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Technical Assistance for Assessment of Türkiye's Potential on Transition to Circular Economy

EuropeAid/140562/IH/SER/TR

Workshop on Roadmap for Single Use Plastics and Marine Litter

Life Cycle Analysis (LCA) for Plastics

Dr. Özge Yılmaz

6-8 Mart 2024 – Dedeman Otel Bostancı, İstanbul

TÜRKİYE CUMHURİYETİ ÇEVRE, ŞEHİRCİLİK VE İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

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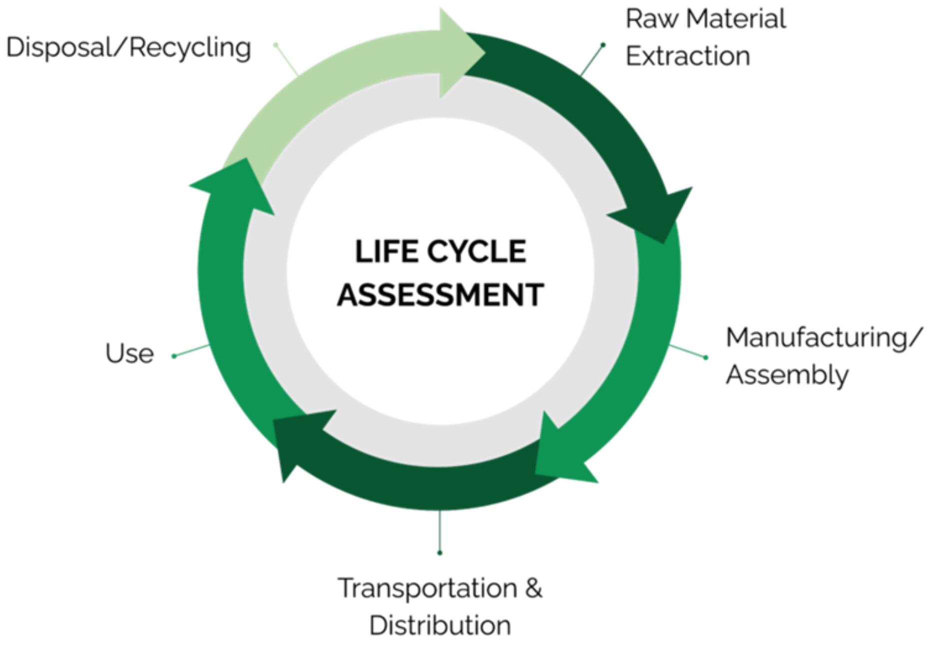
Life Cycle Assessment

The inputs and outputs of a product system throughout its life cycle and the compilation and assessment of potential environmental impacts

LCA helps us to understand the impact of a product or service on available resources and pollution in a holistic way. In this way, it can be assessed whether products and services are truly sustainable.



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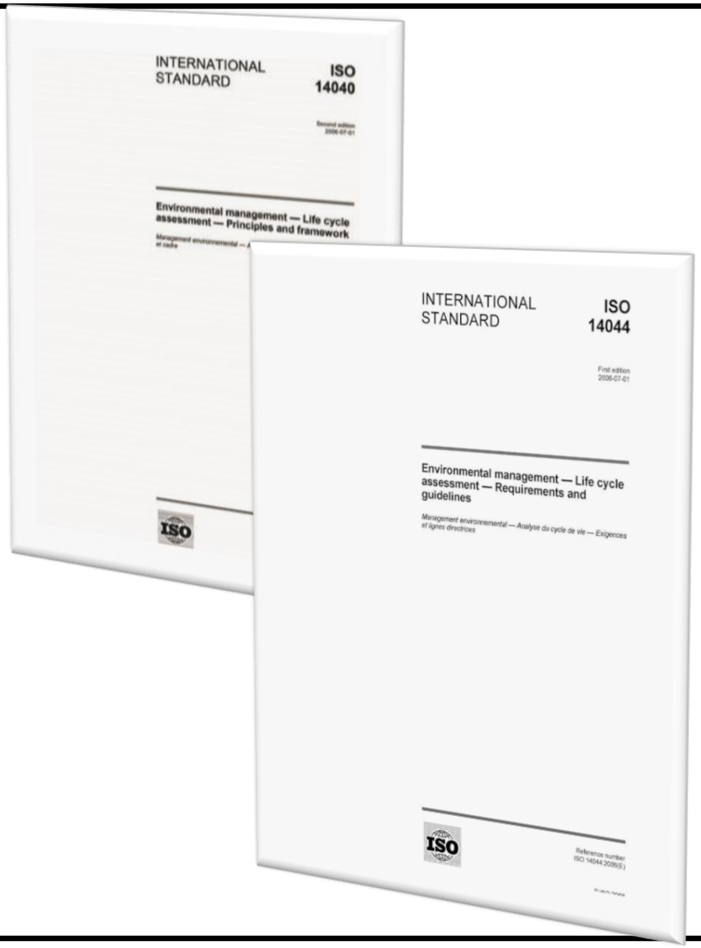
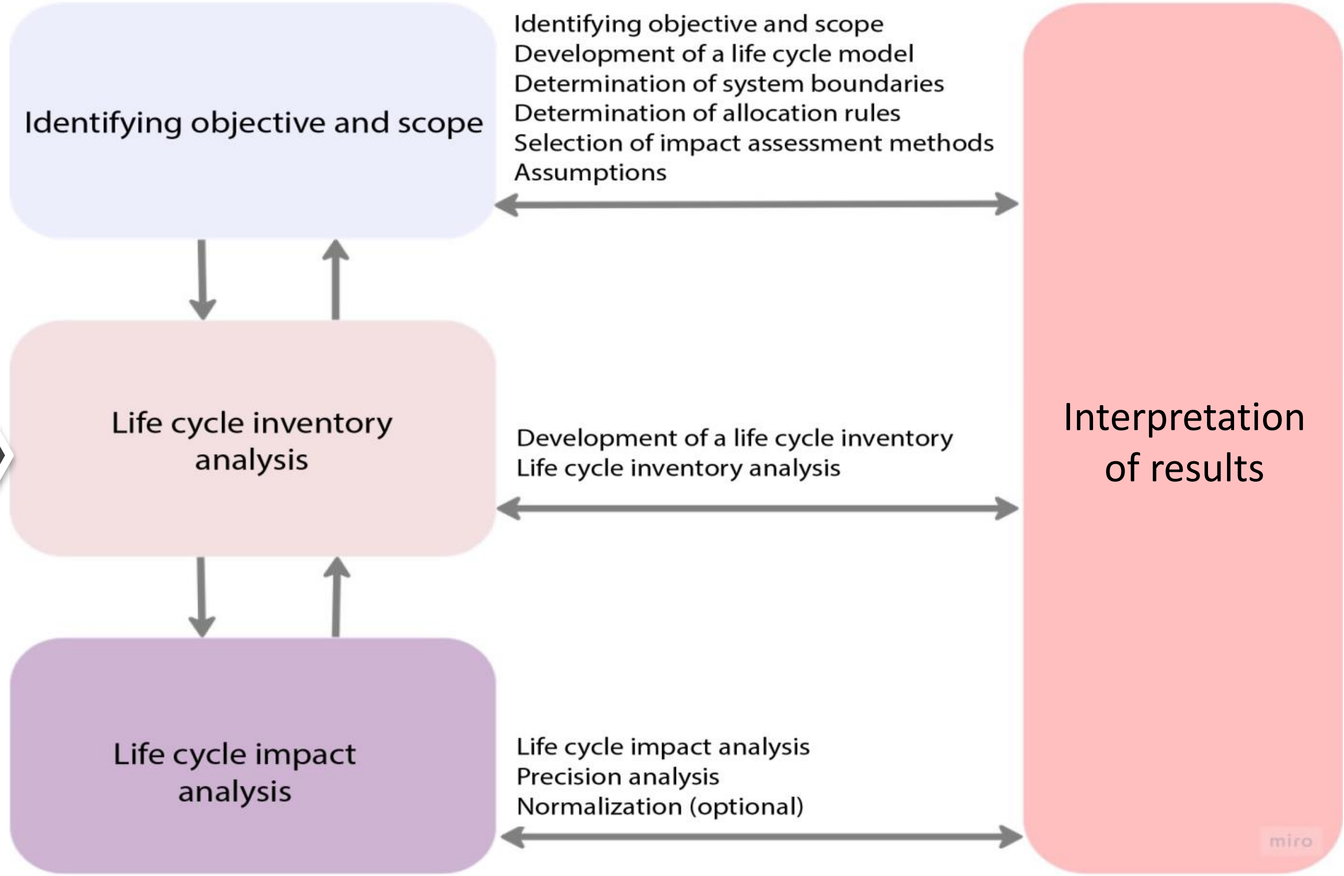


LCA METHODOLOGY



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DEEP Project Plastics Life Cycle Analysis

The purpose of the LCA for plastics is to demonstrate the comparative environmental impacts of **10 selected single-use plastic products and their non-single-use plastic (SUNP) and reusable (MU) alternatives** from **cradle to grave**, starting from raw material procurement, production, shipment, use and end-of-life management.

The findings of this study will examine the environmental impacts of single-use plastics and reveal the extent of negative impacts in categories such as **human health, ecosystem quality and resource consumption**.

The results of the LCA are intended to provide input to the ongoing regulatory impact analysis for the Single Use Plastics Directive.

No	Single-use plastics	Raw material	Alternative products
1	**Cotton Bud Sticks**	Polypropylene	SUNP: Kraft Paper
2	**Cutlery (fork, knife, spoon)**	Polypropylene	SUNP: Wood MU: Steel
3	**Straw**	Polypropylene	SUNP: Paper MU: Glass
4	**Take away food containers**	Expanded polystyrene	SUNP: Paper + PE film composite SUNP: Cardboard
5	**Hot beverage containers (0.35 L)**	Expanded polystyrene	SUNP: Paper + PE film composite MU: Glass
6	**Beverage bottles (1L)**	Polythene (HDPE)	SUNP: Glass MU: Steel (thermos)
7	**Cigarette filters**	Cellulose acetate	SUNP: Cotton + Hemp
8	**Plastic carrier bags (40 cm x 45 cm)**	Polythene (HDPE)	SUNP: Kraft paper MU: Textile
9	**Packages and wrappers**	Polypropylene(LDPE)	SUNP: Paper + PE film composite
10	**Hygiene products**	Cellulose, polythene, ACN	MU: Textile

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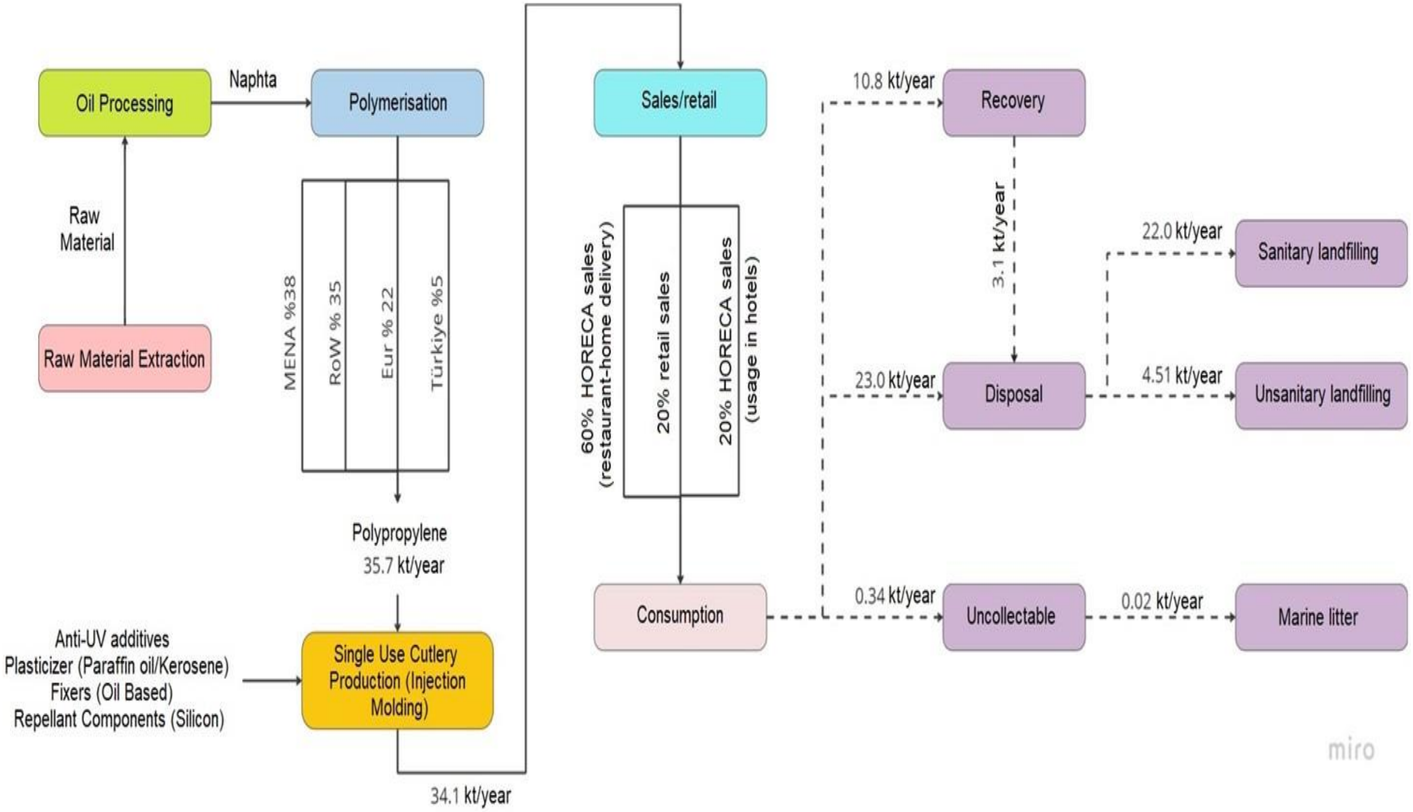
System models and LCA system boundaries

National-scale models representing the substitution of SUPs with SUNPs and MUs at various rates in the market have been established.

Product	Substitution Rate	
	SUNP	MU
Cotton Bud Sticks	100%	--
Cutlery (fork, knife, spoon)	50%	50%
Straw	50%	50%
Take away food containers	50%	50%
Hot beverage containers (0.35 L)	90%	10%
Beverage bottles (1L)	60%	40%
Cigarette filters	100%	--
Plastic carrier bags (40 cm x 45 cm)	50%	50%
Packages and wrappers	100%	--
Hygiene products	--	100%



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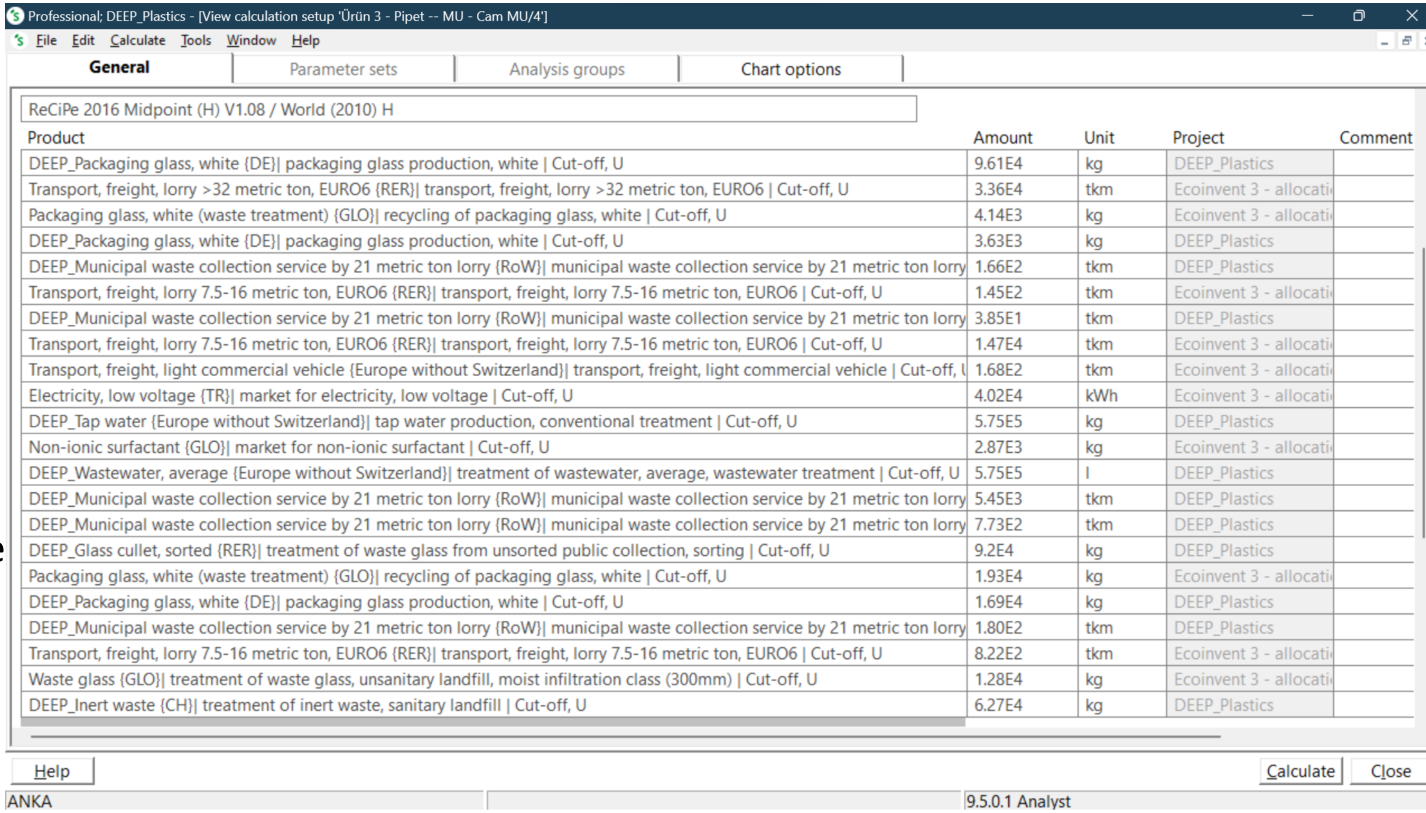
Data processing and analyses

SimaPro 9.5 software and Ecoinvent 3.9.1 database were used.

Processes with geographical and technological representation were selected from the database.

Since country-specific processes are not generally available in the databases, the flows of the processes were analysed and data modifications were made to increase national representation. On half of the nearly 100 ecoinvent processes used for 12 different material types, data modification was made and flows that did not fit Turkish conditions were modified.

ReCiPe 2016 (H) 1.08 method, which can provide both midpoint and endpoint results, was selected for life cycle impact analysis.



Product	Amount	Unit	Project	Comment
DEEP_Packaging glass, white {DE}| packaging glass production, white | Cut-off, U	9.61E4	kg	DEEP_Plastics	
Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, U	3.36E4	tkm	Ecoinvent 3 - allocati	
Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Cut-off, U	4.14E3	kg	Ecoinvent 3 - allocati	
DEEP_Packaging glass, white {DE}| packaging glass production, white | Cut-off, U	3.63E3	kg	DEEP_Plastics	
DEEP_Municipal waste collection service by 21 metric ton lorry {RoW}| municipal waste collection service by 21 metric ton lorry	1.66E2	tkm	DEEP_Plastics	
Transport, freight, lorry 7.5-16 metric ton, EURO6 {RER}| transport, freight, lorry 7.5-16 metric ton, EURO6 | Cut-off, U	1.45E2	tkm	Ecoinvent 3 - allocati	
DEEP_Municipal waste collection service by 21 metric ton lorry {RoW}| municipal waste collection service by 21 metric ton lorry	3.85E1	tkm	DEEP_Plastics	
Transport, freight, lorry 7.5-16 metric ton, EURO6 {RER}| transport, freight, lorry 7.5-16 metric ton, EURO6 | Cut-off, U	1.47E4	tkm	Ecoinvent 3 - allocati	
Transport, freight, light commercial vehicle {Europe without Switzerland}| transport, freight, light commercial vehicle | Cut-off, U	1.68E2	tkm	Ecoinvent 3 - allocati	
Electricity, low voltage {TR}| market for electricity, low voltage | Cut-off, U	4.02E4	kWh	Ecoinvent 3 - allocati	
DEEP_Tap water {Europe without Switzerland}| tap water production, conventional treatment | Cut-off, U	5.75E5	kg	DEEP_Plastics	
Non-ionic surfactant {GLO}| market for non-ionic surfactant | Cut-off, U	2.87E3	kg	Ecoinvent 3 - allocati	
DEEP_Wastewater, average {Europe without Switzerland}| treatment of wastewater, average, wastewater treatment | Cut-off, U	5.75E5	l	DEEP_Plastics	
DEEP_Municipal waste collection service by 21 metric ton lorry {RoW}| municipal waste collection service by 21 metric ton lorry	5.45E3	tkm	DEEP_Plastics	
DEEP_Municipal waste collection service by 21 metric ton lorry {RoW}| municipal waste collection service by 21 metric ton lorry	7.73E2	tkm	DEEP_Plastics	
DEEP_Glass cullet, sorted {RER}| treatment of waste glass from unsorted public collection, sorting | Cut-off, U	9.2E4	kg	DEEP_Plastics	
Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Cut-off, U	1.93E4	kg	Ecoinvent 3 - allocati	
DEEP_Packaging glass, white {DE}| packaging glass production, white | Cut-off, U	1.69E4	kg	DEEP_Plastics	
DEEP_Municipal waste collection service by 21 metric ton lorry {RoW}| municipal waste collection service by 21 metric ton lorry	1.80E2	tkm	DEEP_Plastics	
Transport, freight, lorry 7.5-16 metric ton, EURO6 {RER}| transport, freight, lorry 7.5-16 metric ton, EURO6 | Cut-off, U	8.22E2	tkm	Ecoinvent 3 - allocati	
Waste glass {GLO}| treatment of waste glass, unsanitary landfill, moist infiltration class (300mm) | Cut-off, U	1.28E4	kg	Ecoinvent 3 - allocati	
DEEP_Inert waste {CH}| treatment of inert waste, sanitary landfill | Cut-off, U	6.27E4	kg	DEEP_Plastics	

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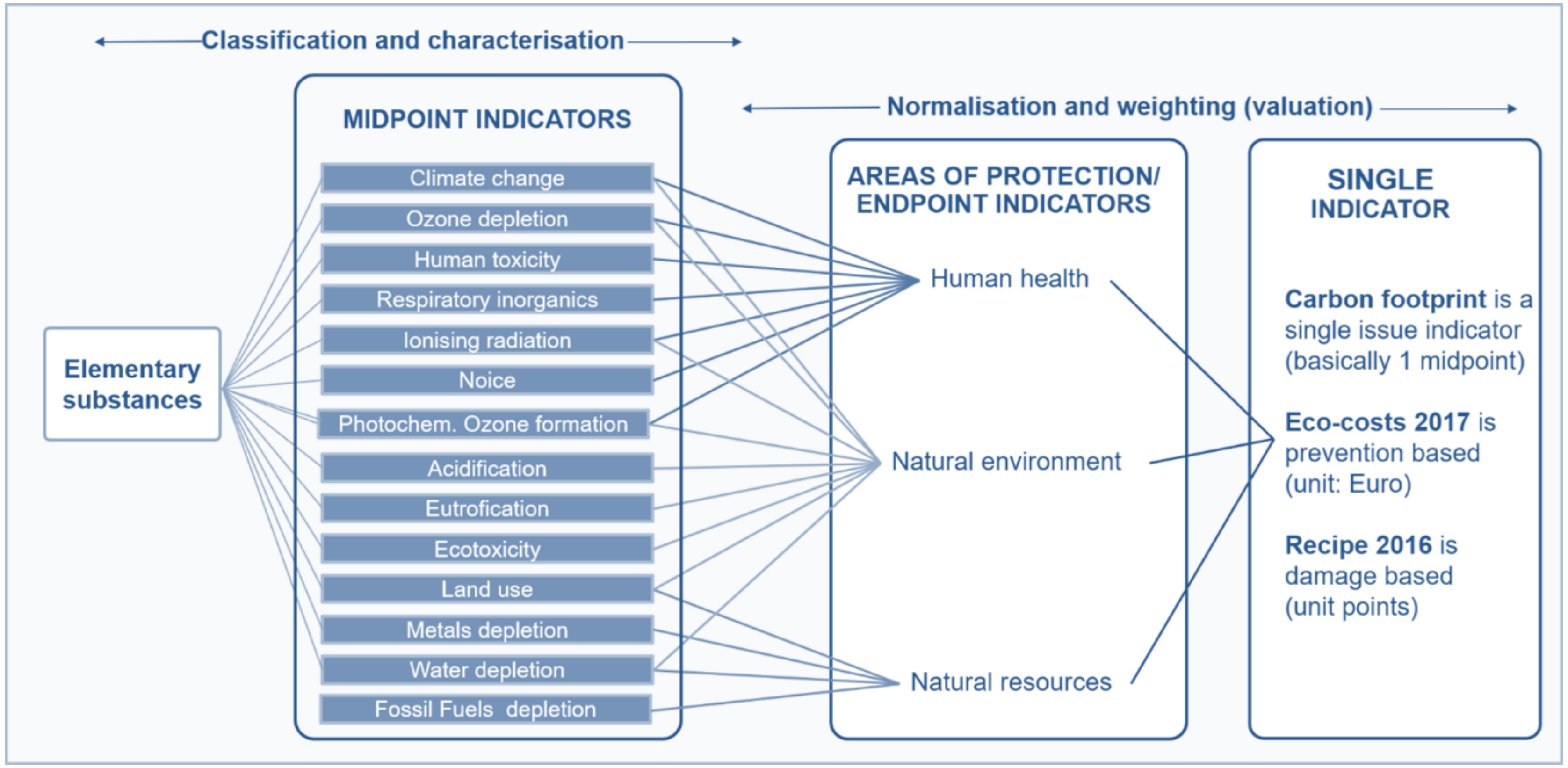
Data processing and analyses

Results were analysed at midpoint and endpoint indicator level.

In addition, single scores results were also analysed.



LCA results - Midpoint indicator results

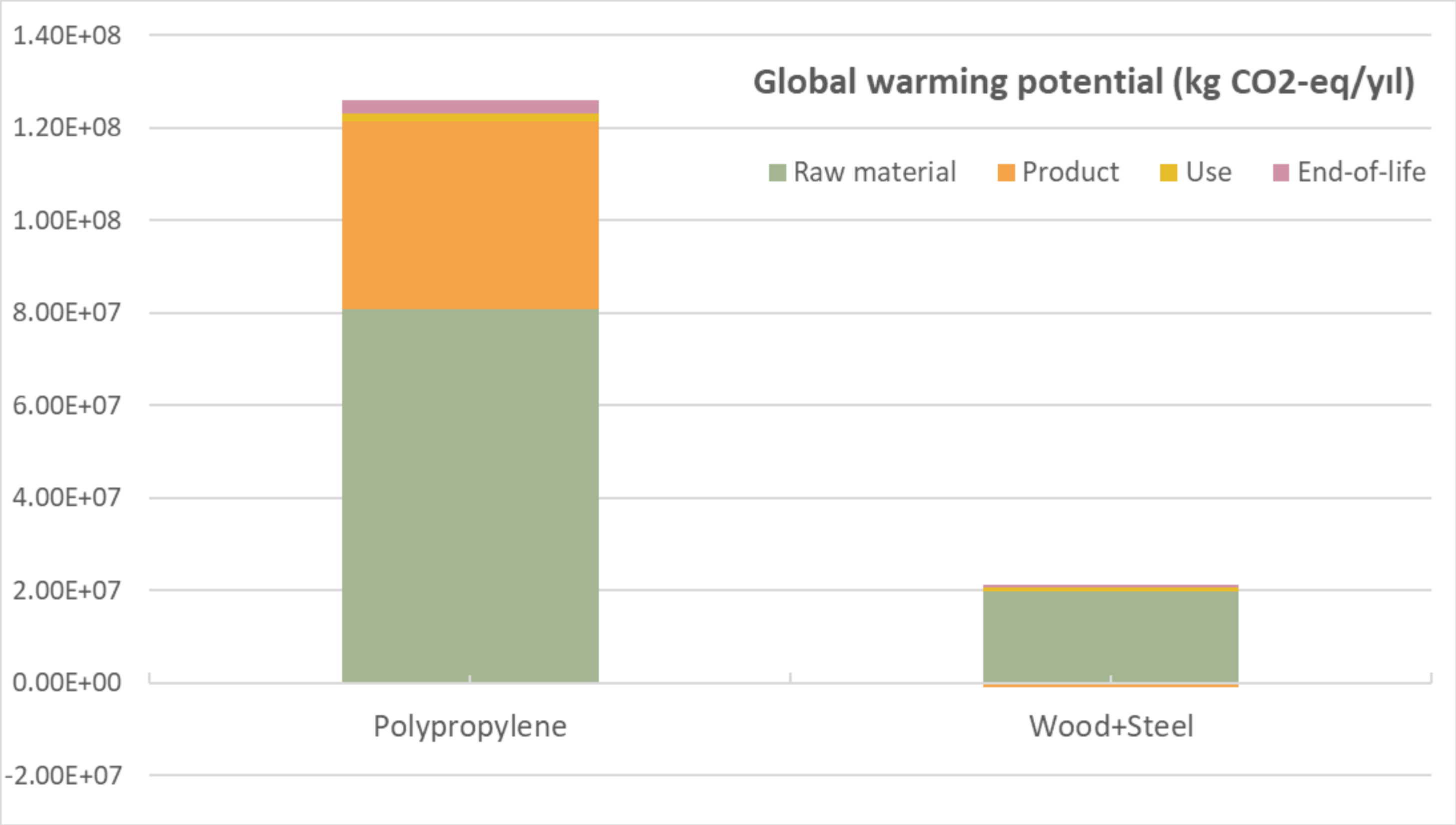
Example: Cutlery (Fork-knife-spoon)

SUP: PP

SUNP: Wood (%50 Substitute) + MU: Steel (%50 substitute)

The results presented represent a wide range of products such as plastic forks, knives, spoons and mixers.

Substitution of single-use plastics resulted in an 85% reduction in global warming potential.



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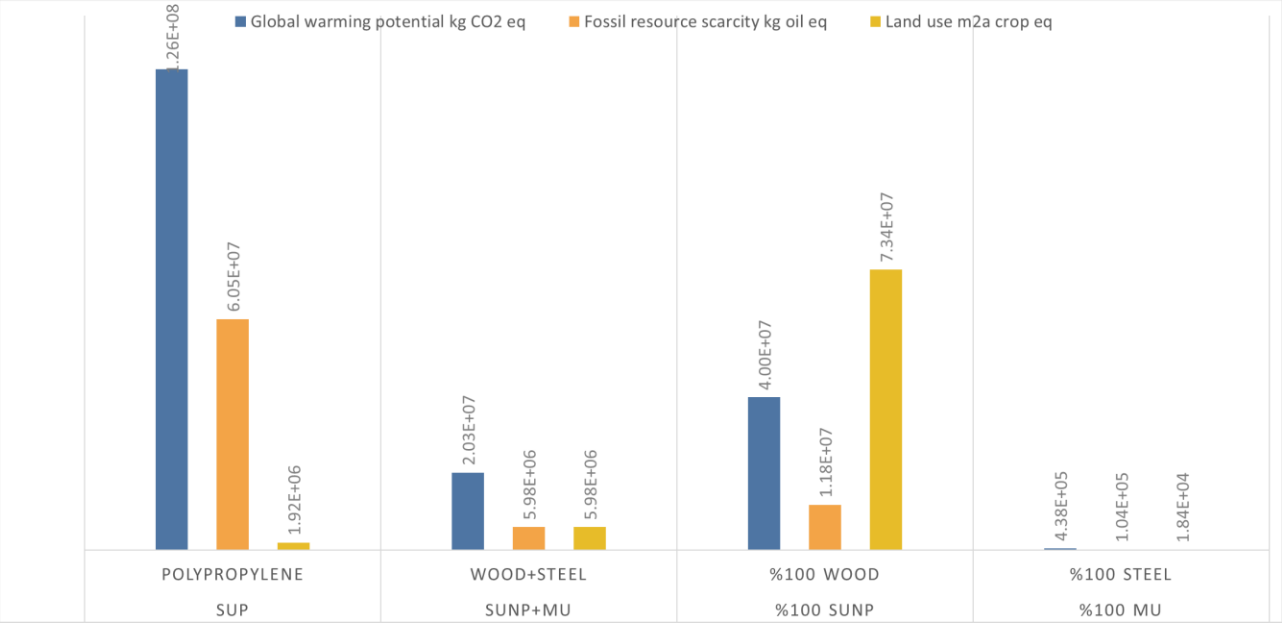
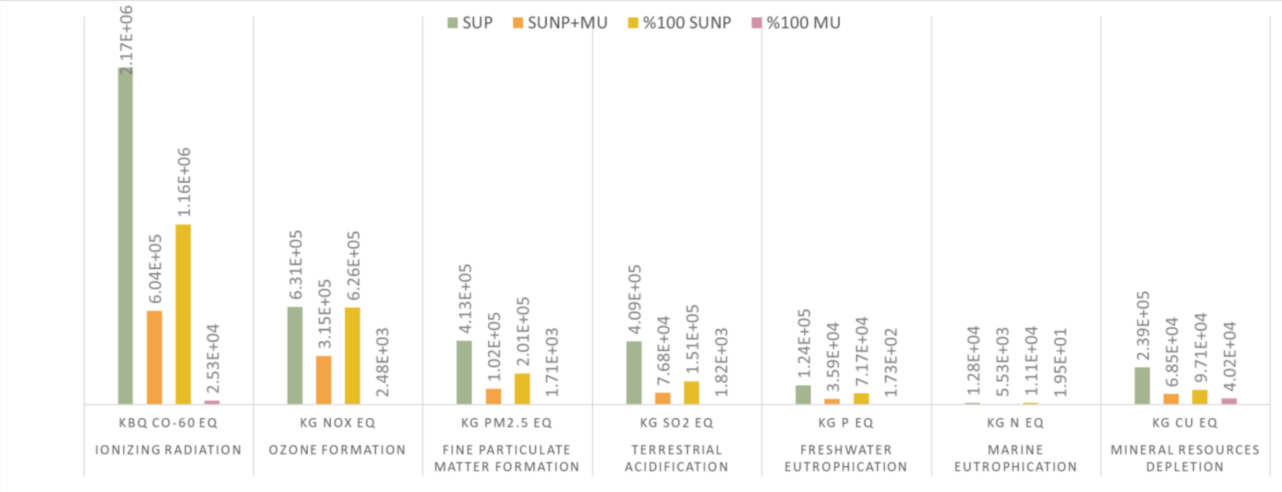
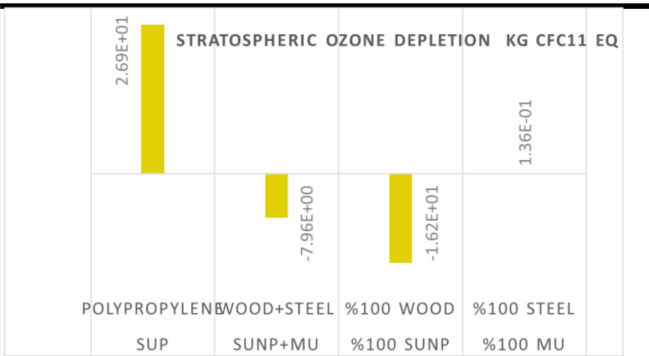
The substitution of single-use plastic products with reusable alternatives create reduction in several life cycle environmental impacts.

However, in the scenario where only single-use wood products are used, environmental trade-offs are observed in indicators such as land use and water consumption.







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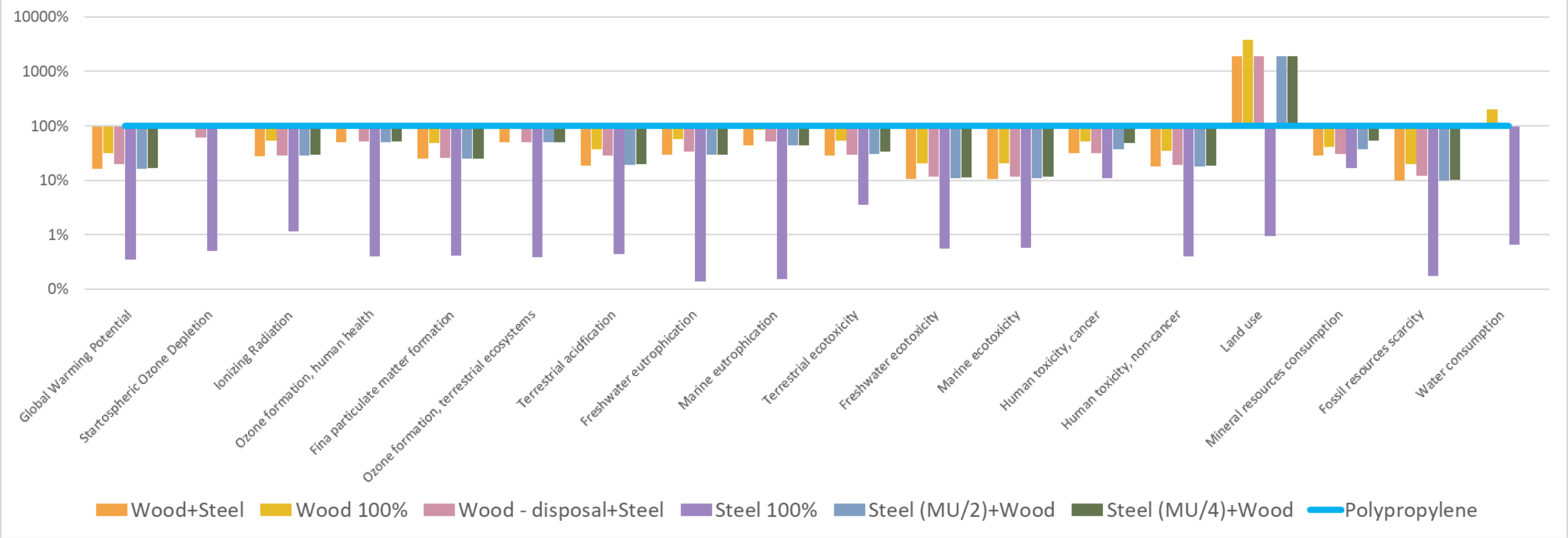
As a result of the sensitivity analysis, even in cases where the wood is not recovered or the number of reuses is reduced to half or a quarter, the impacts are lower than for single-use plastics.

LCA results and findings - Sensitivity analysis



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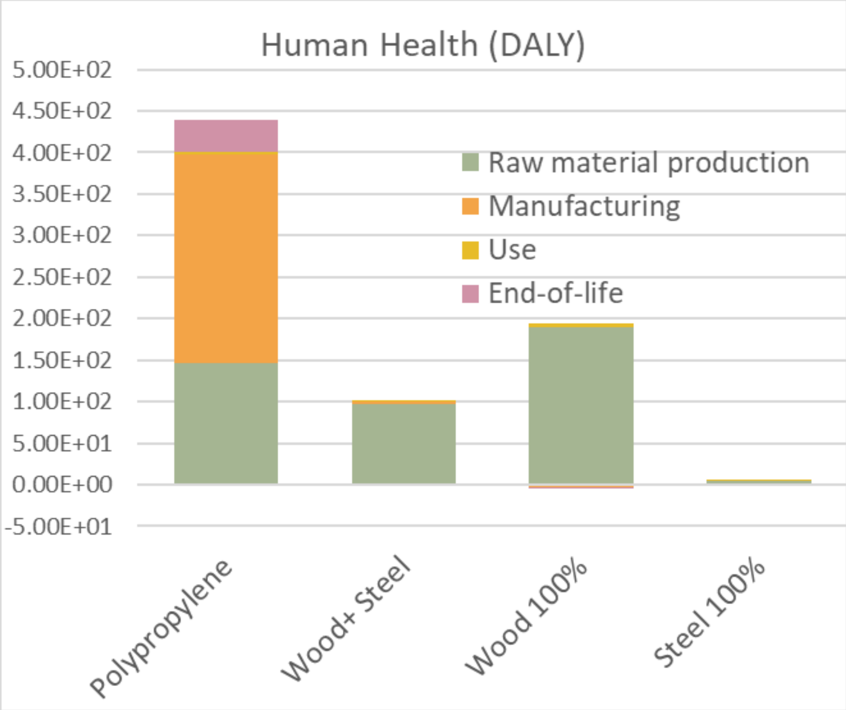
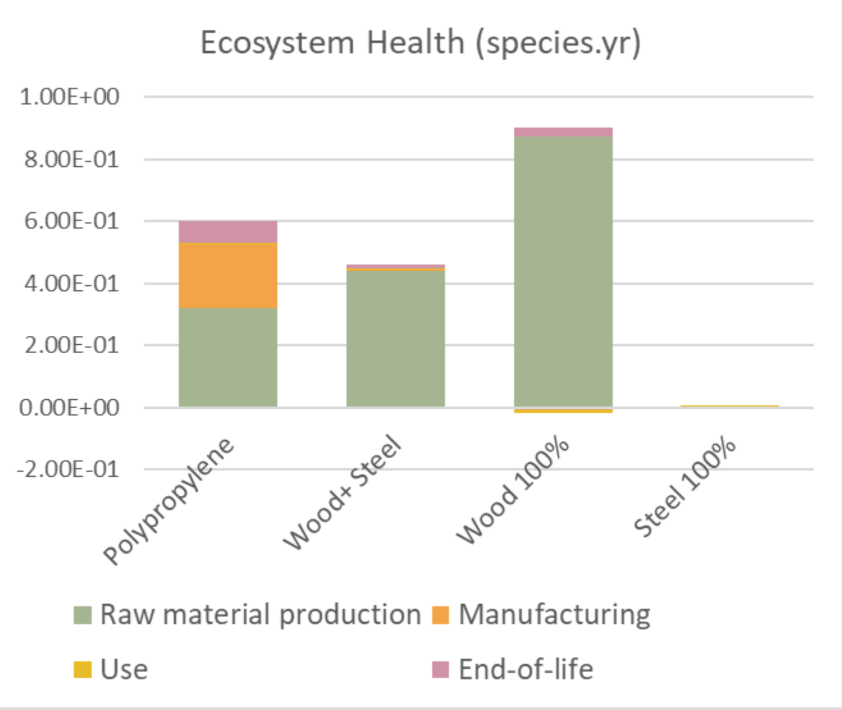
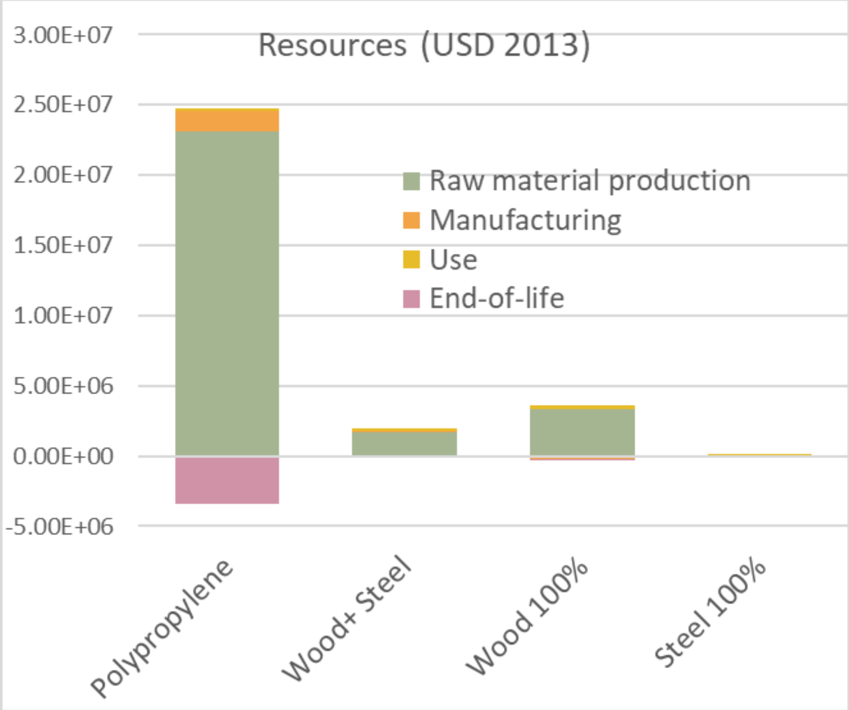
While wood and steel alternatives are better in terms of human health and resource consumption, the land occupation and water consumption effects of wood production are evident.

LCA results and findings - Endpoint indicator results







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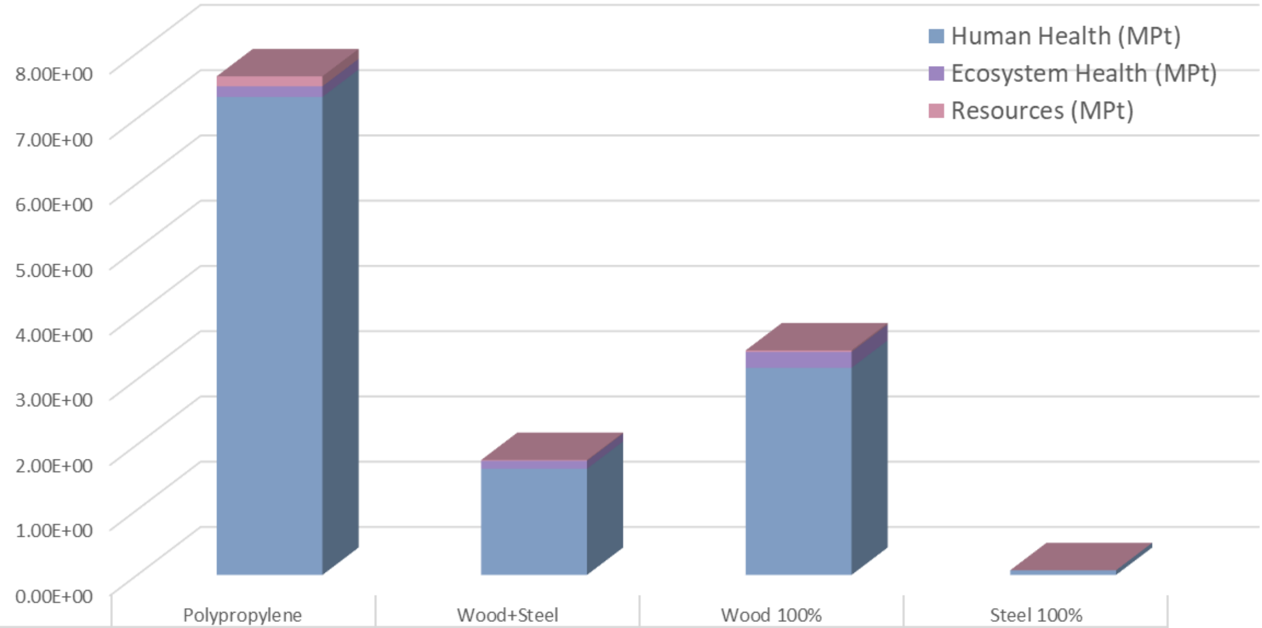
LCA RESULTS AND FİNDİNGS - SİNGLE SCORE RESULTS

WHEN ALL DAMAGE CATEGORİES ARE AGGREGATED UNDER A SİNGLE SCORE, THE SUBSTİTUTİON OF SİNGLE-USE PLASTİC CUTLERY PRODUCTS WİTH SİNGLE-USE WOODEN ALTERNATİVES AND REUSABLE STEEL PRODUCTS İS ENVİRONMENTALLY ADVANTAGEOUS.



	Polypropylene	Wood+Steel	Wood 100%	Steel 100%
Resources (MPt)	1.53E-01	1.20E-02	2.37E-02	2.49E-04
Ecosystem Health (MPt)	1.62E-01	1.22E-01	2.43E-01	6.22E-04
Human Health (MPt)	7.33E+00	1.63E+00	3.17E+00	7.07E-02

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LCA results - Midpoint indicator results

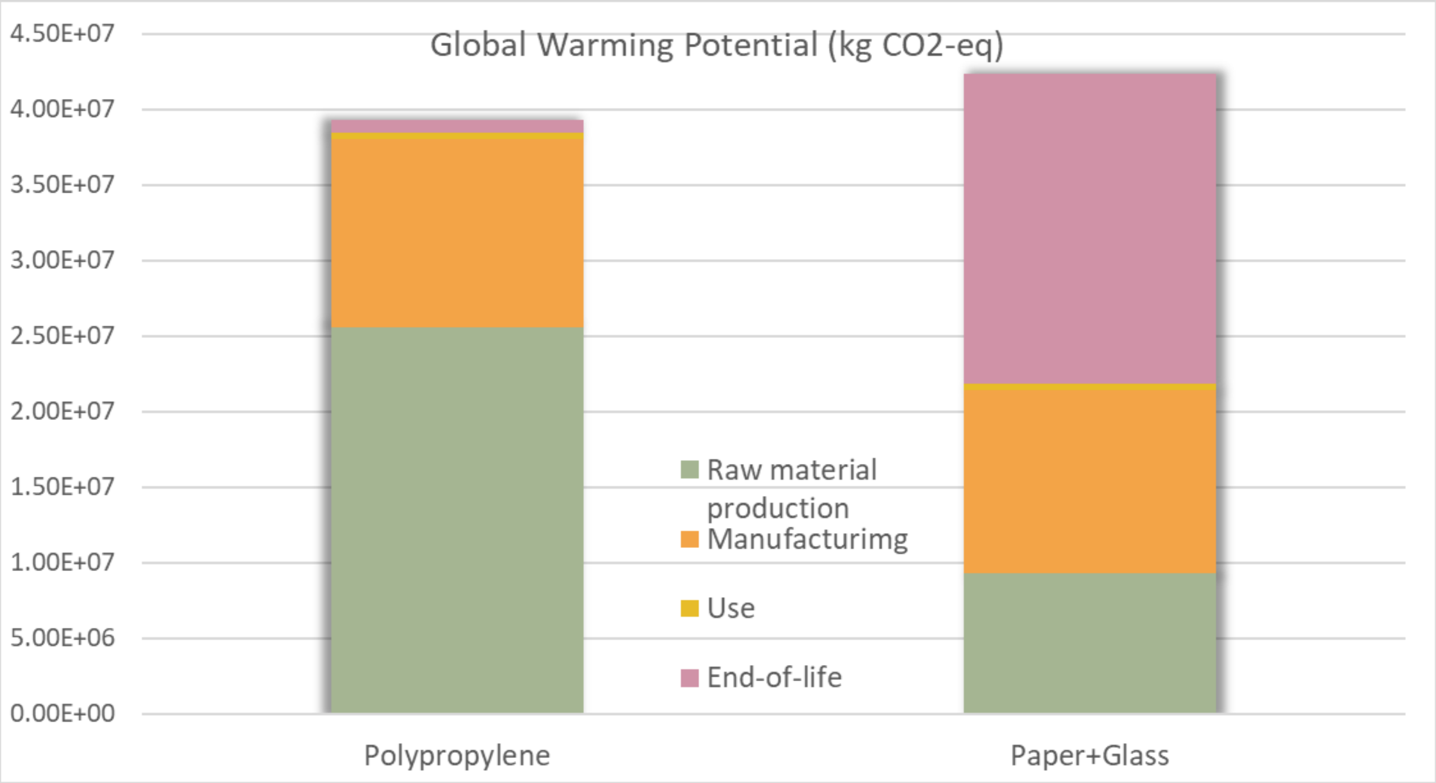
Example: Straws

SUP: PP

SUNP: Paper (50% substitution) + MU: Glass (50% substitution)

In the case of straws, there is an approximate increase of 8% in GHG emissions under the substitution scenario.

- Food-soaked paper straws cannot be recycled.
- According to the process inventories, the disposal of plastics in landfills causes predominantly CO2 emissions, while paper largely causes methane emissions.



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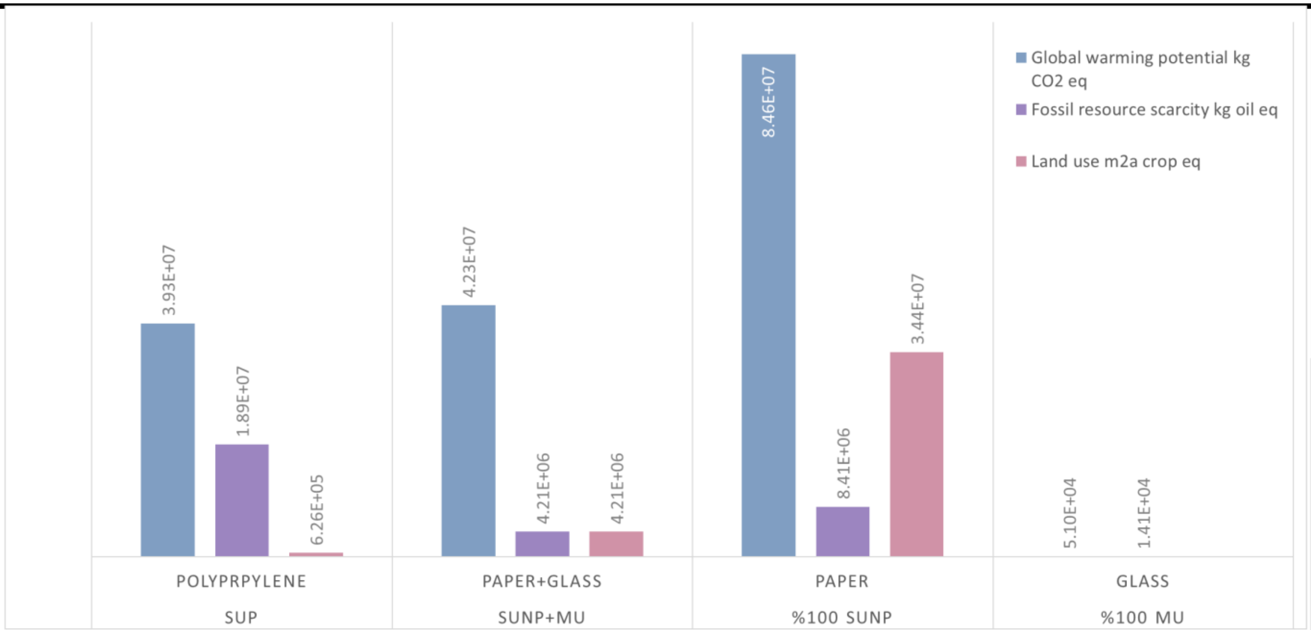
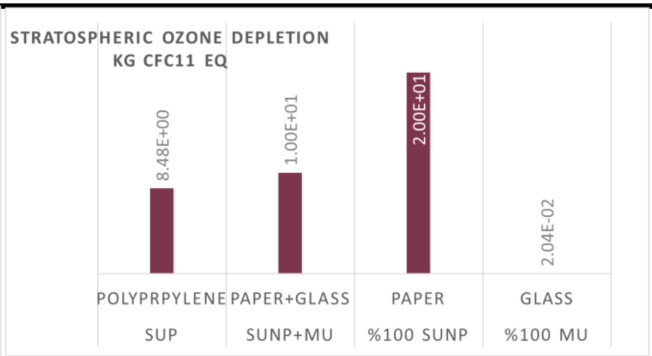
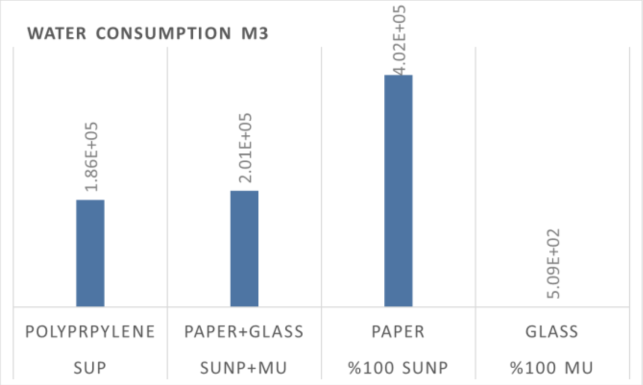
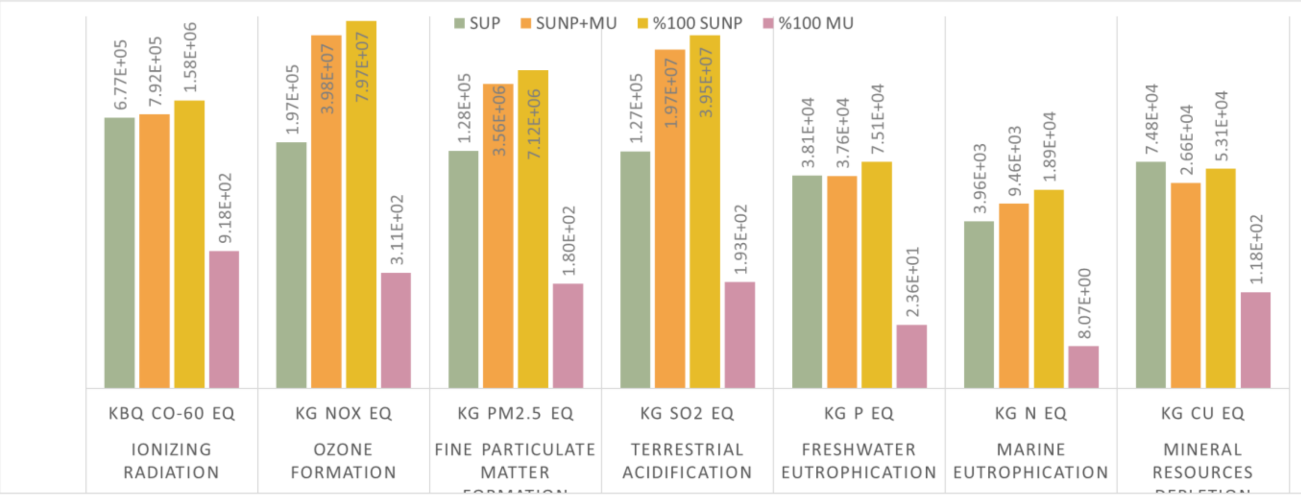
While paper products create trade-offs in a few indicators compared to their plastic counterparts, reusable glass products lead to significantly lower impacts in all life cycle impacts.

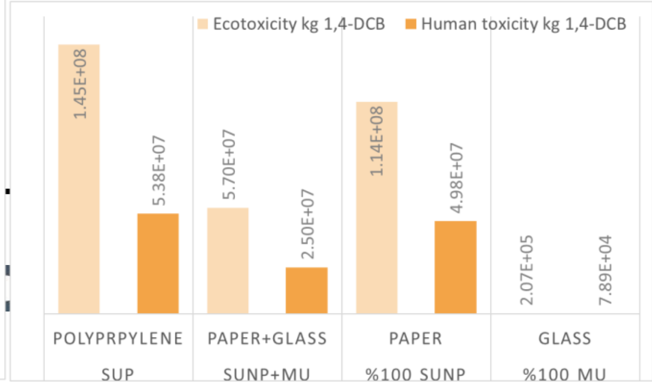
A similar conditions can be expected for other reusable alternatives, such as steel straws.











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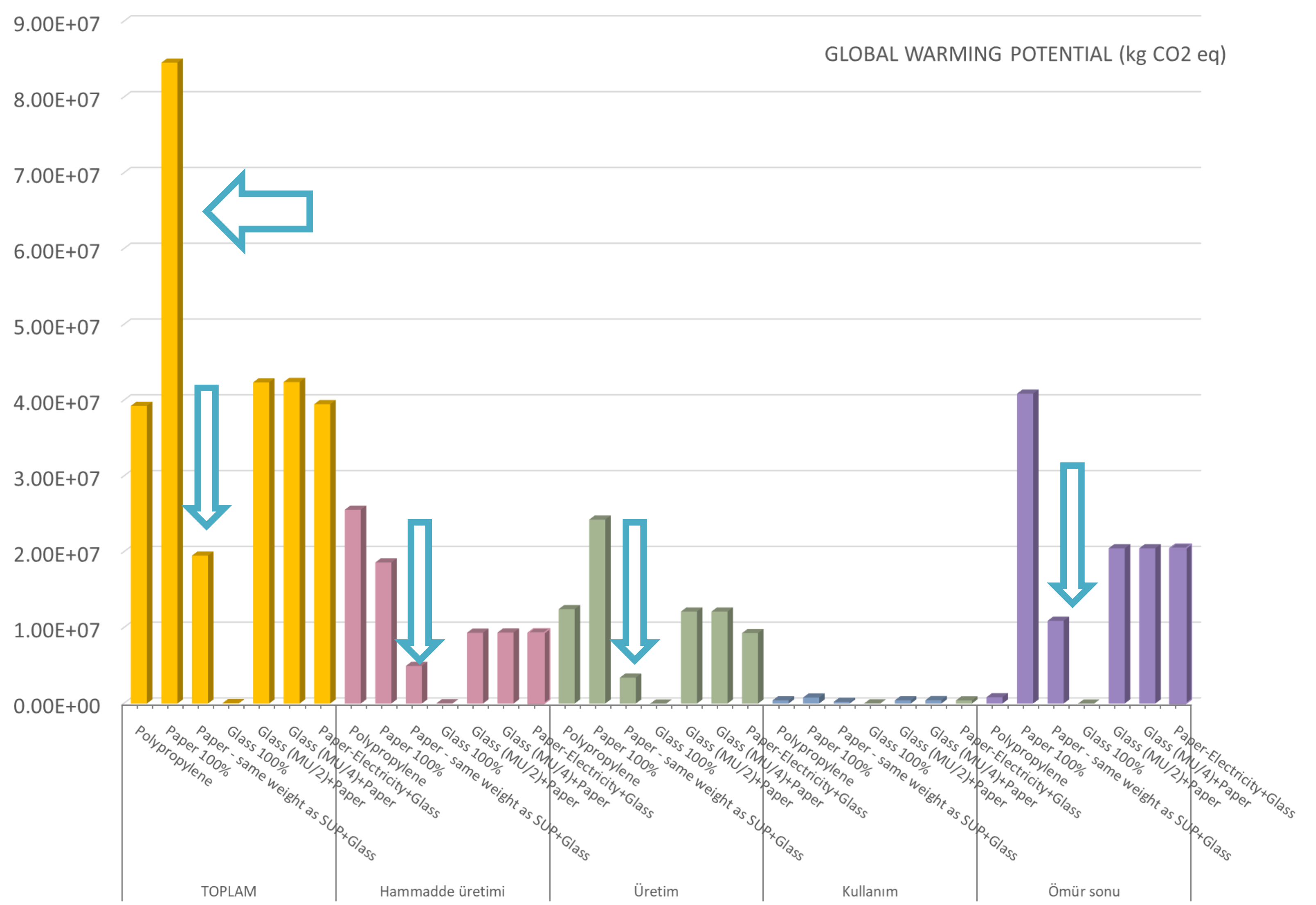
LCA results and findings - Sensitivity analysis

According to the results of the sensitivity analysis, the most important factor that reduces the environmental impact of paper straws is to reduce their weight.

This is an indication that circular economy strategies such as eco-design can play an important role.

In addition, it would be beneficial to investigate ways to utilise paper products at end-of-life.



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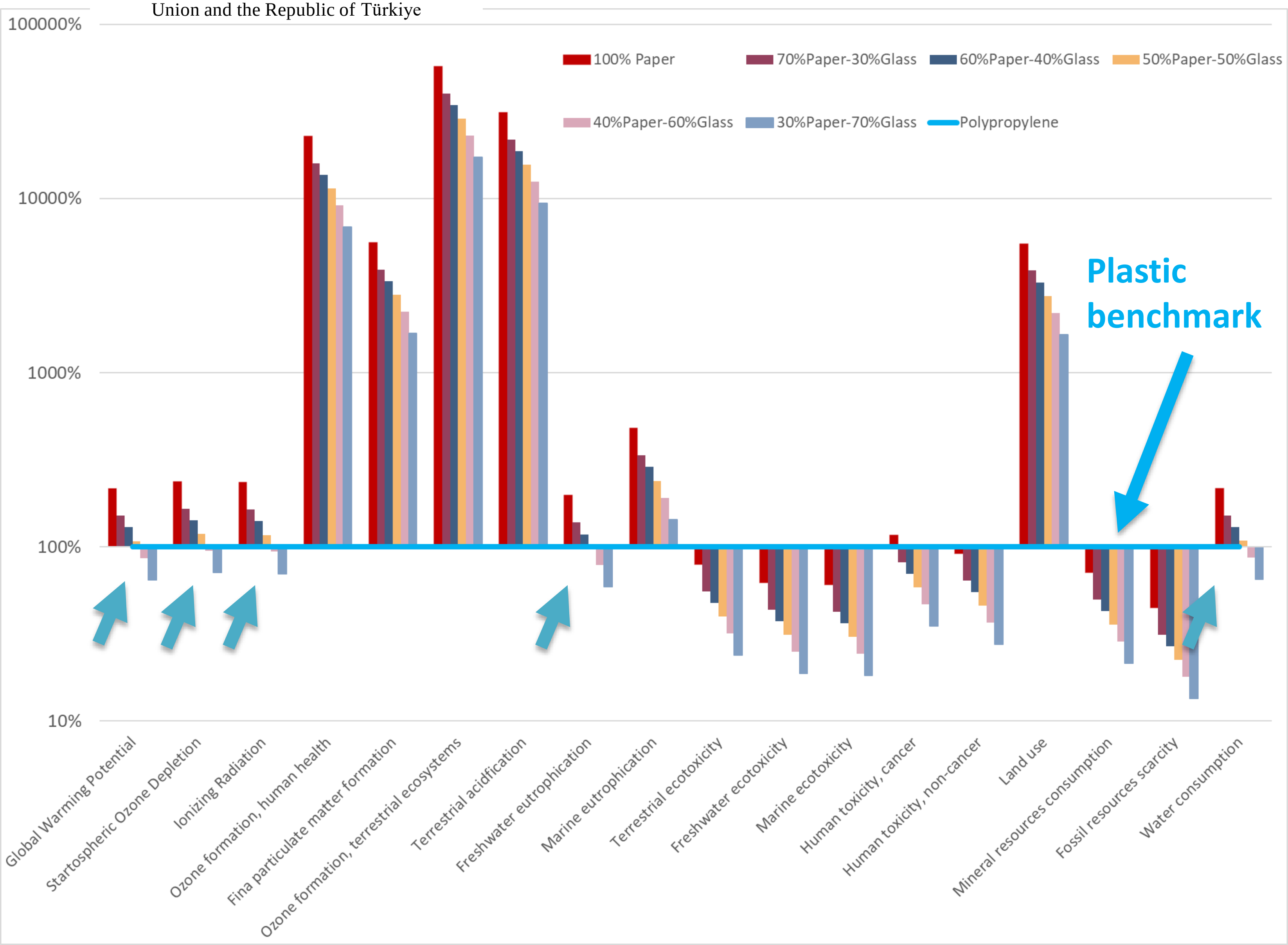
LCA results and findings - Sensitivity analysis

Increasing the glass substitution rate above 50% results in lower impacts on global warming, stratospheric ozone depletion, ionising radiation, freshwater eutrophication and water consumption indicators compared to single-use plastics.



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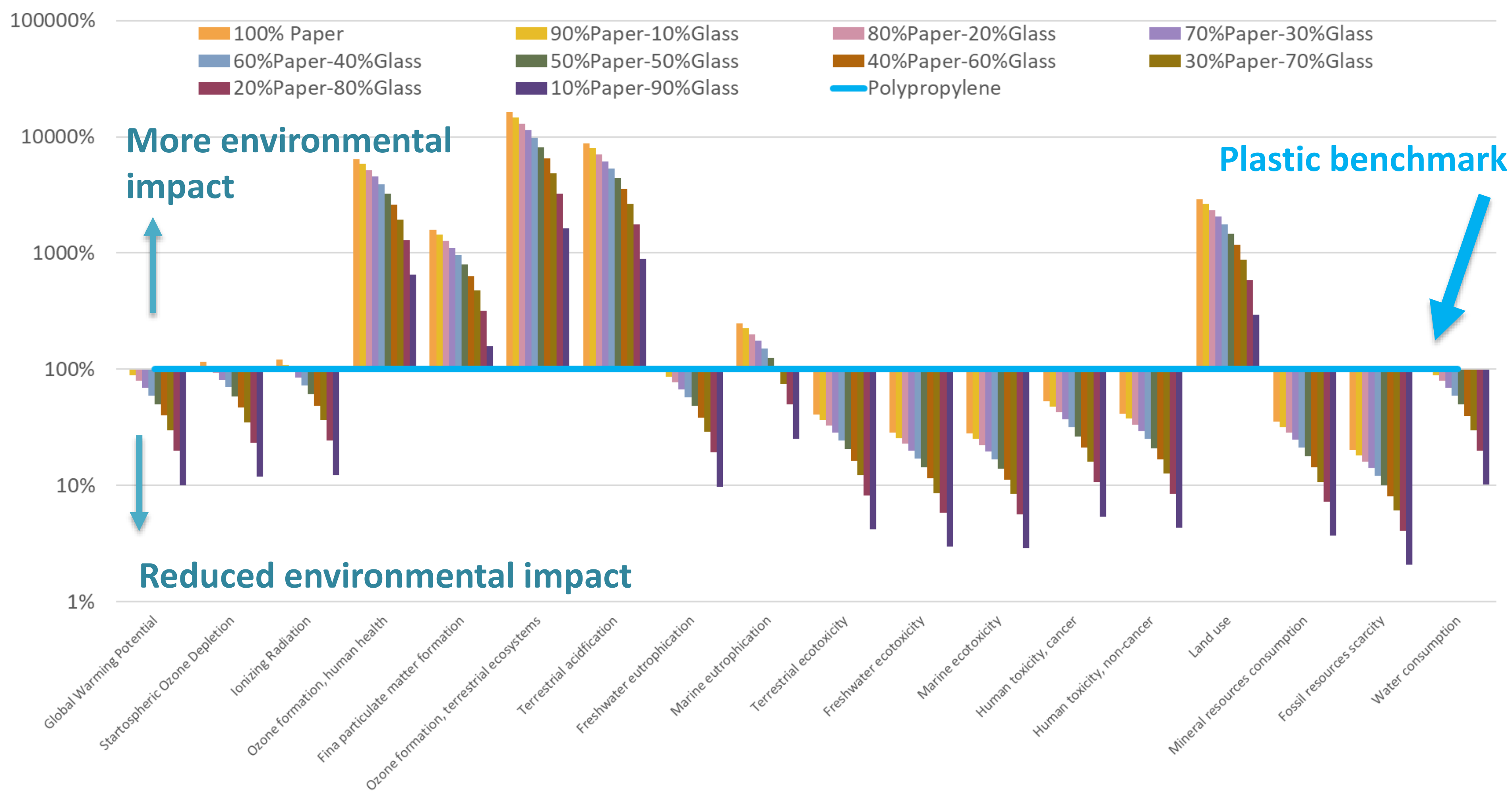
LCA results and findings - Sensitivity analysis

More significant environmental advantages can be achieved when the weight of paper products is equalised with plastic straws.

When product design is combined with increasing substitution rates, it may be possible to move away from single-use plastic products.



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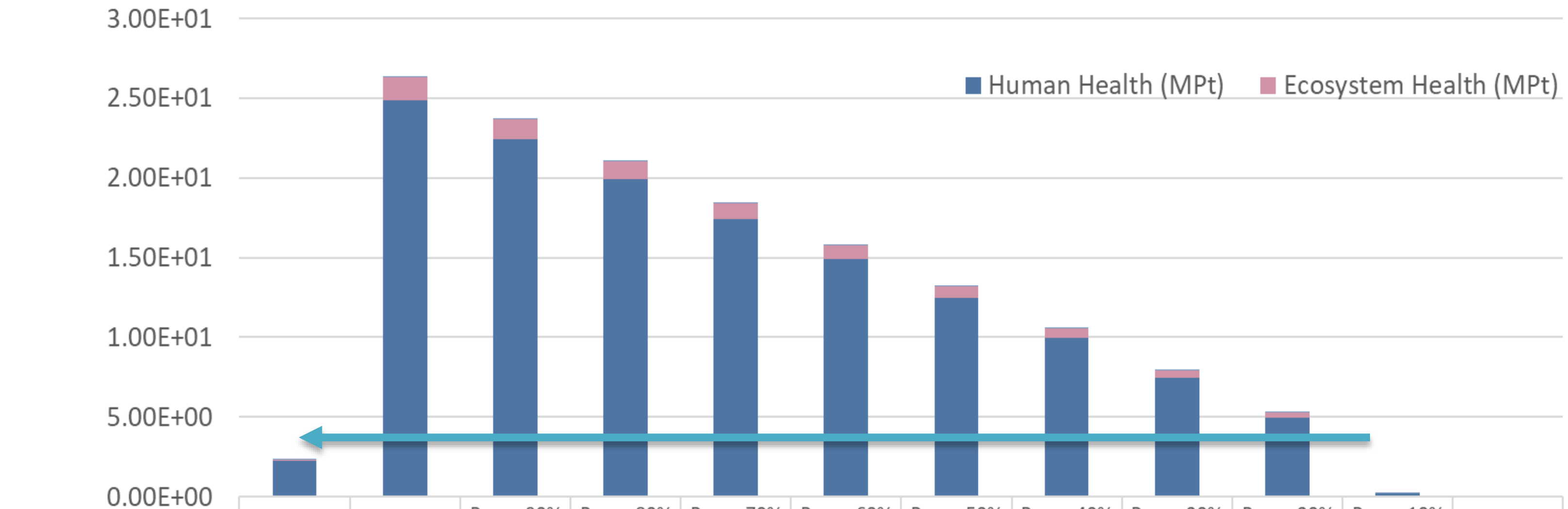
LCA results and findings - Single score results

THE STRAWS ARE AN EXAMPLE THAT EMPHASİSES THE İMPORTANCE OF THE MATERİAL TO BE SUBSTİTUTED.

IT İS POSSİBLE TO REPLACE PLASTİC STRAWS BY REDUCİNG THE WEİGHT OF THE PAPER PRODUCT, WHİCH CAUSES A HİGH ENVİRONMENTAL İMPACT FOR THİS PRODUCT, AND İNCREASİNG THE PROPORTİON OF REUSABLE PRODUCTS.



	PP	Paper 100%	Paper 90% - Glass 10%	Paper 80% - Glass 20%	Paper 70% - Glass 30%	Paper 60% - Glass 40%	Paper 50% - Glass 50%	Paper 40% - Glass 60%	Paper 30% - Glass 70%	Paper 20% - Glass 80%	Paper 10% - Glass 90%	Glass 100%
Resources (MPt)	4.78E-02	7.09E-03	6.38E-03	5.68E-03	4.97E-03	4.27E-03	3.56E-03	2.86E-03	2.15E-03	1.44E-03	4.81E-03	3.19E-05
Ecosystem Health (MPt)	5.05E-02	1.43E+00	1.29E+00	1.14E+00	1.00E+00	8.57E-01	7.14E-01	5.71E-01	4.29E-01	2.86E-01	5.11E-03	7.52E-05
Human Health (MPt)	2.27E+00	2.49E+01	2.24E+01	1.99E+01	1.74E+01	1.49E+01	1.24E+01	9.96E+00	7.47E+00	4.98E+00	2.30E-01	3.13E-03

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When the results of the LCA are evaluated in general:

- The importance of considering the effects of materials that will be alternative to single-use plastics is appearant. It will be necessary for the sectors producing alternative materials to intervene in areas that create high emissions with eco-design.
- It is observed that especially the production and end-of-life stages are evident in their contribution to results.
- The more consumer habits shift towards reusable alternatives, the higher the level of environmental impacts avoided.

IN THE MEDİUM TERM, TRANSİTİON TO SİNGLE-USE NON PLASTİC AND REUSABLE ALTERNATİVES UNDER CONDİTİONS THAT DO NOT CREATE ENVİRONMENTAL COMPROMİSES,

IN THE LONG TERM, THE CHANGE İN CONSUMER HABİTS AND THE TRANSİTİON TO REUSABLE PRODUCTS İN ACCORDANCE WİTH THE PRİNCİPLES OF CİRCULAR ECONOMY CAN BE CONSİDERED.

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Limitations of LCA studies for plastics: Marine Litter and Microplastics

Plastic pollution can interact with biota and humans through various exposure pathways and methods, such as ingestion, inhalation, dermal contact and trophic transfer.

Plastics contain a variety of chemicals, including additives and plasticisers. As plastics break down into smaller particles (such as microplastics and nanoplastics) through UV light, mechanical forces and wave action, these toxic substances can be leaked into the environment.

Microplastics can also adsorb pollutants such as heavy metals, persistent organic pollutants (POPs) and endocrine disrupting chemicals.

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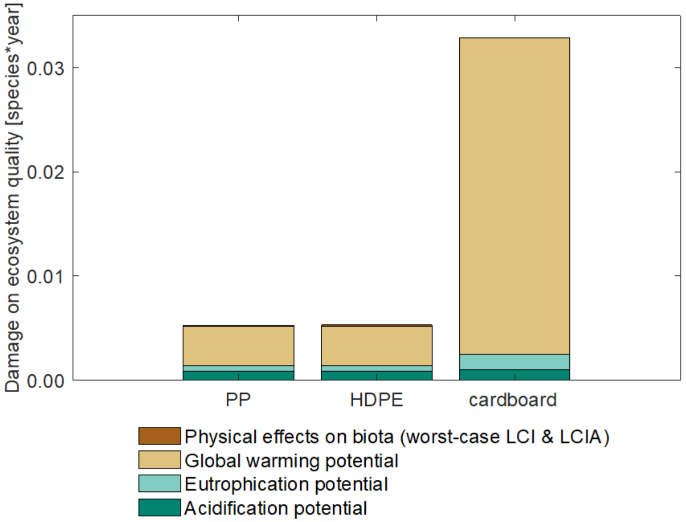
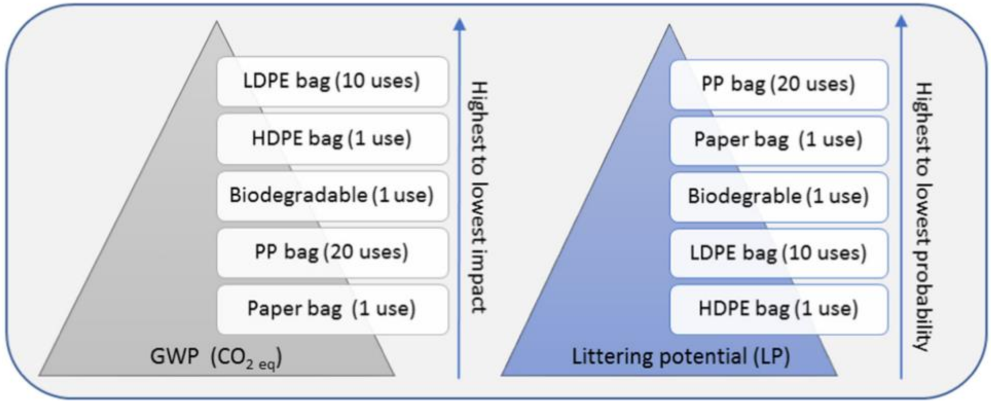
Limitations of LCA studies for plastics: Marine Litter and Microplastics

Currently, LCA impact analysis methods do not adequately capture the devastating impacts of marine litter and microplastics on ecosystem and human health.

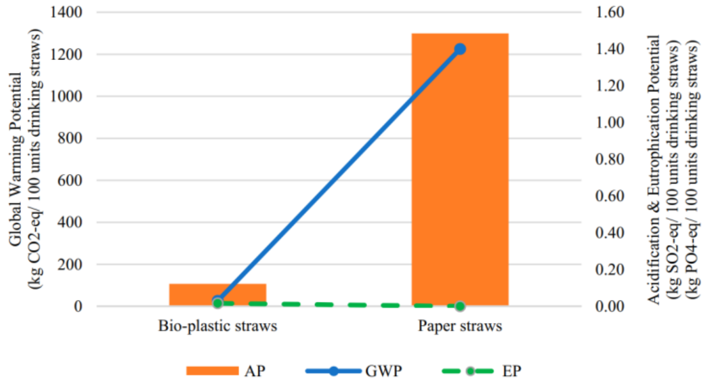
Therefore, it is possible to state that the life cycle impacts of plastics on the environment and humans are underestimated in current LCA studies..



Source : UNEP, 2022. Single-use supermarket food packaging and its alternatives: Recommendations from life cycle Assessments.



Source: Civancık-Uslu, D., Puig R., Hauschild, M., Fullana-i-Palmer, P., 2019. Life cycle assessment of carrier bags and development of a littering indicator. Science of Total Environment, 685, 621 – 630.



Source: Moy, C., Tan, L., shoparwe, N.F., Shariff, A. M., Tan, J., 2021. Comparative Study of a Life Cycle Assessment for Bio-Plastic Straws and Paper Straws: Malaysia's Perspective. Process, 9, 1007.

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MarILCA
MARINE IMPACTS IN LCA

Phase 1

Provide a first Framework paper developing and illustrating the different impact pathways associated with marine litter to be developed and identify the gaps and building blocks (January 2019 – December 2019).

Phase 2

Coordinate and launch different research projects (Master's and PhDs) aiming at filling identified gaps and act as a central scientific reference on the topic to avoid overlaps (2019 - 2022), welcoming members who are working and contributing on the topic. Findings and updates are regularly discussed with stakeholders via a platform and workshops.

Phase 3

Consensus building (2023-2025). Deliver a harmonized and consensus-based impact pathway framework and methods addressing plastic litter impacts (and potentially other complementary marine impacts) in LCA.

Table 1
Default physical effects on biota characterization factors (CFs) of aquatic microplastic emissions of different polymer densities (low, medium, high) and shapes (abbreviated in the table: microbeads/spheres/fragments of unspecified shape, microfibers/cylinders, microplastic film fragments). More specific CFs for different polymers, shapes and sizes, as well as the CF uncertainties, can be found in Multimedia component 5.

Shape	Polymer type	Default size	Midpoint CFs (PAF*m^3*day/$kg_{emitted}$)		Endpoint CFs (PDF*m^2*year/$kg_{emitted}$)	
			Marine	Freshwater	Marine	Freshwater
Microplastic beads	Low-density <0.8 g/cm^3	1000 µm	1.08E+08	8.12E+07	7.35E+01	5.51E+01
	Medium-density 0.8–1.1 g/cm^3		2.12E+07	1.59E+07	1.44E+01	1.08E+01
	High-density >1.1 g/cm^3		1.74E+04	1.74E+03	1.18E-02	1.18E-03
Plastic microfibers	Low-density <0.8 g/cm3	10 µm	1.53E+06	1.15E+06	1.04E+00	7.79E-01
	Medium-density 0.8–1.1 g/cm^3		8.90E+06	6.68E+06	6.05E+00	4.53E+00
	High-density >1.1 g/cm^3		1.73E+04	1.73E+03	1.17E-02	1.17E-03
Microplastic film fragments	Medium-density 0.8–1.1 g/cm^3	100 µm	1.92E+07	1.44E+07	1.31E+01	9.80E+00
	High-density >1.1 g/cm3		1.74E+04	1.74E+03	1.18E-02	1.18E-03
Microplastic beads	EPS	1000 µm	1.08E+08	8.12E+07	7.35E+01	5.51E+01
	HDPE		1.93E+07	1.45E+07	1.31E+01	9.83E+00
	LDPE		1.75E+07	1.31E+07	1.19E+01	8.93E+00
	PA (Nylon)		1.73E+04	1.73E+03	1.18E-02	1.18E-03
	PET		1.74E+04	1.74E+03	1.18E-02	1.18E-03
	PHA		1.63E+04	1.63E+03	1.11E-02	1.11E-03
	PLA		1.74E+04	1.74E+03	1.18E-02	1.18E-03
	PP		1.35E+07	1.01E+07	9.14E+00	6.86E+00
	PS		2.12E+07	1.59E+07	1.44E+01	1.08E+01
	PVC		1.71E+04	1.71E+03	1.16E-02	1.16E-03
	TRWP		1.73E+04	1.73E+03	1.18E-02	1.18E-03
Plastic microfibers	EPS	10 µm	1.53E+06	1.15E+06	1.04E+00	7.79E-01
	HDPE		3.85E+06	2.89E+06	2.61E+00	1.96E+00
	LDPE		2.41E+06	1.81E+06	1.64E+00	1.23E+00
	PA (Nylon)		1.44E+04	1.44E+03	9.78E-03	9.78E-04
	PET		1.66E+04	1.66E+03	1.12E-02	1.12E-03
	PHA		3.97E+03	3.97E+02	2.70E-03	2.70E-04
	PLA		1.73E+04	1.73E+03	1.17E-02	1.17E-03
	PP		5.16E+05	3.87E+05	3.50E-01	2.63E-01
	PS		8.90E+06	6.68E+06	6.05E+00	4.53E+00
	PVC		1.71E+04	1.71E+03	1.16E-02	1.16E-03
	TRWP		1.70E+04	1.70E+03	1.15E-02	1.15E-03
Microplastic film fragments	HDPE	100 µm	1.45E+07	1.09E+07	9.84E+00	7.38E+00
	LDPE		1.16E+07	8.68E+06	7.86E+00	5.89E+00
	PA (Nylon)		1.71E+04	1.71E+03	1.16E-02	1.16E-03
	PET		1.73E+04	1.73E+03	1.17E-02	1.17E-03
	PHA		1.35E+04	1.35E+03	9.17E-03	9.17E-04
	PLA		1.74E+04	1.74E+03	1.18E-02	1.18E-03
	PP		5.60E+06	4.20E+06	3.80E+00	2.85E+00
	PS		1.92E+07	1.44E+07	1.31E+01	9.80E+00
	PVC		1.71E+04	1.71E+03	1.16E-02	1.16E-03

Kaynak: Corella-Puertas, E., Hajjar, C., Lavoie, J., Boulay, A, 2023. MarILCA characterization factors for microplastic impacts in life cycle assessment: Physical effects on biota from emissions to aquatic environments. Journal of Cleaner Production, 418, 138197.

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TÜRKİYE CUMHURİYETİ
ÇEVRE, ŞEHİRCİLİK VE
İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

Çevre ve İklim
Eylemi Sektör
Operasyonel Programı

deep
Türkiye Döngüsel Ekonomi Eylem Planı

DAI

This project is co-funded by the European Union and the Republic of Türkiye

Assumptions

- SUP - SUNP/MU substitution rates *
- Product specifications - material, capacity/size, unit weights
- Numbers of re-use for MUs (product number conjugates) *
- Consumption amounts for raw materials and products in the light of production, import and export figures
- SUP, SUNP and MU production technologies
- Production wastage quantities
- Models of use - retail sale, use in the HOREKA sector or home delivery
- Impacts of use - impacts due to dishwashing and laundry
- Logistics model parameters (logistics mode and distances)
- Rates of conversion to uncontrolled litter and marine litter *
- Recovery and disposal rates

Data sources

Data category	Data source
Substitution rates	EU SUP Regulation Regulatory Impact Assessment
Product specifications	Literature (existing LCA studies), expert opinion
Numbers of re-use for MUs	EU SUP Regulation Regulatory Impact Assessment
Consumption data	Calculated based on production, import and export data on product basis:PAGEV, TÜİK, Ministry of Trade and Ministry of Industry and Technology 2022 datasets, UN COMTRADE and TOBB industry databases, sectoral reports prepared by public institutions and sector associations (plastics, paper, tobacco products, glass iron and steel, etc.).
Production and processing technologies	Literature (existing LCA studies), expert opinion, Ecoinvent database
Production wastage	Expert opinion
Models of use	Expert opinion
Impacts of use	Literature (existing LCA studies)
Logistics mode	UN COMTRADE, Deniz Mesafesi Hesaplayıcı, Modül:Konum haritası modülü
Uncontrolled litter and marine litter rates	EU SUP Regulation Regulatory Impact Assessment
Rates of recovery and disposal	MOEUCC