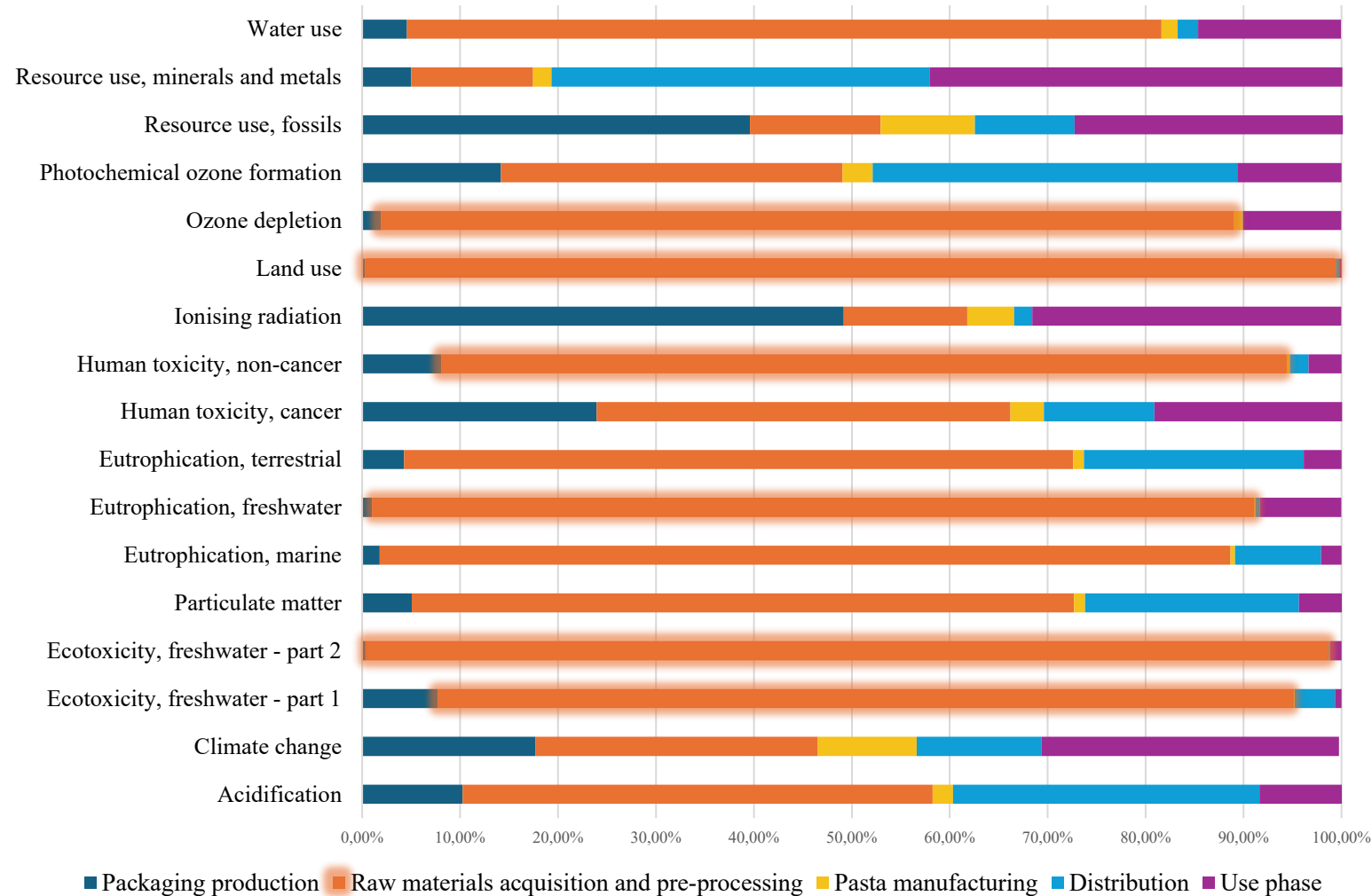
Impact categories	Normalization factors EF 3.1	Normalized result EF 3.1
Acidification	1.80E-02	1.85E-04
Climate change	1.32E-04	3.11E-01
Ecotoxicity, freshwater - part 1	1.76E-05	1.77E+01
Ecotoxicity, freshwater - part 2	1.76E-05	2.27E+00
Particulate matter	1.68E+03	2.59E-01
Eutrophication, marine	5.12E-02	7.21E-01
Eutrophication, freshwater	6.22E-01	1.90E-01
Eutrophication, terrestrial	5.66E-03	3.46E-01
Human toxicity, cancer	5.80E+04	5.42E-02
Human toxicity, non-cancer	7.77E+03	4.90E-01
Ionising radiation	2.37E-04	2.08E-02
Land use	1.22E-06	2.34E-01
Ozone depletion	1.91E+01	5.41E-05
Photochemical ozone formation	2.45E-02	1.76E-01
Resource use, fossils	1,54E-02	6.00E-01
Resource use, minerals and metals	15.718	3.68E-02
Water use	8,72E-02	8.33E-02

Weighting results

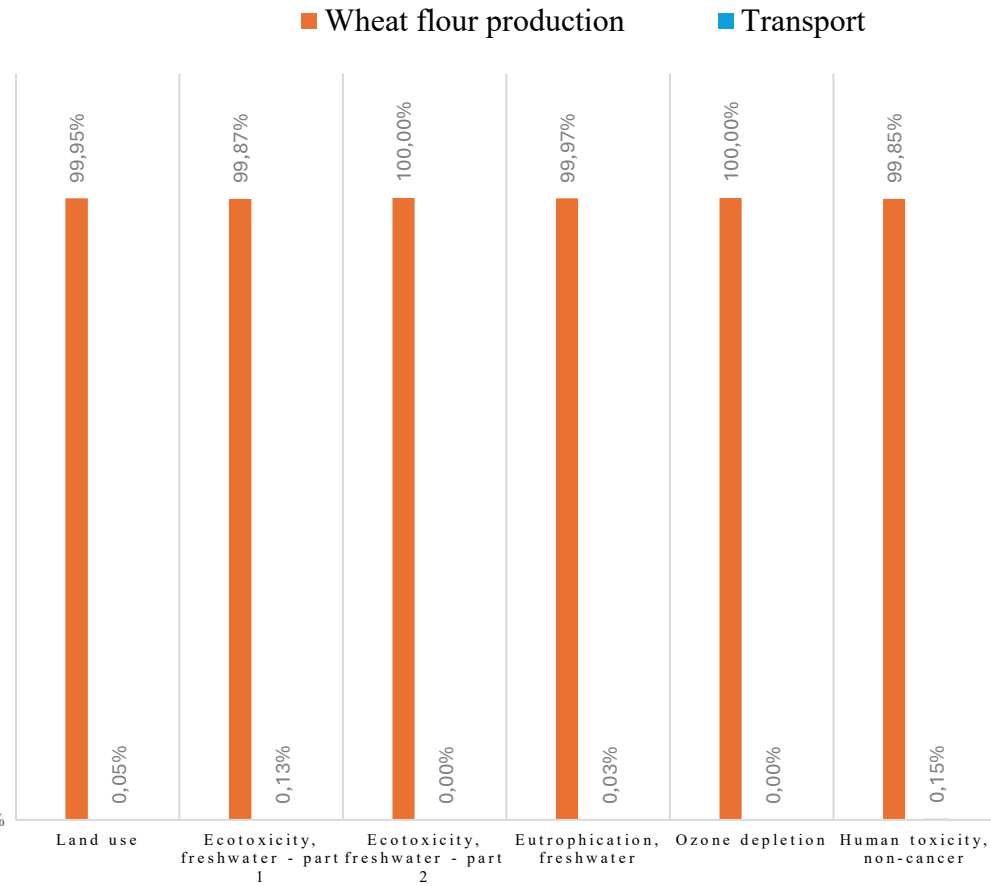
Impact categories	Unit	Weighting factors	Weighting results
Total	Pt		2.36E+00
Acidification	Pt	6.20E-02	1.20E-01
Climate change	Pt	2.11E-01	3.80E-01
Ecotoxicity, freshwater part 1	Pt	1.92E-02	0.00E+00
Ecotoxicity, freshwater part 2	Pt	1.92E-02	6.00E-02
Particulate matter	Pt	8.96E-02	1.40E-01
Eutrophication, marine	Pt	2.96E-02	2.00E-02
Eutrophication, freshwater	Pt	2.80E-02	1.50E-01
Eutrophication, terrestrial	Pt	3.71E-02	3.00E-02
Human toxicity, cancer	Pt	2.13E-02	1.50E-01
Human toxicity, non-cancer	Pt	1.84E-02	9.00E-02
Ionising radiation	Pt	5.01E-02	1.00E-02
Land use	Pt	7.94E-02	1.00E-02
Ozone depletion	Pt	6.31E-02	0.00E+00
Photochemical ozone formation	Pt	4.78E-02	7.00E-02
Resource use, fossils	Pt	8.32E-02	0.00E+00
Resource use, minerals and metals	Pt	7.55E-02	1.12E+00
Water use	Pt	8.51E-02	1.00E-02



Dominance analysis

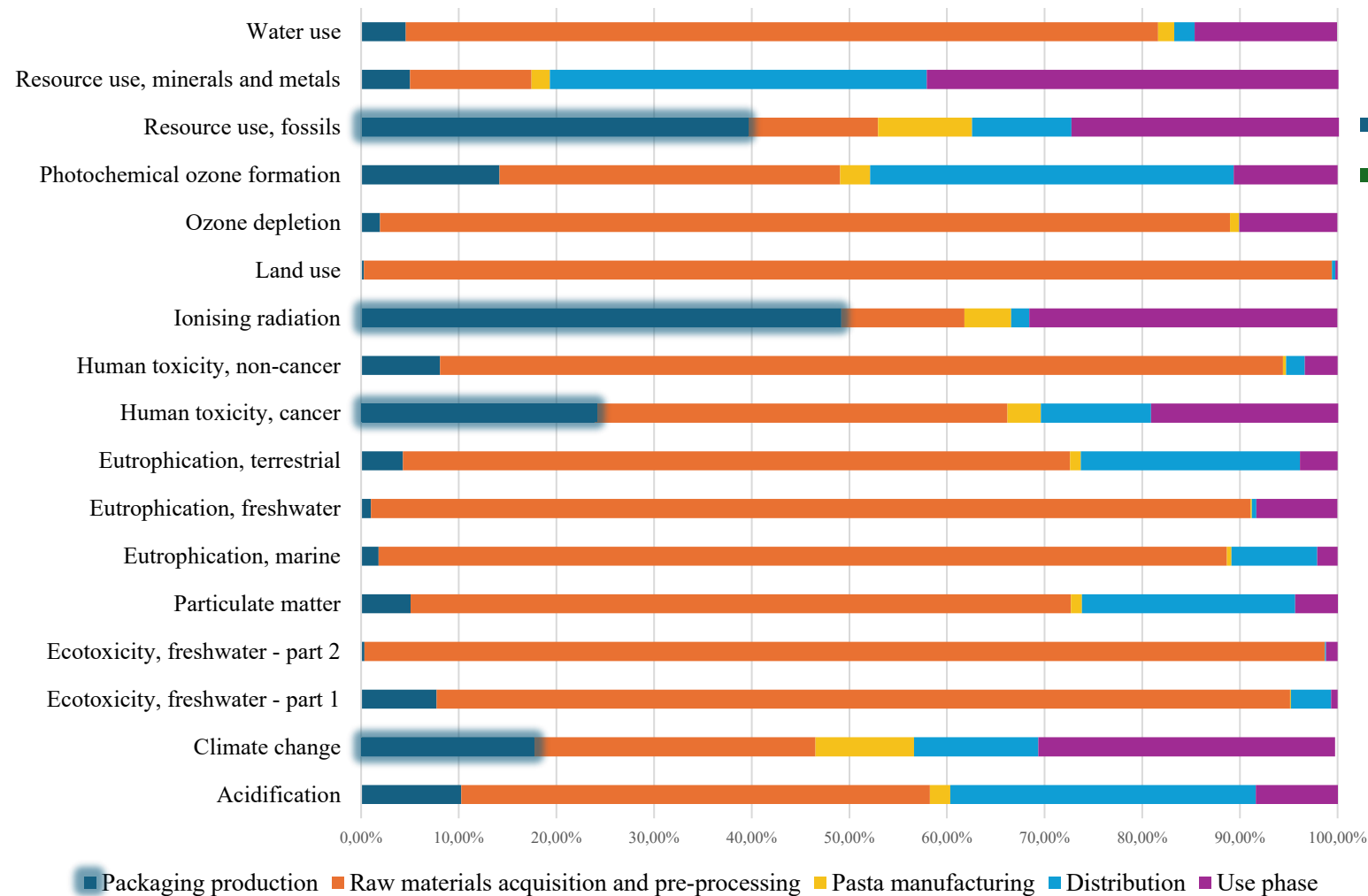


Contribution of raw material acquisition subprocesses to environmental impact categories



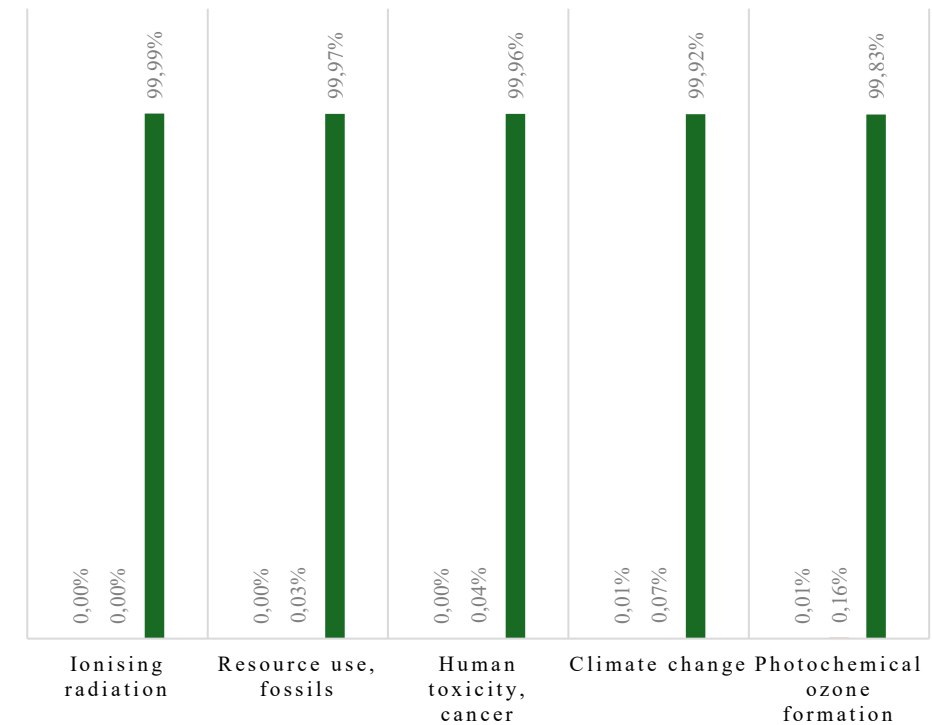


Dominance analysis



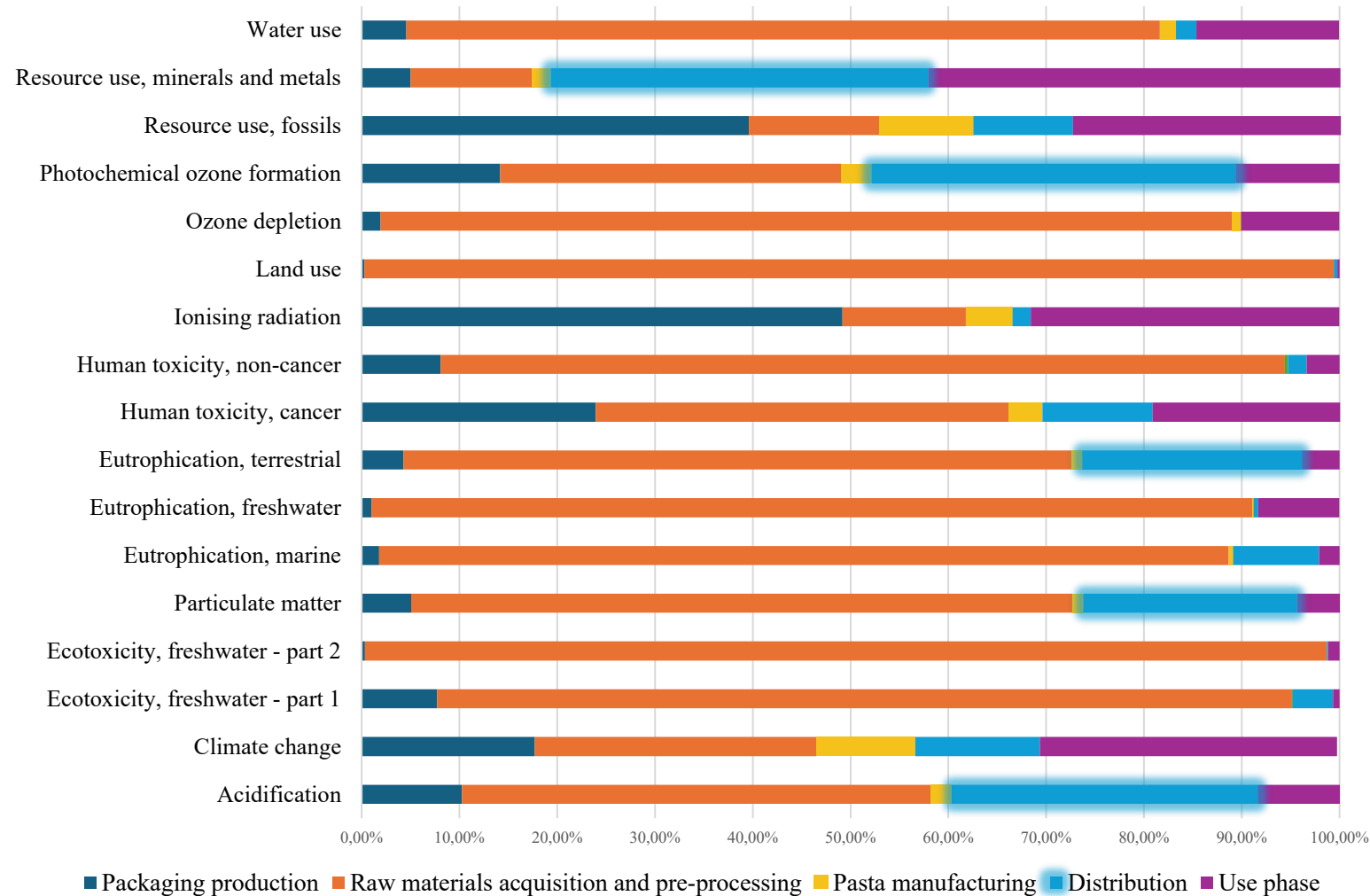
Contribution of packaging production subprocesses to environmental impact categories

■ Carboard production and processing ■ Transport of packaging materials
■ Plastic production and processing

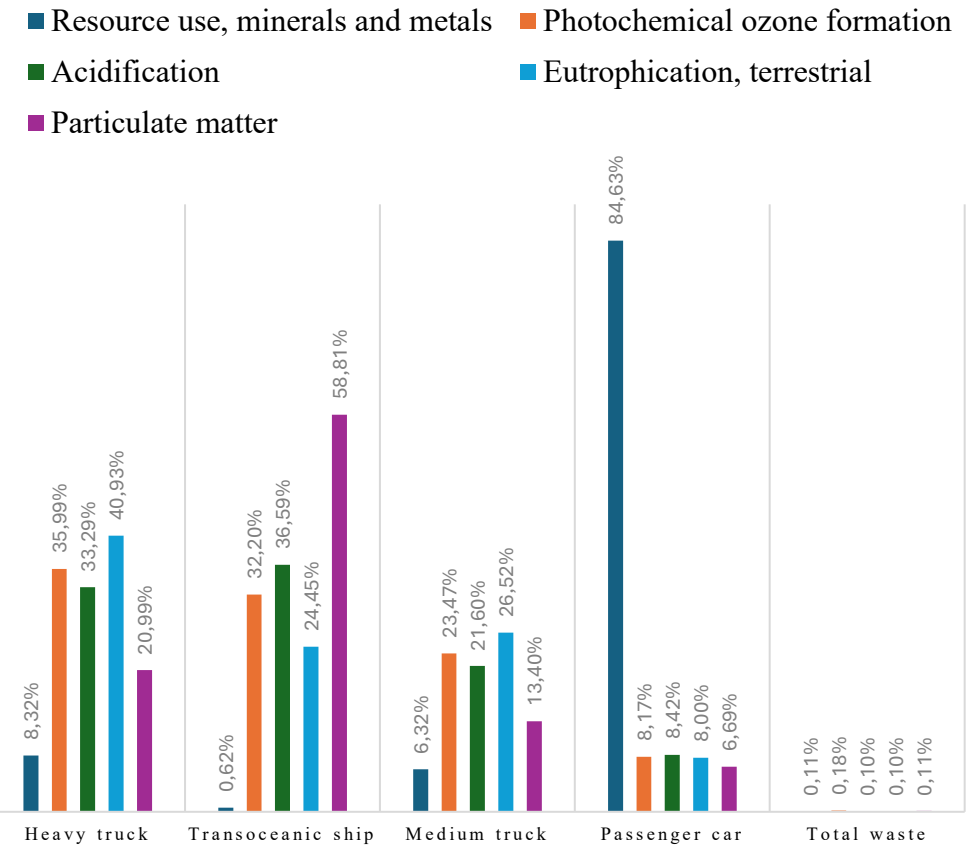




Dominance analysis

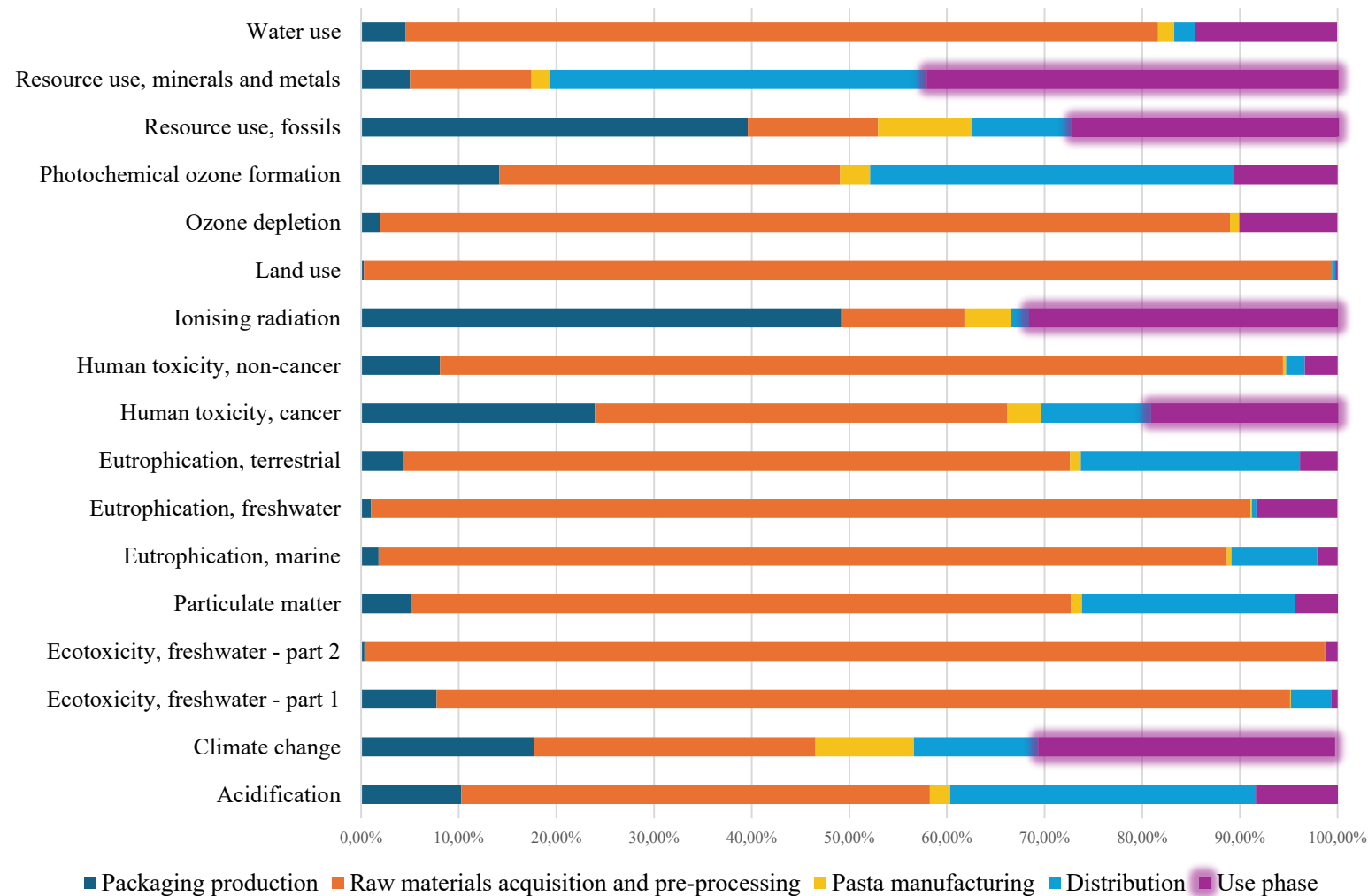


Contribution of distribution subprocesses to environmental impact categories

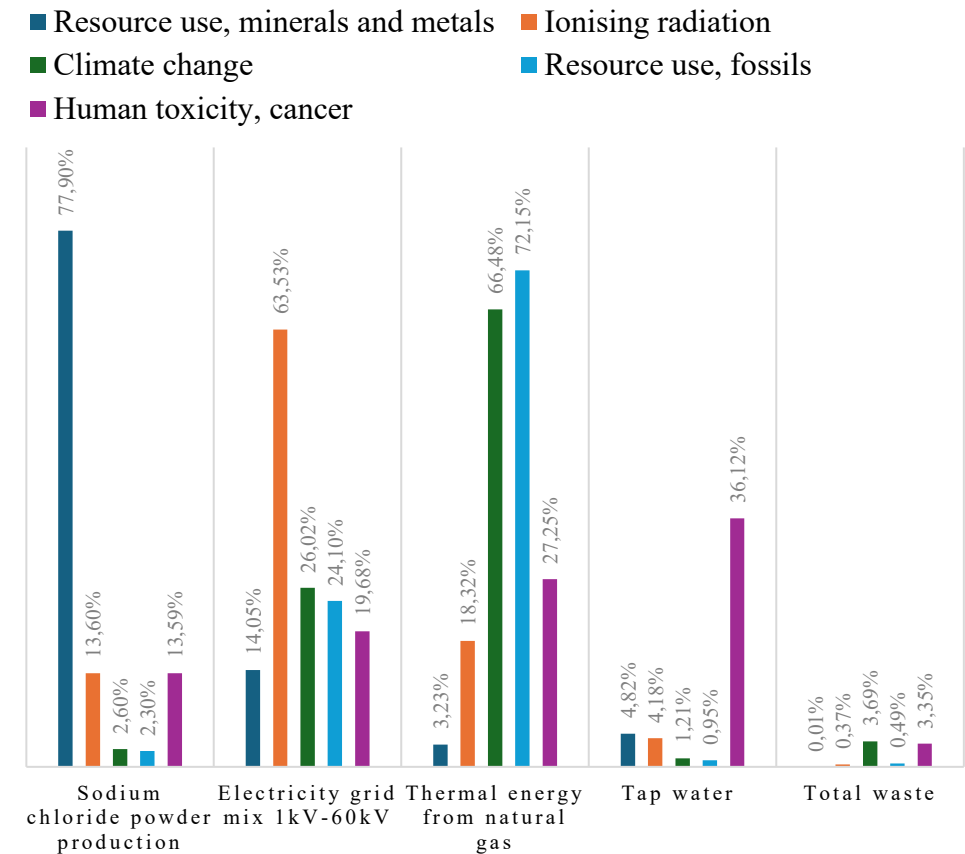




Dominance analysis



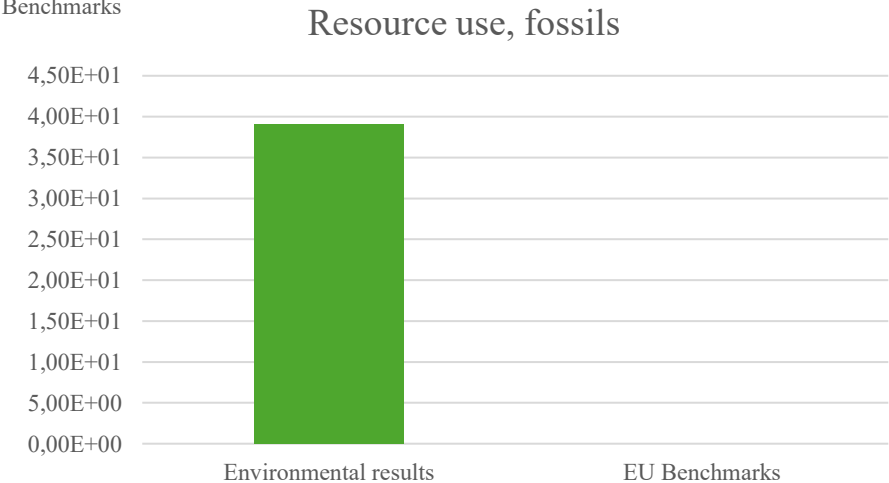
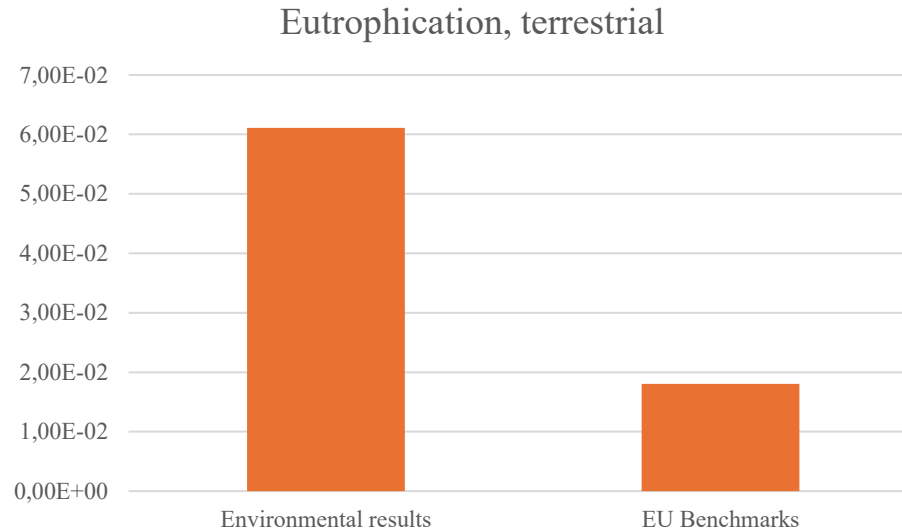
Contribution of use phase subprocesses to environmental impact categories





A comparison was then carried out using the **European benchmarks provided by the EF 3.1 database**, to assess the environmental performance of the product within a broader EU context

Impact categories	Unit	Environmental results	EU Benchmarks	Relative difference
Climate change	kg CO2 eq	2.33E+00	2.92E+00	-20.07%
Ozone depletion	kg CFC11 eq	1.91E-09	6.27E-08	-96.96%
Particulate matter	disease inc.	1.54E-07	3.38E-07	-54.62%
Ionising radiation	kBq U-235 eq	8.65E-02	2.66E-01	-67.45%
Photochemical ozone formation	kg NMVOCeq	7.12E-03	8.25E+00	-99.91%
Acidification	mol H+ eq	1.02E-02	4.59E-02	-77.85%
Eutrophication. marine	kg N eq	1.41E-02	1.93E-01	-92.70%
Eutrophication. freshwater	kg P eq	2.97E-04	4.76E-04	-37.56%
Eutrophication. terrestrial	mol N eq	0.06107272	0.018034	238.65%
Land use	Pt	1.92E+02	6.41E+02	-70.01%
Water use	m3 depriv.	9.53E-01	1.34E+00	-28.98%
Resource use. fossils	MJ	3.90E+01	6.38E-06	611800554.25%
Resource use. minerals and metals	kg Sb eq	1.39E-06	3.60E+01	-100.00%





Hotspots



Raw material acquisition and preprocessing → wheat flour production and milling



Domestic use → electricity used for the cooking of pasta



Distribution → heavy and medium truck, transoceanic ship, consumer's car



Packaging → production – end-of-life not relevant (recycling)

Recommendations

Adopt local, high-yield cultivars and sustainable farming practices to reduce inputs, land use, and resource depletion.

Raise consumer awareness on energy-efficient cooking practices

Re-design logistics through delivery aggregation and digital tools to reduce transport impacts.

Support eco-design in packaging by promoting biodegradable, recyclable, and lightweight materials.



Methodological barriers

Lack of data monitoring systems in SMEs, leading to gaps and assumption-based estimates.

Technical complexity in applying PEF rules within small production contexts



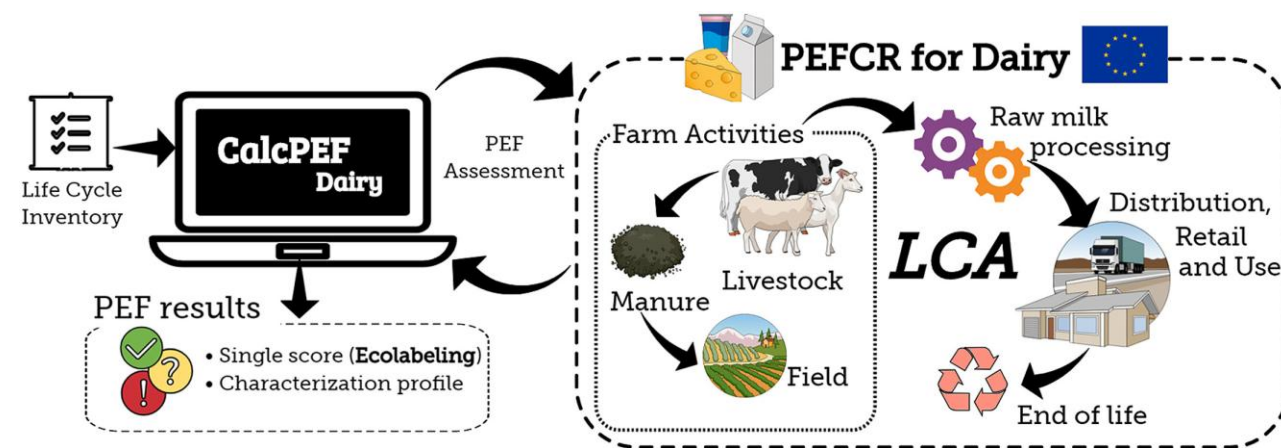
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Proposed solutions

User-friendly modelling tools with standardized flows and datasets
Improved technical support networks, including training courses





The case study confirmed the potential of the PEF methodology, but also its current challenges for SMEs: unrepresentative secondary data, poorly accessible measurements and some methodological inconsistencies.

Simpler tools, localized databases and support from universities and institutions are needed to make sustainability truly operational in the local production system.

Acknowledgements

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**Thank you for your
kind attention**

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