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Polymers for a Safe and Sustainable Future

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Life cycle assessment: Blends of Recycled PET and Bio-PET in the Circular Economy

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RECPET project is part of the **SUSTAINABLE PLASTICS** initiative to promote a Sustainable Plastics sector in Portugal.

- **Consortium:**

Trim NW Moulded Parts and Nonwovens, Lda

Ecoibéria Reciclados Ibéricos, S.A.

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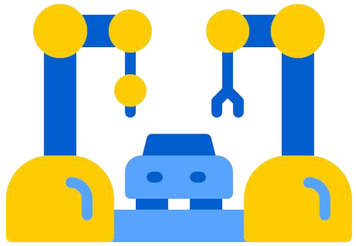
- **Main Project's Goal:**

Valorization of recycled PET (rPET) and bio-PET for the development of non-woven textiles for the automotive and medical industries.



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Topics to be covered

01

Project Background

Plastic;
Textile industry;
Circular economy;
rPET and Bio-PET.

02

Goal

03

Life Cycle Assessment - LCA

Goal and Scope definition;
Inventory Analysis;
Impact Assessment;
Interpretation.

04

Conclusion

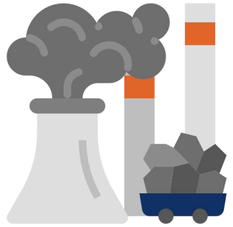
01 Background

- **Plastic:**

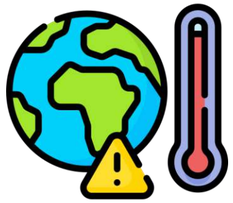
Main features[1]:

- Versatility;
- Chemical and thermal stability;
- Durability;
- Transparency;
- Cost.

Environmental challenges[2,3]:



Fossil-fuel dependency (non-renewable natural resource).



Greenhouse gas (GHG) emissions

Short lifetime and disposal of waste

[1] Chairat, S.; Gheewala, S. H. (2023). Life cycle assessment and circularity of polyethylene terephthalate bottles via closed and open loop recycling, Environmental Research, 236 (1), 116788. https://doi.org/10.1016/j.envres.2023.116788.

[2] Stubbe, B.; Van Vrekhem, S.; Huysman, S.; Tilkin, R.G.; De Schrijver, I.; Vanneste, M. (2024). White Paper on Textile Fibre Recycling Technologies. Sustainability, 16(2):618. https://doi.org/10.3390/su16020618

[3] Ali SS, Abdelkarim EA, Elsamahy T, Al-Tohamy R, Li F, Kornaros M, Zuorro A, Zhu D, Sun J. 2023. Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environ Sci Ecotechnol. 19(15):100254. https://doi: 10.1016/j.ese.2023.100254.

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01 Background

- **Textile industry:**

Polyester ➡ Used in the production of fibers[4].

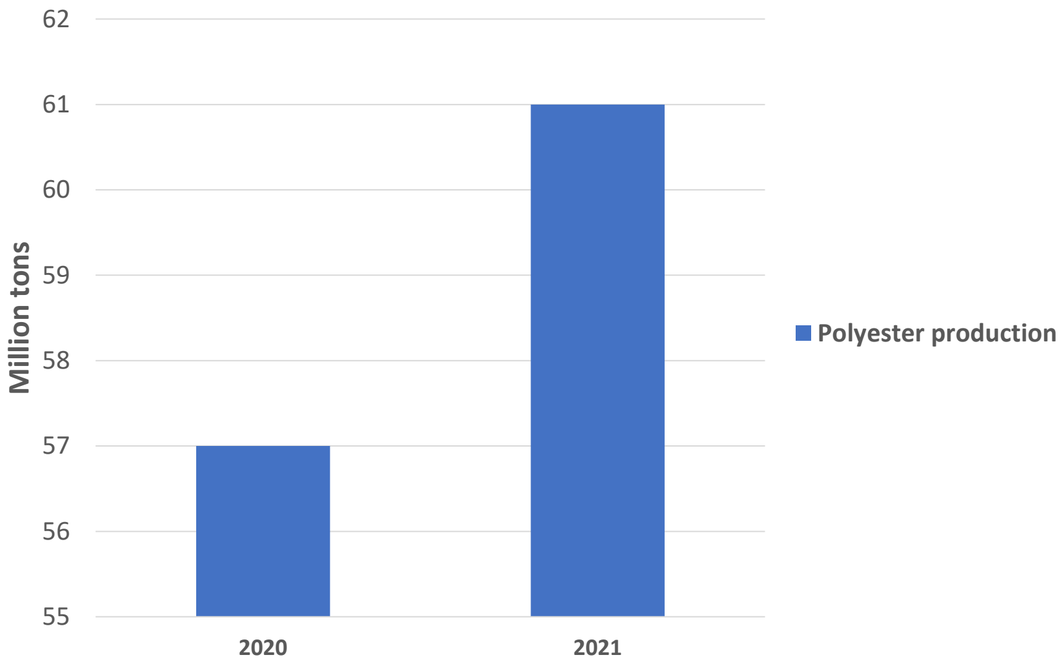

Figure 1 – Fiber production.

One of the most used polymers in textile industry is **Polyethylene Terephthalate (PET)[5].**

Global textile industry has also brought environmental problems[6] .

[4] García-Velásquez, C.; van der Meer, Y. (2022). Can we improve the environmental benefits of biobased PET production through local biomass value chains? – A life cycle assessment perspective. Journal of Cleaner Production, 380(2): 135039, https://doi.org/10.1016/j.jclepro.2022.135039.
[5] Ivanović, T.; Hischier, R.; Som, C. (2021). Bio-Based Polyester Fiber Substitutes: From GWP to a More Comprehensive Environmental Analysis" Applied Sciences 11(7): 2993. https://doi.org/10.3390/app11072993
[6] Sun, G.; Cao, X.; Wang, Y.; Sun, X.; Chen, Q. (2024). Comparative life cycle assessment of two different waste materials for recycled fiber. Resources, Conservation and Recycling, 205: 107518. https://doi.org/10.1016/j.resconrec.2024.107518.

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WHAT CAN WE DO?

01 Background

- **Circular economy**

➡ European Commission: regulations to reduce waste and promote circular economy approaches[7].

Green Deal: stimulate the development of new markets for climate-neutral and circular products, especially in textiles and plastics industry.

Substitutes for traditional plastics: **recycled PET and bio-based** plastics [4].

[7] García-Velásquez, C.; van der Meer, Y. (2022). Can we improve the environmental benefits of biobased PET production through local biomass value chains? – A life cycle assessment perspective. Journal of Cleaner Production, 380(2): 135039, https://doi.org/10.1016/j.jclepro.2022.135039.
[4] Ivanović, T.; Hischier, R.; Som, C. (2021). Bio-Based Polyester Fiber Substitutes: From GWP to a More Comprehensive Environmental Analysis" Applied Sciences 11(7): 2993. https://doi.org/10.3390/app11072993

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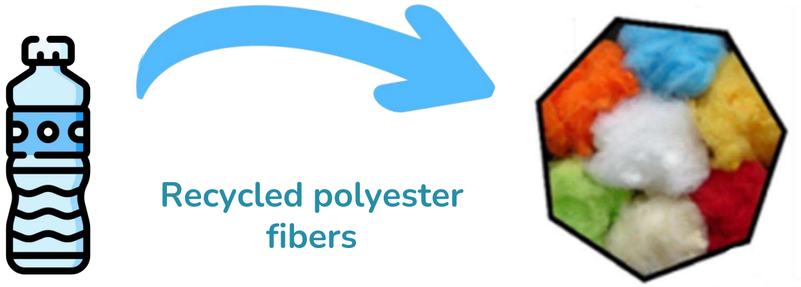
01 Background

- **Recycled PET:**

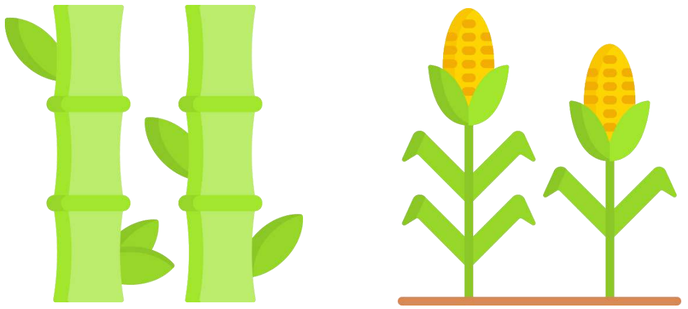
- **Recycled PET (rPET)**: type of plastic that is made by recycling PET.



rPET is produced by processing used PET products, such as plastic bottles, into new material, including fiber.

- **Bio-based PET:**

- **Bio-based** are made totally or partially using renewable resources instead of fossil feedstock[3].



Studies indicate that producing polyester fiber from rPET and bio-based sources can contribute to reducing environmental impacts [1,3,8]:

- Plastic waste;
- Energy use;
- Greenhouse gas emissions;
- Depletion of fossil resources.

[1] Chairat, S.; Gheewala, S. H. (2023). Life cycle assessment and circularity of polyethylene terephthalate bottles via closed and open loop recycling, Environmental Research, 236 (1), 116788. https://doi.org/10.1016/j.envres.2023.116788.
[3] Ali SS, Abdelkarim EA, Elsamahy T, Al-Tohamy R, Li F, Kornaros M, Zuorro A, Zhu D, Sun J. 2023. Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environ Sci Ecotechnol. 19(15):100254. https://doi: 10.1016/j.ese.2023.100254.
[8] Serrano-Aguirre, L. & Prieto, M.A. (2024) Can bioplastics always offer a truly sustainable alternative to fossil-based plastics? Microbial Biotechnology, 17, e14458. Available from: https://doi.org/10.1111/1751- 7915.14458

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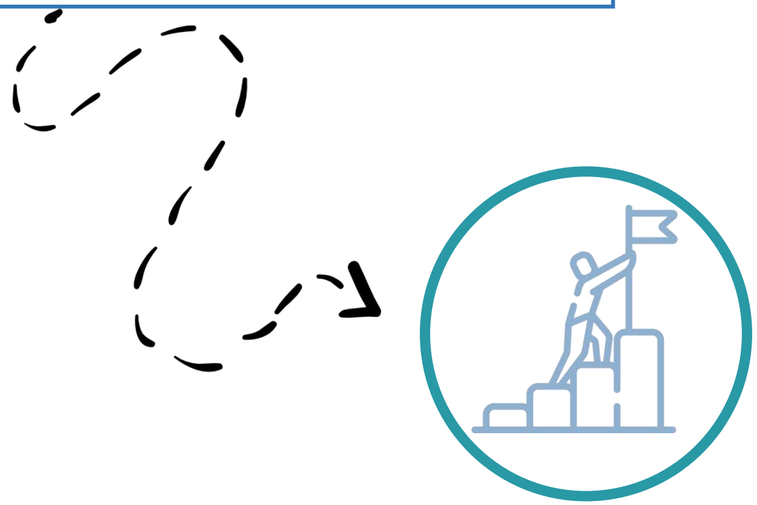
02 Goal

Compare the environmental performance of producing 1 kg of fiber with different materials.



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03 Life Cycle Assessment (LCA):

The **environmental impacts** were obtained using the LCA methodology based on ISO 14040:44[9,10].

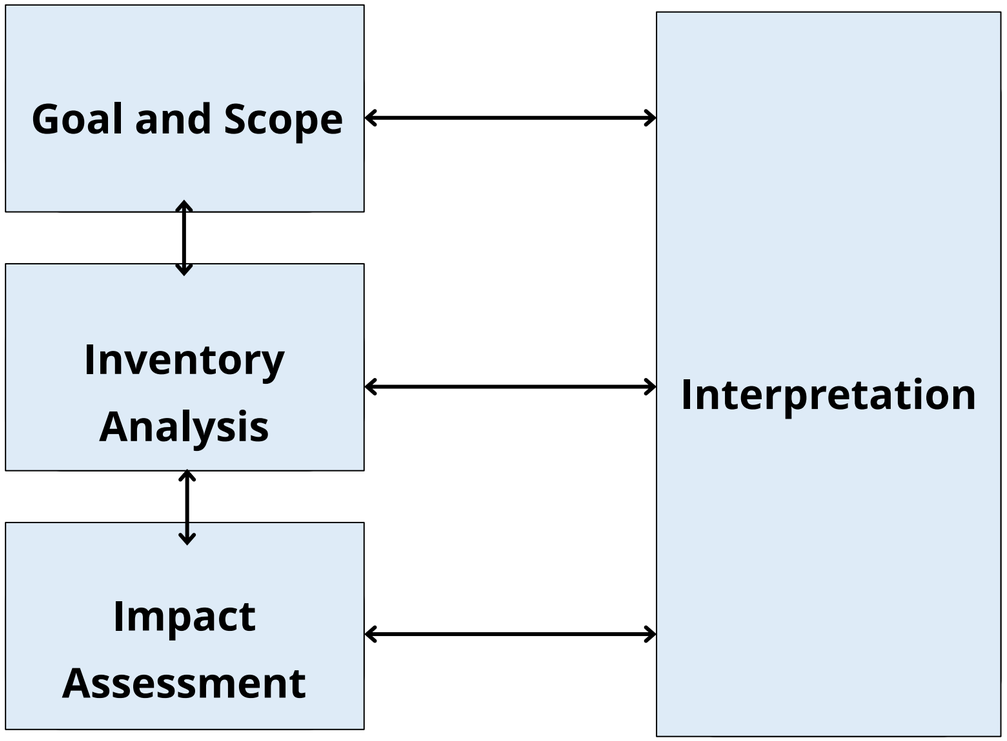

Figure 2 - LCA methodology accordingly to ISO14040:44.

[9] ISO 14040:2006 Environmental management. Life cycle assessment. Principles and framework.
[10] ISO 14044:2006 Environmental management. Life cycle assessment. Requirements and guidelines.

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03 Life Cycle Assessment (LCA):

GOAL:

Compare the environmental performance of producing 1 kg of fiber:

(i) Baseline: virgin PET;

(ii) Innovation: project formulation using recycled PET, bio-PET and additives.

SCOPE:

Declared Unit: Production of 1 kg of fiber.

System limits: Cradle-to-gate

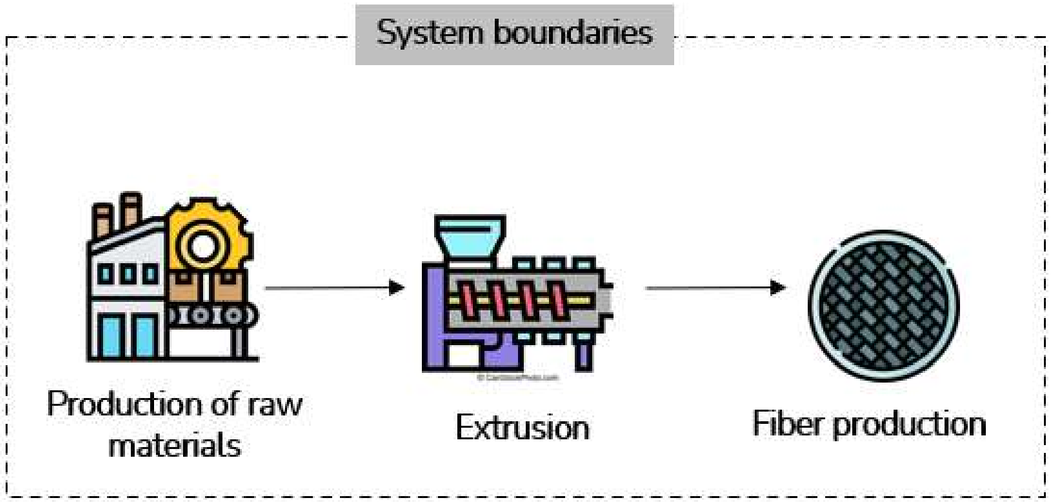

Figure 3 - Production stages.

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03 Life Cycle Assessment (LCA):

- Inventory:

- For the baseline, secondary data available in the EcoInvent database was used.
- For the innovation, primary and secondary (EcoInvent) database were used.
- In the innovation, the formulation was developed through project tests.
- The inventory for bio-PET was obtained from literature[4].

[4] Ivanović, T.; Hischier, R.; Som, C. (2021). Bio-Based Polyester Fiber Substitutes: From GWP to a More Comprehensive Environmental Analysis" Applied Sciences 11(7): 2993. https://doi.org/10.3390/app11072993

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03 Life Cycle Assessment (LCA):

- Limitations and Considerations:

- The study presented preliminary results of the RECPET project.
- The formulation was developed on a laboratory scale.
- The construction of infrastructure and equipment, as well as the end-of-life considerations, were excluded from the analysis.

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03 Life Cycle Assessment (LCA):

Impact Assessment

Software: SimaPro
Version 9.4.0.1

Database: EcoInvent Version 3.9.1 (2023)

Impact method: EPD (2018)
Environmental Product Declaration

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03 Life Cycle Assessment (LCA):

Impact Assessment

The environmental **impact categories** analyzed were:

Impact categories	Unit	Impact categories	Unit
Acidification	Kg SO_2 eq.	Abiotic depletion (elements)	Kg Sb eq.
Eutrophication	Kg PO_4^3 – eq.	Abiotic depletion (fossil fuels)	MJ
Global Warming (GWP)	Kg CO_2 eq.	Water scarcity	m^3 eq.
Photochemical oxidation	Kg NMVOC	Depletion of the ozone layer	Kg CFC-11 eq.

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03 Life Cycle Assessment (LCA):

Interpretation: Global Warming (GWP100a)

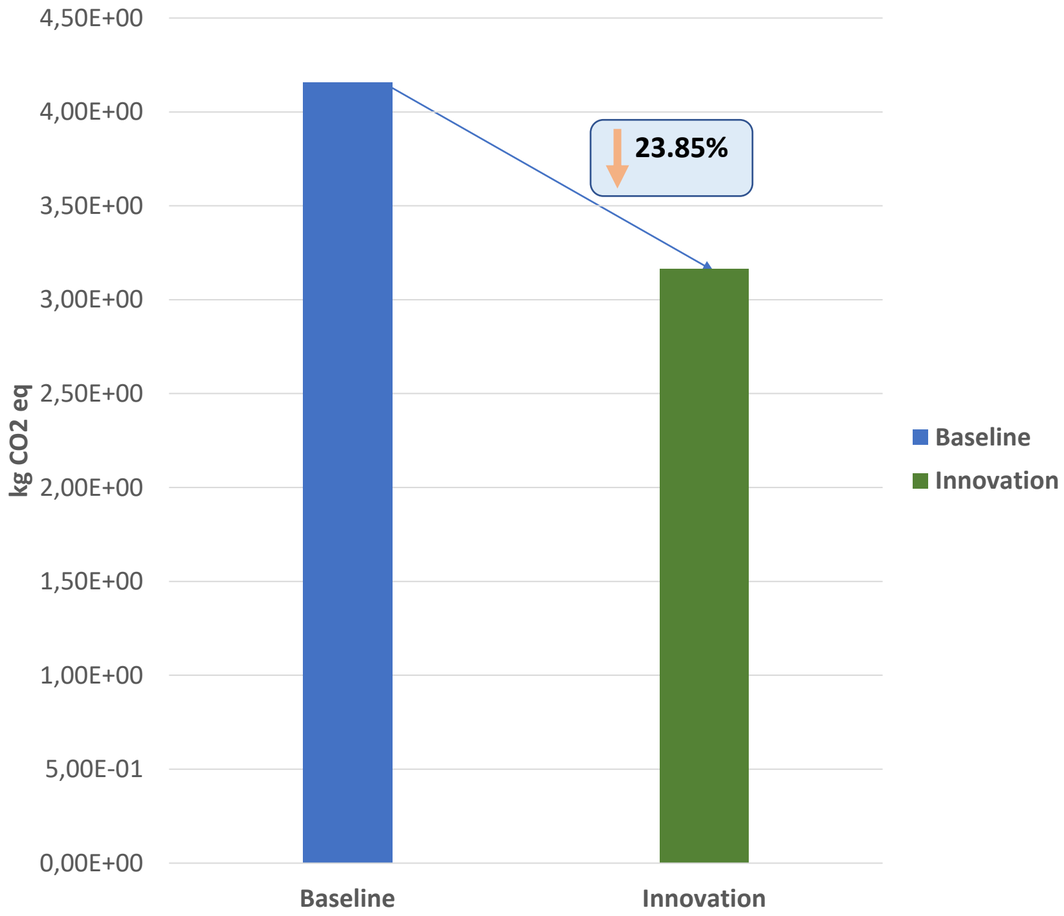

Figure 4 – Global warming results for the options analyzed.

Global Warming is **the most** analyzed category in similar studies.

The **innovation reduced kg $CO_{2\ eq}$ emissions** by 23.85% **when compared to the baseline.**

The **innovation represents less use of fossil** resources as expected according to the literature.

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03 Life Cycle Assessment (LCA):

Interpretation:

The **baseline** scenario results were **worse** in almost all categories:

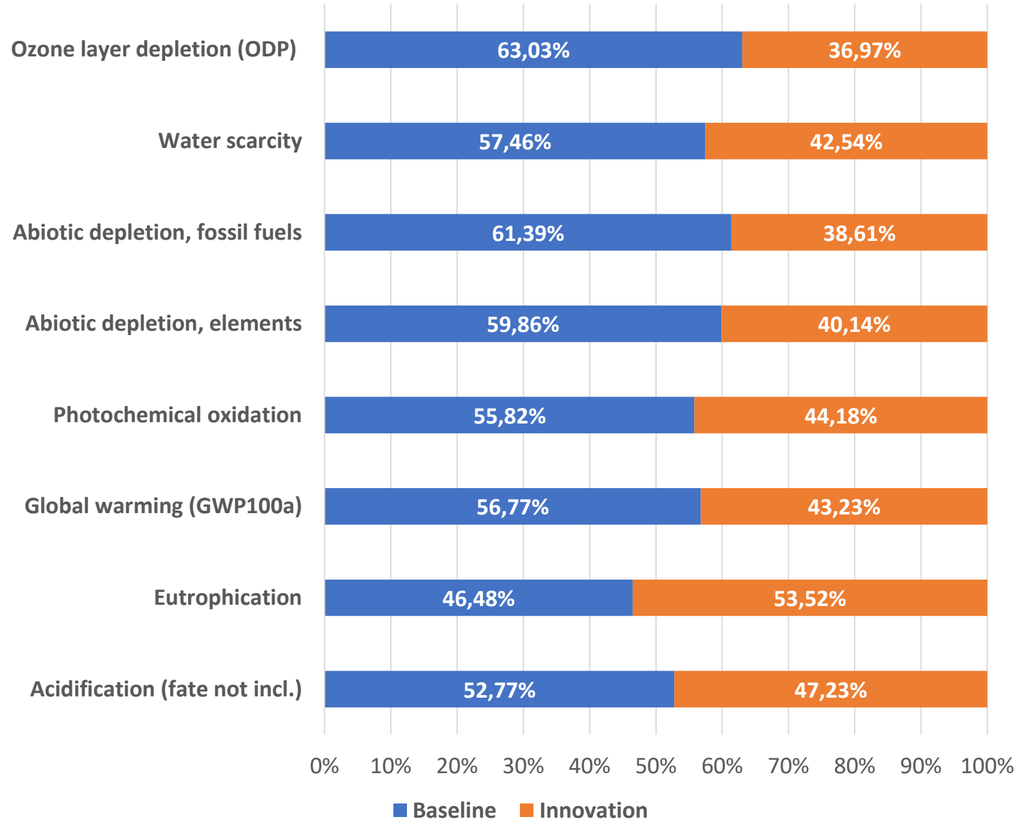

Figure 5 – Environmental impacts for the options analyzed.

Recycled PET and Bio-PET: in addition to reducing dependence on fossil fuels, it avoids the extraction of virgin material and less consumption of energy and other resources.

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03 Life Cycle Assessment (LCA):

Interpretation:

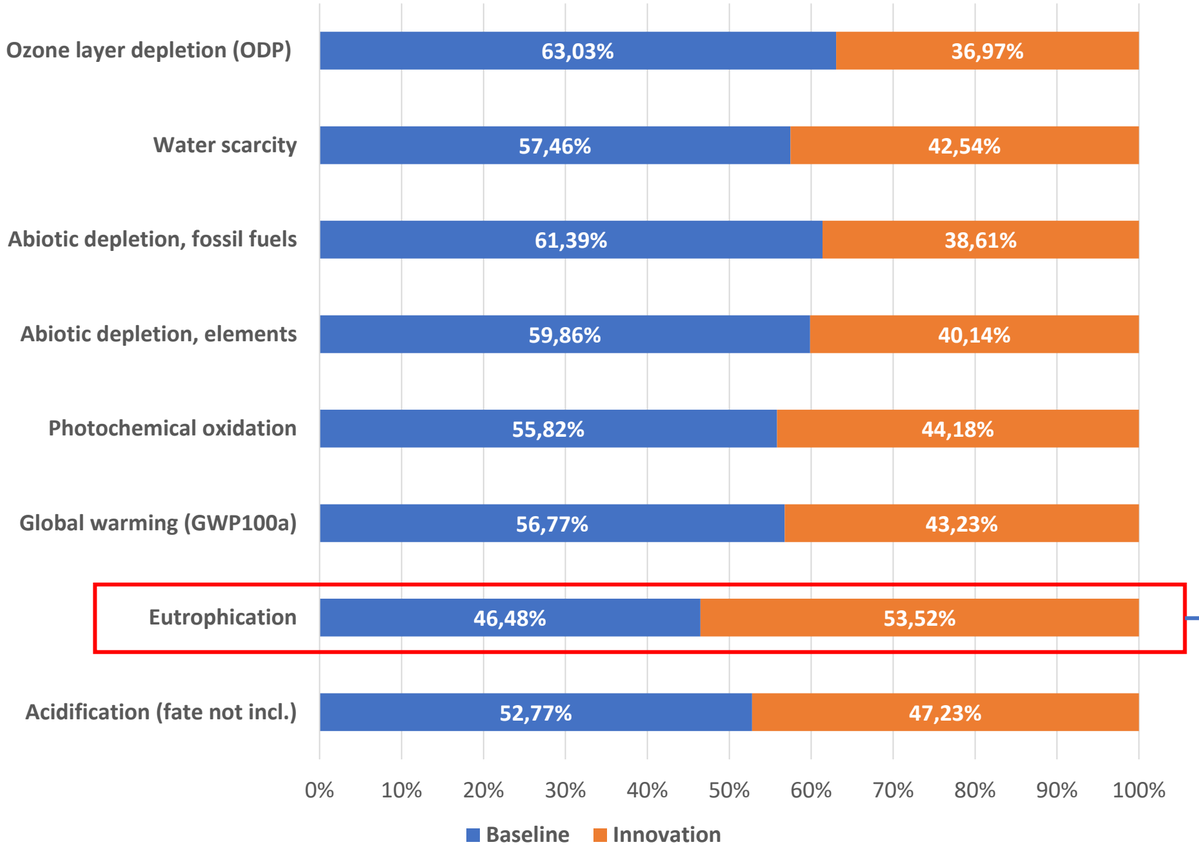
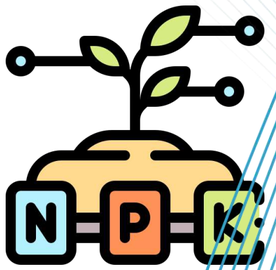


Figure 5 – Environmental impacts for the options analyzed.

The **innovation** had the **highest** environmental impact contribution in the **eutrophication category.**

Comparative **LCA studies** identified this **same behavior** on bio-based fibers productions[3,11].

Use of **fertilizer** in the agriculture phase to **produce bio-based** materials.



[3] Ali SS, Abdelkarim EA, Elsamahy T, Al-Tohamy R, Li F, Kornaros M, Zuorro A, Zhu D, Sun J. 2023. Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environ Sci Ecotechnol. 19(15):100254. https://doi: 10.1016/j.ese.2023.100254.

[11] Chen, L; Pelton, R. E.O.; Smith, T. M.. 2016. Comparative life cycle assessment of fossil and bio-based polyethylene terephthalate (PET) bottles, Journal of Cleaner Production, 137, 667-676. https://doi.org/10.1016/j.jclepro.2016.07.094.

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04 Conclusion

This study presented initial considerations on the environmental performance of fibers produced from virgin PET (baseline) and a formulation (innovation) produced on a laboratory scale with recycled PET, bio-PET and additives.

According to preliminary results, the innovation showed better environmental performance compared to the baseline.

The project intends to carry out tests on an industrial scale.

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Thank you for your attention!

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