SUSTAINABLE FIBERS BASED ON RECYCLED PET

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Topics to be covered

01 Background

- Project;
- Textile industry;
- rPET and Bio-PET

02 Goal

03 Strategy

04 Experimental Results

05 Conclusion

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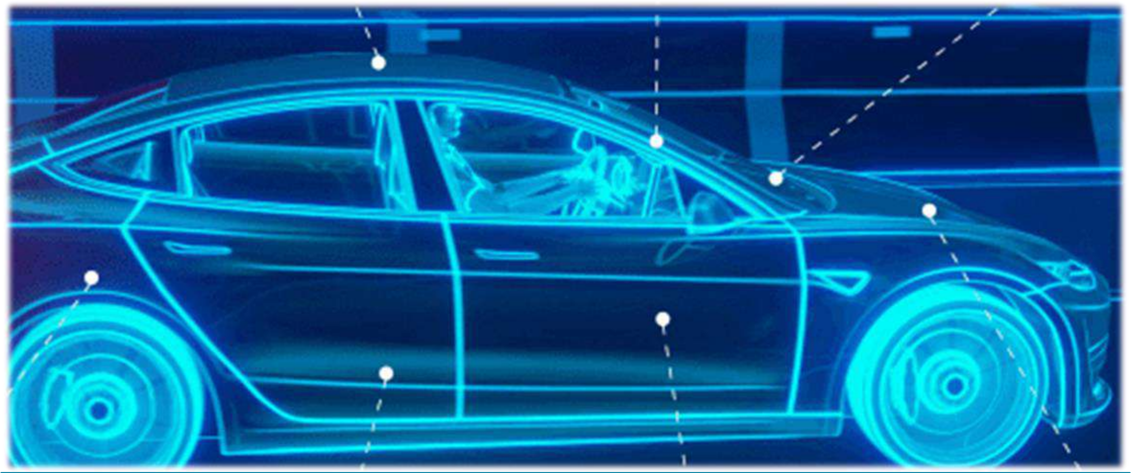
RECPET PROJECT

Part of the *SUSTAINABLE PLASTICS* initiative to promote a Sustainable Plastics sector in Portugal



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.

Consortium:

Trim NW Moulded Parts and Nonwovens, Lda

Ecoibéria Reciclados Ibéricos, S.A.

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piep innovation in polymer engineering

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01 Background

PET [1]

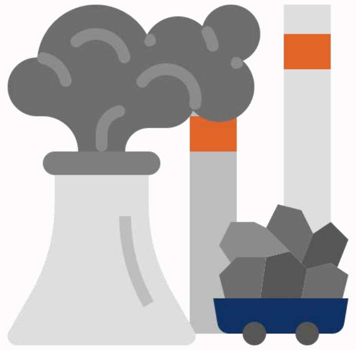
Convenience:

- Versatility;
- Chemical and thermal stability;
- Non-toxic;
- Lightweight;
- Durability;
- Low cost

- **Raw materials from fossil-resources**

600 billion plastic bottles sold by the end of 2021 [4]

Severe environmental impact[2,3]:



Fossil-fuel dependency (non-renewable natural resource)

Short lifetime and waste accumulation

[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.
[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.
[3] Ali S.S., Abdelkarim E.A., 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.
[4] Barletta, M., Aversa, C., Puopolo, M., Vesco, S. (2019). Extrusion blow molding of environmentally friendly bottles in biodegradable polyesters blends. In (Vol. 77): Elsevier BV.

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01 Background

- **Textile industry:**
  - ➡ Important role in global economy
  - ➡ Prospects of continuous growth

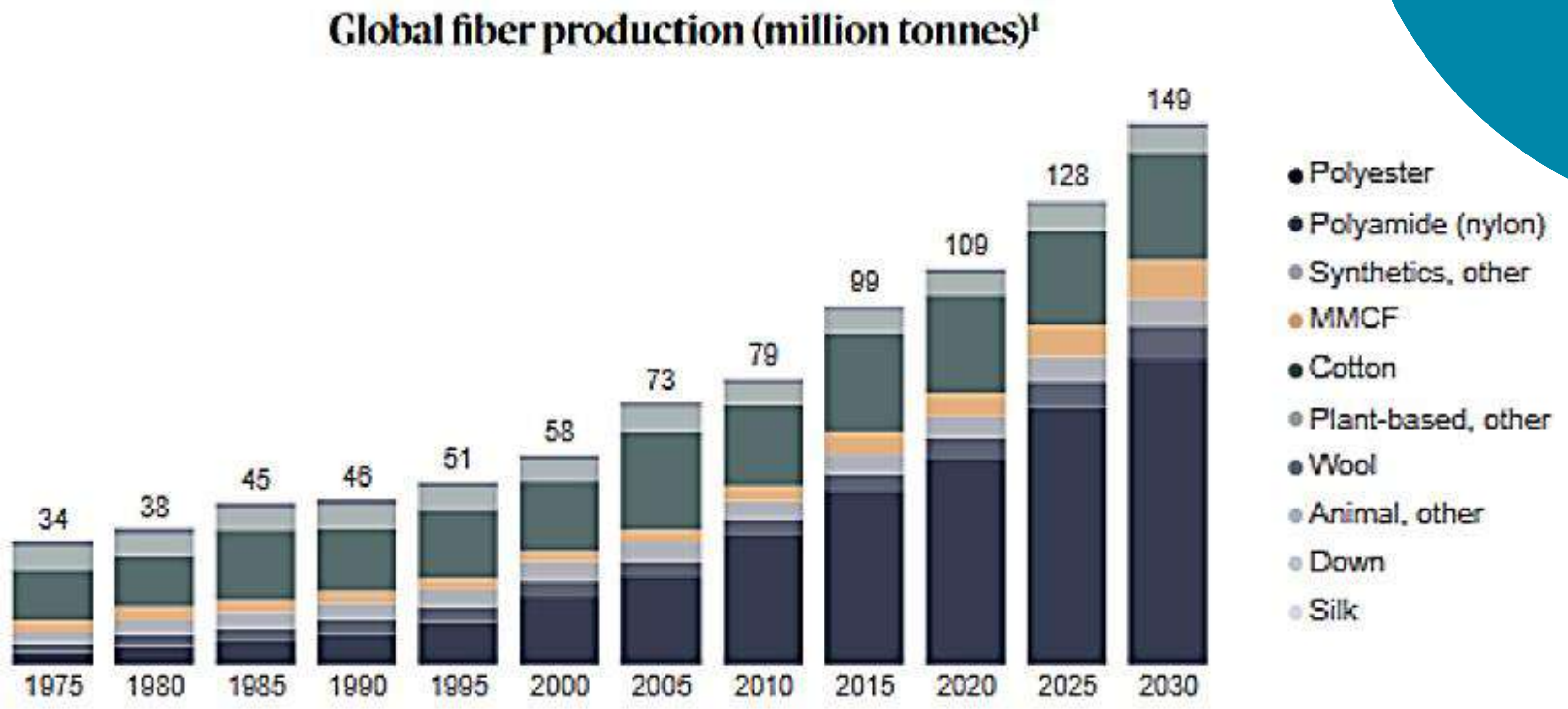

Figure 1 – Fiber production[7]

One of the most used polymers in textile fiber industry is **PET**[5]

Global textile industry facing environmental problems[6]

[5] Majumdar, A.; Shukla, S.; Singh, A.A.; Arora, S. (2020) Circular fashion: Properties of fabrics made from mechanically recycled poly-ethylene terephthalate (PET) bottles,Resources, Conservation and Recycling, 161, 104915. https://doi.org/10.1016/j.resconrec.2020.104915

[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.,

[7]Gojic, A.; Bukhonka, N.. (2023). Recycled Textile Fibers and Materials – Current State and Development Perspectives. Conference Proceedings ICPAE 2023 At: Zrenjanin, Serbia

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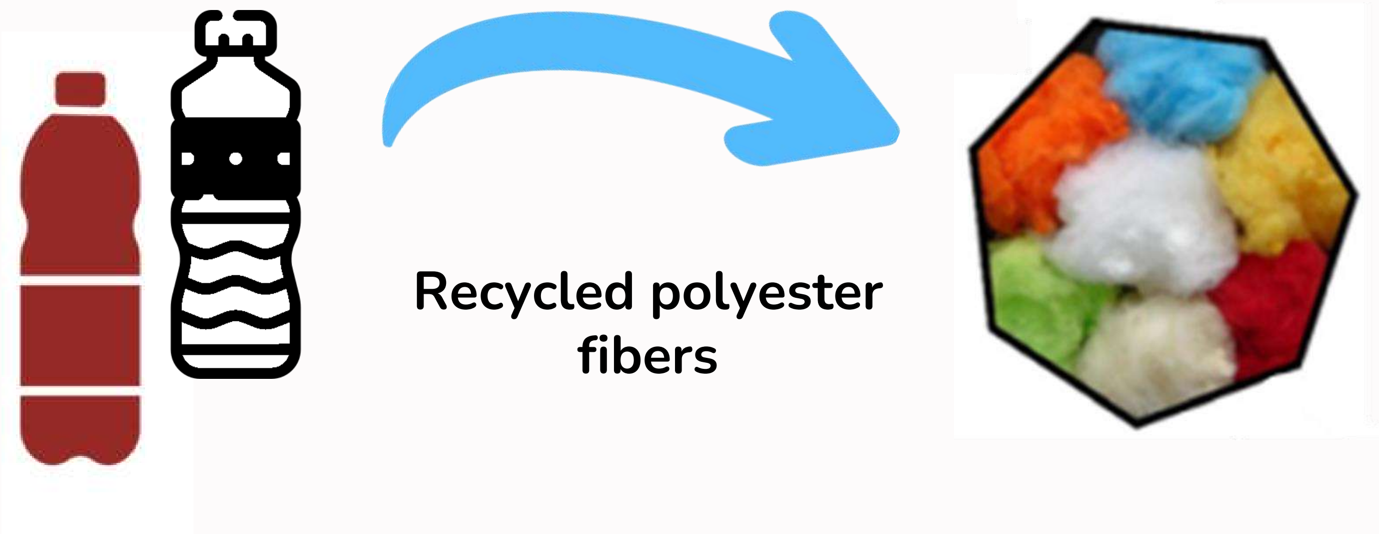
01 Background

European Commission: Regulations to reduce waste and promote circular economy approaches[8]

Materials: Substitutes for traditional plastics: **recycled PET and bio-based** plastics [9]

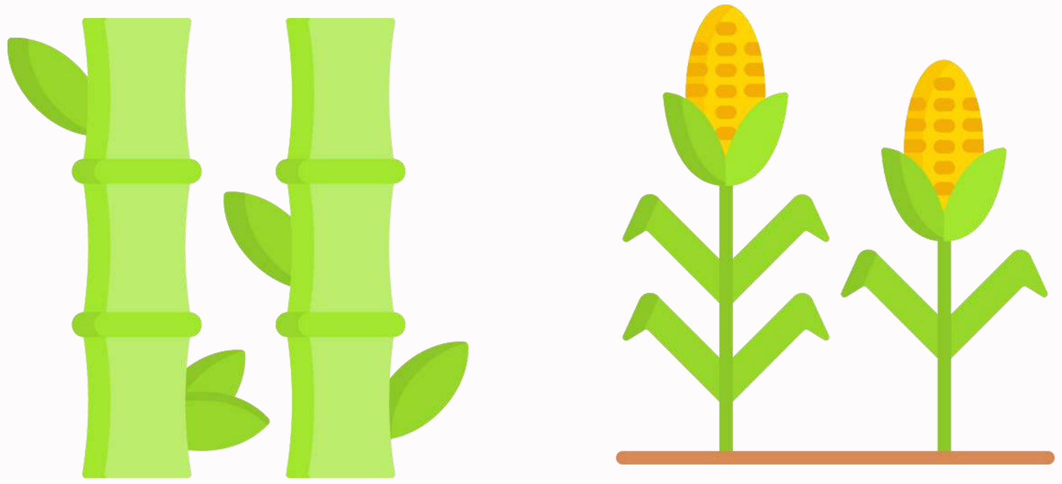
• Recycled PET:

Recycled PET (rPET): produced by processing used PET products, such as plastic bottles, into new material, including fibers



• Bio-based PET:

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



[8] 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.
[9] 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

02 Goal

Sustainable microfibers made of rPET and bio-PET, with improved overall performance for non-wovens

- *Antimicrobial*
- *Soft-Touch*
- *rPET flakes as simple as possible in terms of plastic raw material selection*

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03 Strategy

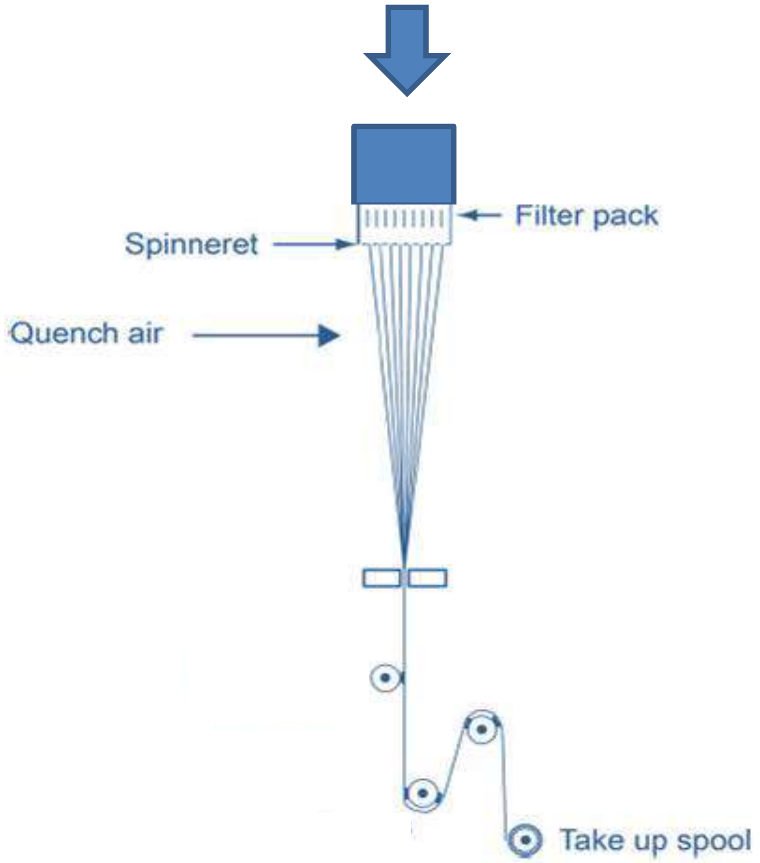
- Development of sustainable fibers

rPET flakes → Composition → Selection → Melt spinning → Fibers

rPET + bio-PET + Additives

Melt mixing

Screw-extruder



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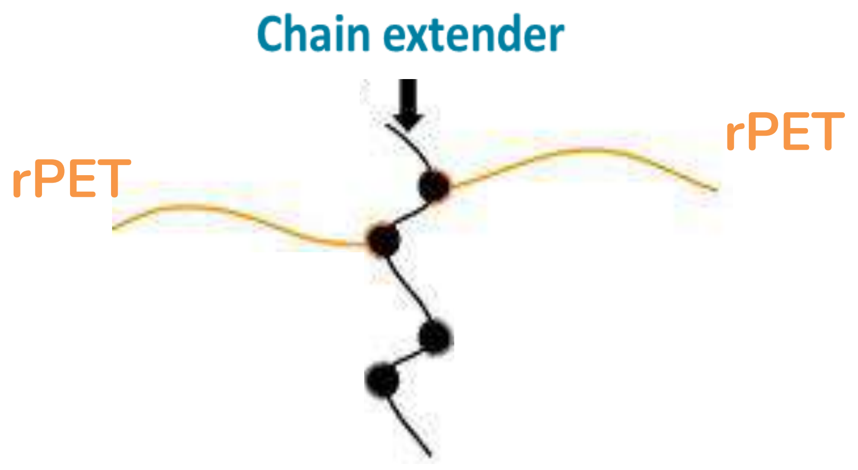
03 Strategy

Development of compositions

- During recycling and reprocessing, **PET undergoes chemical, mechanical, thermal and oxidative degradation**, which limits its use in many added-value applications [10]

- This problem arises when recycled PET derived from different sources [10]



Chain extender [10]

[10] Raffa, P.; Coltelli, M-B.; Savi, S.; Bianchi, S.; Castelvetro, V. (2012). Chain extension and branching of poly(ethylene terephthalate) (PET) with di- and multifunctional epoxy or isocyanate additives: An experimental and modelling study. Reactive and Functional Polymers. 72(1): 50-60. https://doi.org/10.1016/j.reactfunctpolym.2011.10.007

03 Strategy

Development of compositions

- During the reprocessing of rPET and its usage as product , it may occur oxidation and degradation caused by heat and sunlight
- Special additives:

Antioxidants[11;12]

Thermal / Light Stabilizers[11;12]

Inhibit the degradation of polymers through the removal of free radicals formed when polymers oxidize

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[11] Schyns, Z. O. G.; Shaver, M. P. (2021) Mechanical Recycling of Packaging Plastics: A Review. Macromol. Rapid Commun. 42, 2000415. https://doi.org/10.1002/marc.202000415.
[12] Siriorn, I.N.A; Munchumart, B; et al. (2009) Viscosity improvement of recycled poly (ethylene terephthalate) from waste bottles by adding antioxidants and chain-extender. E3S Web of Conferences 302, 02019. https://doi.org/10.1051/e3sconf/202130202019

04 Experimental Results

Formulations:

- rPET
- Chain extender
- Masterbatch Antioxidant/UV protection
- Bio-PET
- Masterbatch Soft-touch
- Masterbatch Antimicrobial

Fórmula 4

Fórmula 10

Formulation	F1 (%)	F2 (%)	F3 (%)	F4 (%)	F5 (%)	F6 (%)	F7 (%)	F8 (%)	F9 (%)	F10 (%)	F11(%)
rPET 2509	100	97	67	63							
rPET 2903					63	67	100				
rPET 12000								100	97	64	75
Chain extender		1	1	1	1	1			1	1	1
Master. (antioxidant/thermal-UV protection)		2	2	2	2	2			2	2	2
Bio-PET (20% biobased)			30	30	30	30				30	30
Master. Soft-touch				4	4						4
Master. Antimicrobial										3	3

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04 Experimental Results

Selection

Formulation	F1 (%)	F2 (%)	F3 (%)	F4 (%)	F5 (%)	F6 (%)	F7 (%)	F8 (%)	F9 (%)	F10 (%)	F11(%)
rPET 2509	100	97	67	63							
rPET 2903					63	67	100				
rPET 12000								100	97	64	75
Chain extender		1	1	1	1	1			1	1	1
Master. (antioxidant/thermal-UV protection)		2	2	2	2	2			2	2	2
Bio-PET (20% biobased)			30	30	30	30				30	30
Master. Soft-touch				4	4						4
Master. Antimicrobial										3	3

Intrinsic viscosity (IV) of rPET formulations

Formulation	Bio-PET	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Mean IV (dl/g)	**0.77**	**0.71**	**0.80**	**0.69**	**0.7**	**0.52**	**0.47**	**0.43**	**0.61**	**0.75**	**0.65**	**0.61**
Std	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**

VI values according to literature [13] :

- virgin PET: ≈0.7 dl/g;
- rPET ≈ 0.5 dl/g

- Formulations of rPET 2903 with low IV
- Chain extender, antioxidant and soft-touch additives led to an **increase in the IV and molecular weight**
- **Formulations of rPET 2509 with VI close to virgin PET**

[13] Candal, M.V.; Safari, M.; Fernández, M.; Otaegi, I.; Múgica, A.; Zubitur, M.; Gerrica-echevarria, G.; Sebastián, V.; Irusta, S.; Loaeza, D.; et al. Structure and Properties of Reactively Extruded Opaque Post-Consumer Recycled PET. *Polymers* **2021**, 13, 3531.

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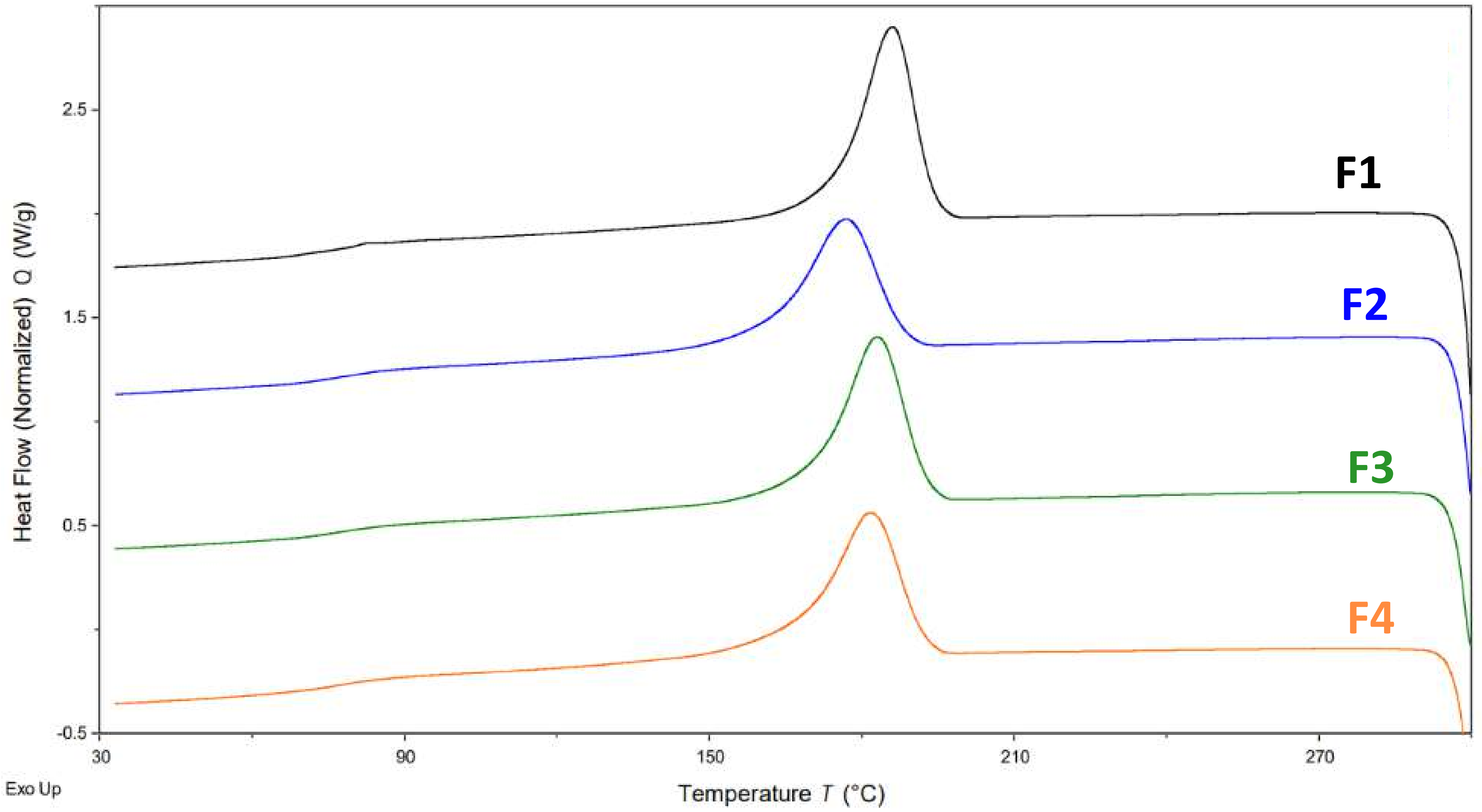
04 Experimental Results –Differential scanning calorimetry **(DSC)**

Formulation	F1 (%)	F2 (%)	F3 (%)	F4 (%)
rPET 2509	100	97	67	63
rPET 2903				
rPET 12000				
Chain extender		1	1	1
Master. (antioxidant/thermal-UV protection)		2	2	2
Bio-PET (20% biobased)			30	30
Master. Soft-touch				4

2nd heating

Thermal transition		Bio-PET	F1	F2	F3	F4
Glass transition	$T_{1/2,g}$ (°C)	82	82	80	82	82
Melting	$T_{p,m}$ (°C)	247	245	246	245	246
	ΔH_m (J/g)	38	39	43	39	41
Crystallization	$T_{p,c}$ (°C)	167	178	185	178	182
	ΔH_c (J/g)	21	36	40	36	39
	Xc (%)	27	28	31	28	29

2nd heating



Additives (Chain extender/ Antioxidant/ Soft-touch) led to an increase in the crystallization temperature

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04 Experimental Results

Production of melt-spun fibers

Formulation	F1 (%)	F2 (%)	F3 (%)	F4 (%)
rPET 2509	100	97	67	63
rPET 2903				
rPET 12000				
Chain extender		1	1	1
Master. (antioxidant/thermal-UV protection)		2	2	2
Bio-PET (20% biobased)			30	30
Master. Soft-touch				4

Short Fibers: F2 **Short Fibers: F3** **Short Fibers: F4**

Mechanical characterization

Formulation	Stress at break (CN) (EN ISO 5079:2020)	Elongation at break (%) (EN ISO 5079:2020)
F1	6,10±0,51	245±25
F3	9,25±0,40	109±8,4
F4	6,58±0,52	301±51

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04 Conclusions and Future work

- This study presented new formulations of recycled PET, bio-PET and additives that improved the intrinsic viscosity of rPET
- Innovative formulations are indicative of a better molecular weight and mechanical performance of rPET, showing great potential to form fibers for non-woven textiles
- Future work includes the production of non-woven textiles, evaluation of their mechanical properties, ageing and antimicrobial effectiveness as well as tests on an industrial scale.

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Thank you for your attention!

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