Horizon 2020 Programme

SCIRT

Innovation Action (IA)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003906

Start date : 2021-06-01 Duration : 36 Months
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Prototypes of yarn from task 2.1 with a recycled content over 50 percent

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SCIRT - Contract Number: 101003906

Project officer:

Document title	Prototypes of yarn from task 2.1 with a recycled content over 50 percent
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Number of pages	104
Document type	Deliverable
Work Package	WP02
Document number	D2.2
Issued by	CETI
Date of completion	2023-04-03 17:24:52
Dissemination level	Public

Summary

This report summarizes the recycling process of post-consumers textiles by using the mechanical and thermo-mechanical process for achieving yarns with a recycled content over 50%.

Approval

Date	By
2023-04-04 08:47:31	Mrs. Isabelle CORNU (CETI)
2023-04-11 09:25:47	Mrs. Evelien DILS (VITO)

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Task 2.2 : Increased value recycling of clothing and spinning

D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Mechanical recycling

CETI	03/04/2023

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Mechanical recycling process – Presentation plan

- Situation of the different recycling process investigation
- Mechanical recycling process and primary materials scientific approach
- Mechanical recycling process – Recycled cotton – Petit Bateau
- Mechanical recycling process – Recycled Wool/PET/Elastane – Xandres
- Mechanical recycling process – Recycled Viscose – Bel & Bo
- Mechanical recycling process – Recycled Denim – HNST

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Mechanical recycling process – Overview of all conducted tests

Partner	Recycling Trials	Raw Materials	Fraying	Blending	Carding	Rotor Spinning	Ring Spinning	Laboratory
PETIT BATEAU	**PRE-CONSUMERS**	*White Cotton Virgin Cotton (TK)*	✓	✓	✓	✓	✓	Regularity Tenacity
	POST-CONSUMERS	*Coloured Cotton Virgin Cotton (TK)*	✓	✓	✓	✓	✓	Regularity Tenacity
XANDRES BELGIUM	**PRE-CONSUMERS**	*PET/Wool/EA*	✓	✓	✓	*Substitute Nonwovens*		Regularity Tenacity
	POST-CONSUMERS	*PET Wool*	✓	✓	✓	✓	✓	Regularity Tenacity
hnst	**PRE-CONSUMERS**	*White Cotton*	✓	✓	✓	✓	✓	Regularity Tenacity
	POST-CONSUMERS	*Denim Tencel*	✓	✓	✓	✓	✓	Regularity Tenacity
Bel&Bo	**PRE-CONSUMERS**	*Viscose Tencel*	✓	✓	✓	✓	✓	Regularity Tenacity
	POST-CONSUMERS	*Viscose Tencel*	✓	✓	✓	✓	✓	Regularity Tenacity

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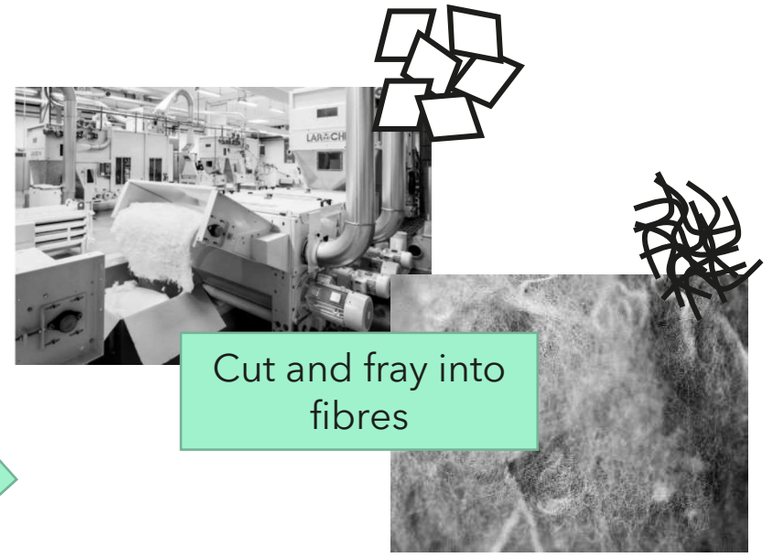
Mechanical recycling process – tests conducted along the workflow

Textile POC

Fabric quality (pilling, colour, resistance and elongation…)

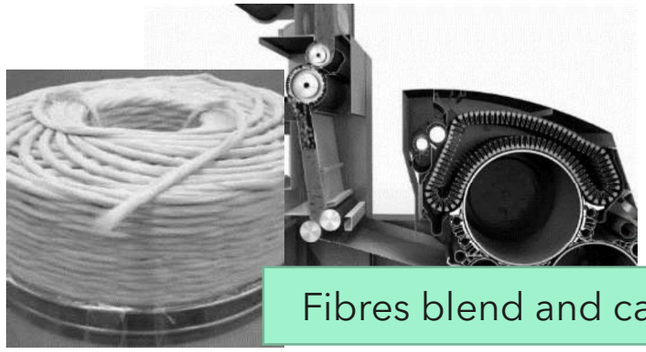
Sorted & dismantled garments

Control of textile feedstock (warp and weft, knit, yarn type…)



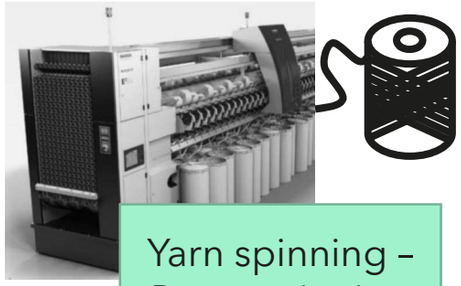
Cut and fray into fibres

Frayed fibres quality Control (Mean Length, short fibre content, fraying quality…)



Fibres blend and carding

Sliver quality control (regularity, fibres length…)



Yarn spinning – Rotor spinning & ring spinning

Yarn quality (regularity, tenacity, elongation…)

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D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Mechanical recycling

Primary materials – Scientific approach

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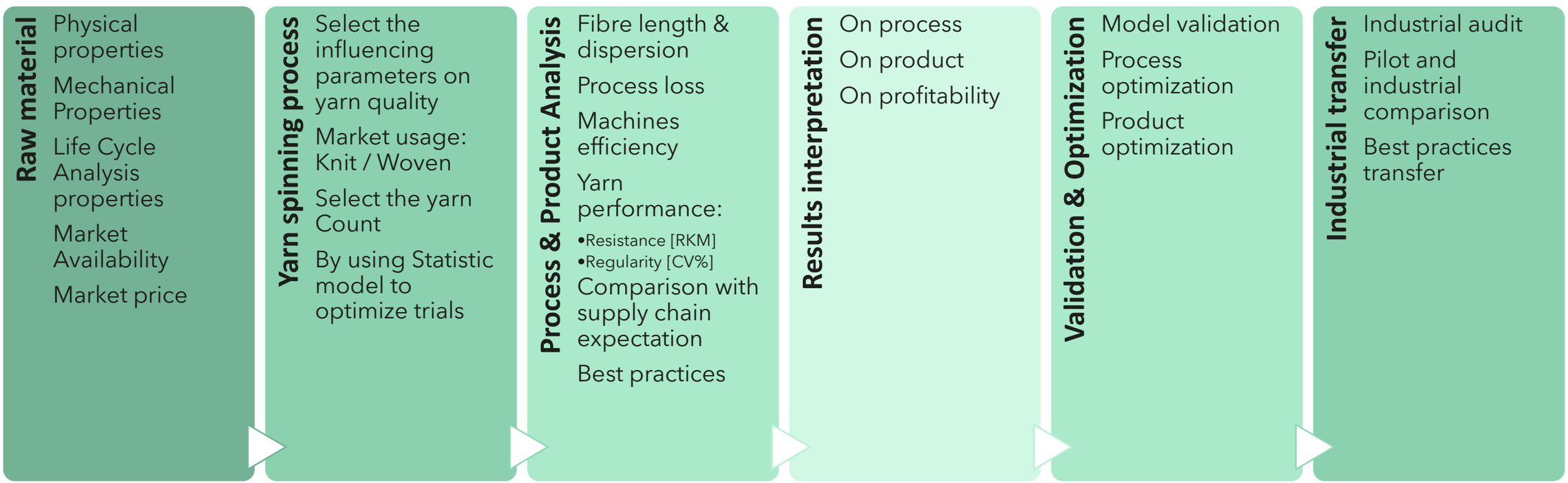
Scientific approach Explanation



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Yarn Spinning Investigation with virgin materials – Investigation plan

Testing on virgin materials allowed us to define the best achievable results on CETI technologies and to evaluate them against the best market practices. Here is the list of material tested and process parameter adaptations.

Raw Materials

- Cotton GOTS [TR] 31mm
- Cotton GOTS [BF] 29,2mm
- PET 1,7dtex/38mm
- rPET 1,7dtex/38mm
- Viscose 1,7dtex/38mm
- Lyocell 1,3dtex/38mm

Yarn Count

- Nm 27
- Nm 34
- Nm 40
- Nm 50
- Nm 60

Yarn Alpha Twist

- 120
- 135
- 150

Process conditions

- Technologie: rotor spinning
- Conditions
  - Comber tools and speed
  - Rotor tools and speed:
  - Adapter tools

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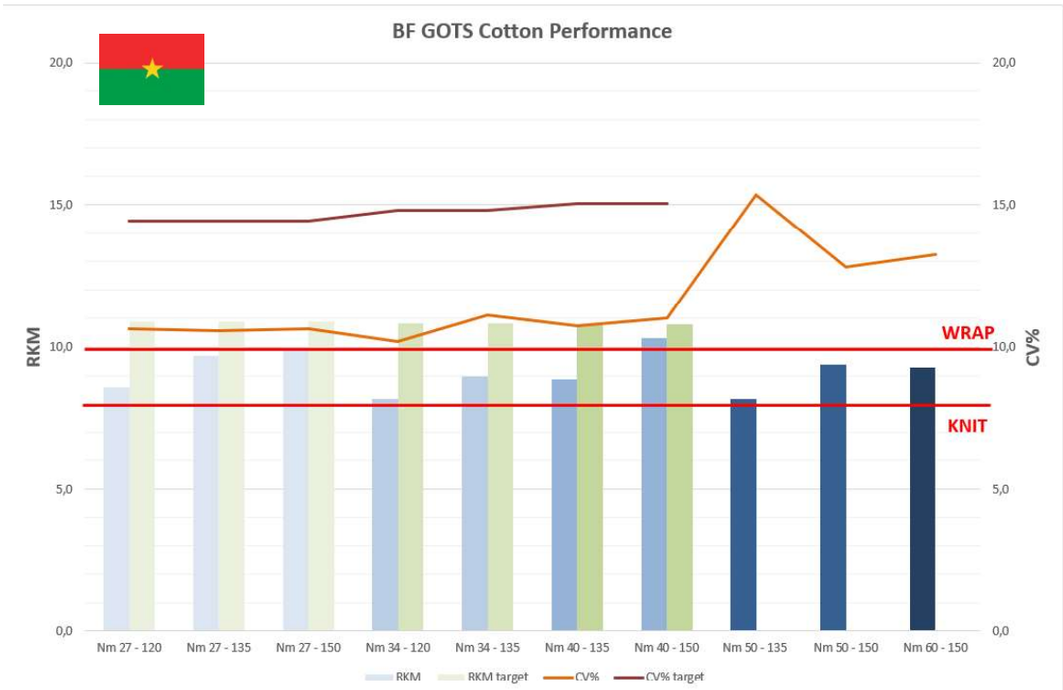
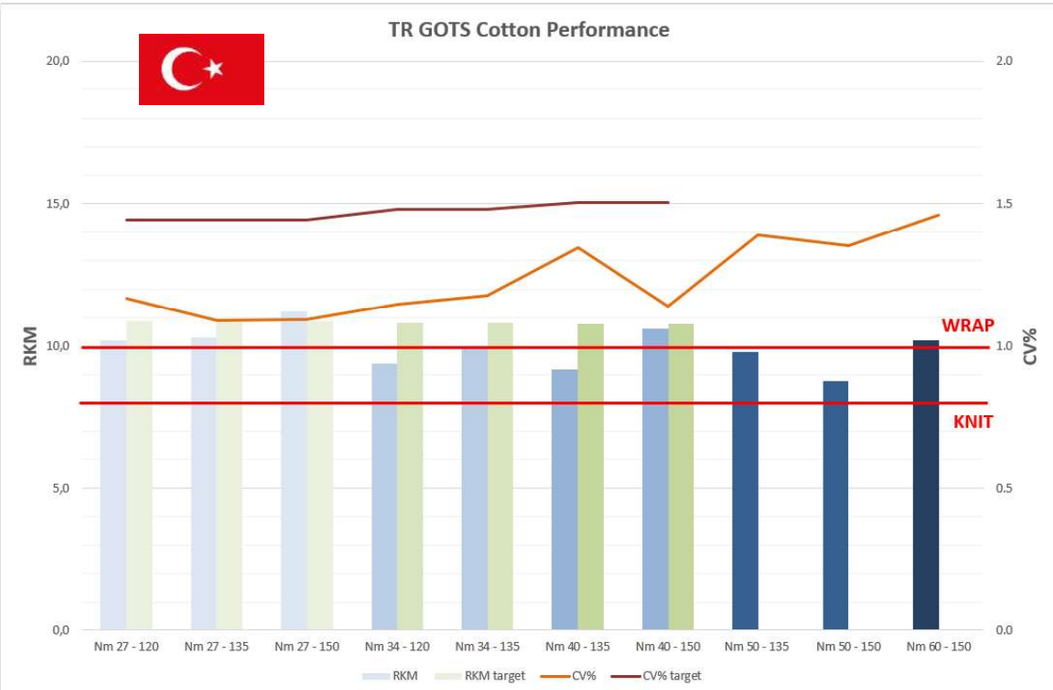
Yarn Spinning Investigation with virgin materials – Cotton Results





GOTS Cotton	Micronaire Index [IM]	Fibre Length
TR	4,35	31mm
BF	3,97	29mm

High IM (still under 4,5)

Better yarn resistance

Stronger fibres in the yarn

Low CV%

Better yarn quality

Finer fibres in the yarn

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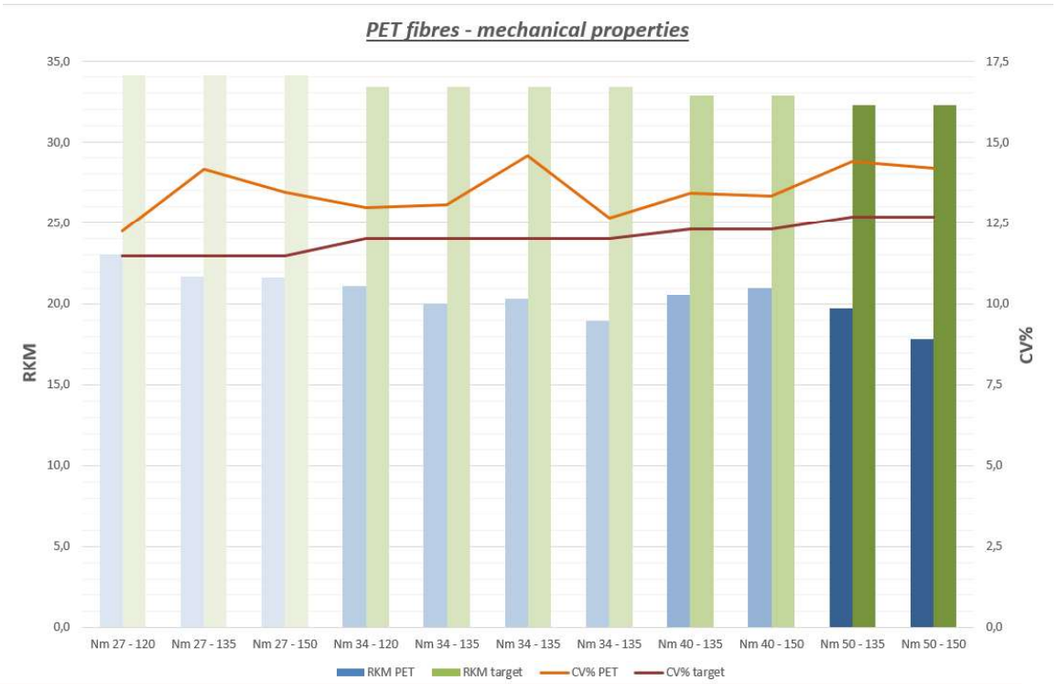
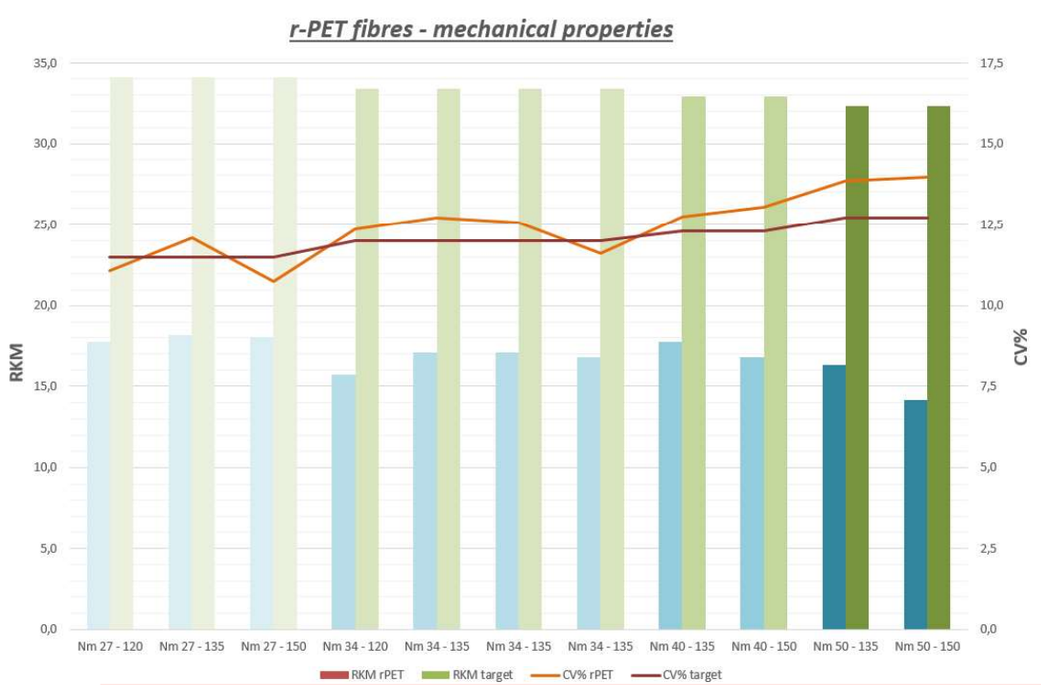
Yarn Spinning Investigation with virgin materials – PET Results





PET vs r-PET

- Fibre specification (tenacity, elongation) ➔ -20% for rPET vs PET
- Regularity: similar CV% linked to the fibre titre and fibre length (1,7dtex/38mm)

Rotor spinning vs Ring spinning

- Difference of 40% for PET and more for rPET
- Regularity linked to the standardized fibres

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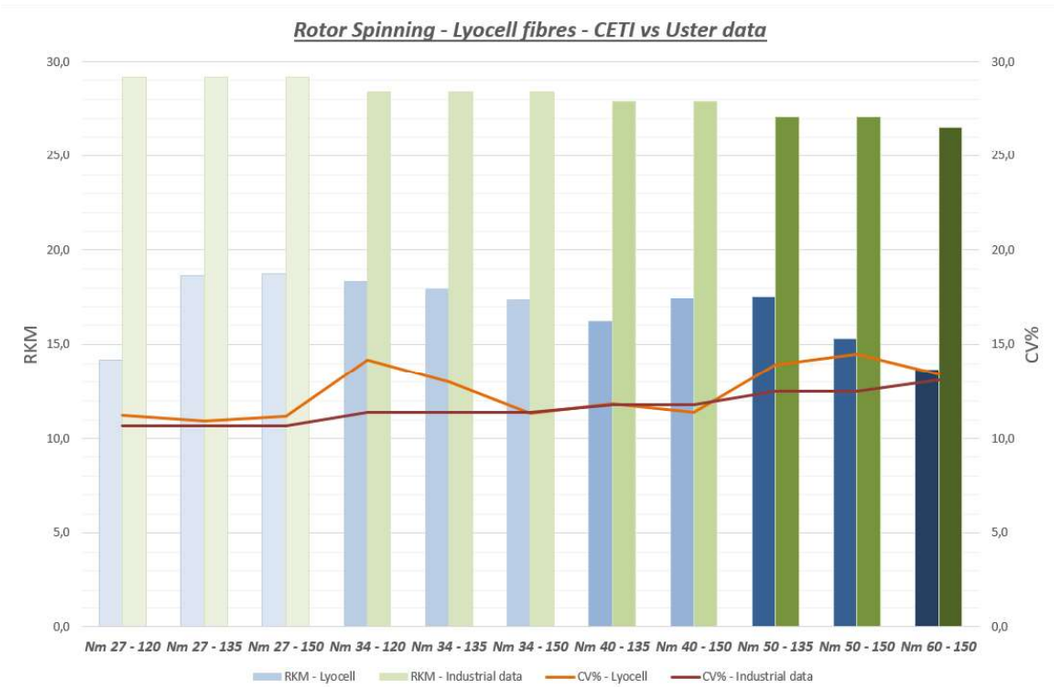
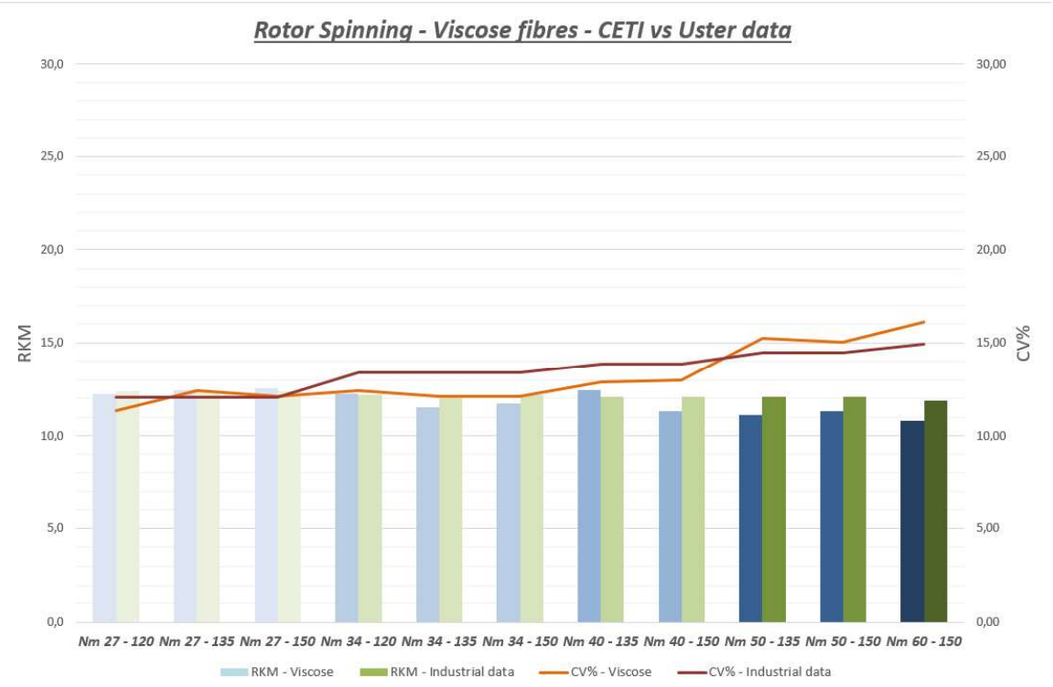
Yarn Spinning Investigation with virgin materials – Viscose & Lyocell Results





Lyocell vs Viscose

- Fibre specification (tenacity, elongation) ➔ -15% viscose vs Lyocell
- Regularity: similar CV% linked to the fibre titre and fibre length (1,7dtex & 1,3dtex/38mm)

Rotor spinning vs Ring spinning

- Lyocell difference of 30%
- Viscose: similar properties
- Regularity linked to the standardized fibres

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D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Mechanical recycling

Recycled Cotton

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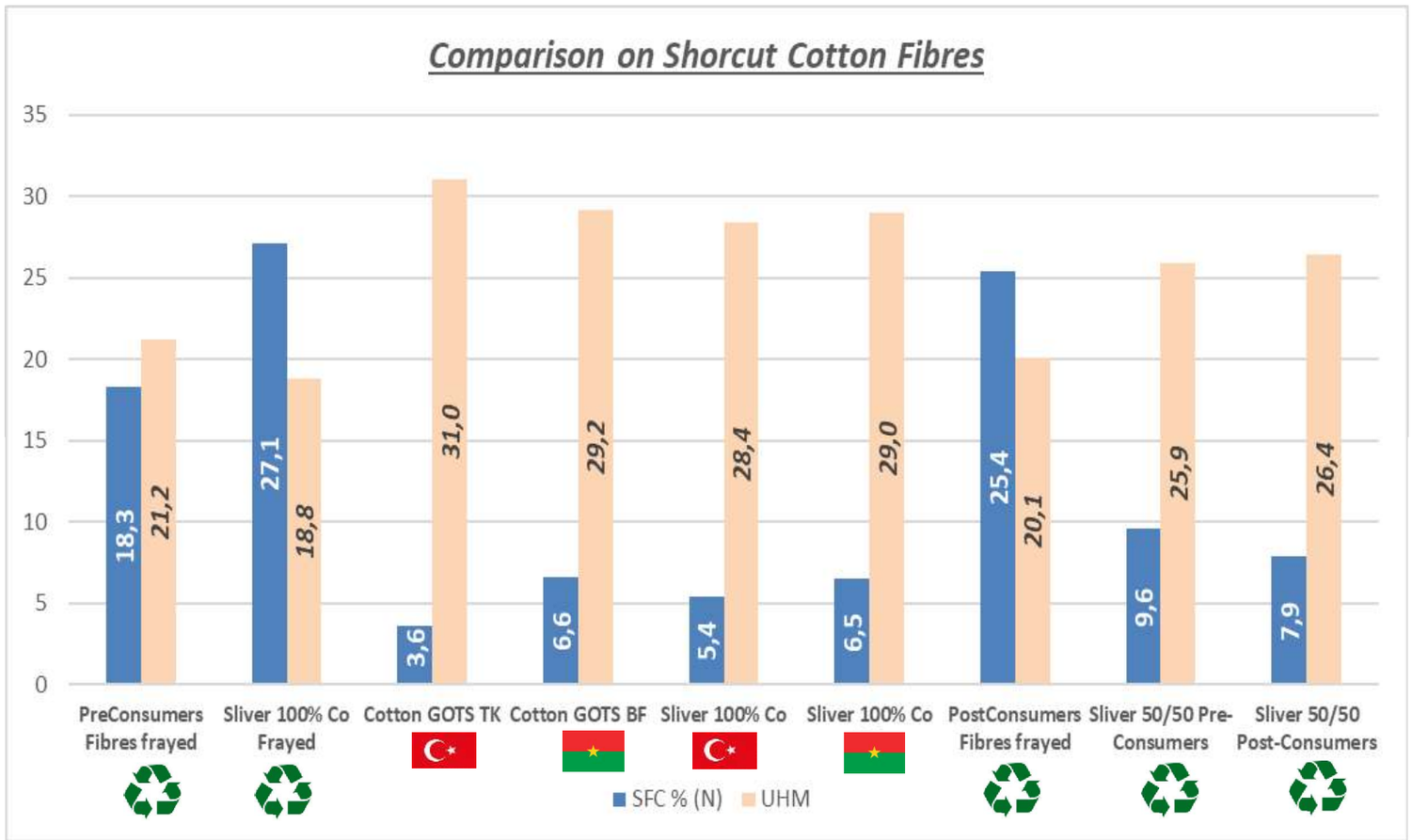
PRIMARY MATERIALS – Carding Analyses



UHM means Upper Half Mean Length
SFC% means Short Fibre Content below 9mm

Loss of **Recycled Cotton** fibre length to **10 %** during the carding

Loss of **Virgin Cotton** fibre length to **8 %** during the carding

Mixing fibres enable to ease the carding process **for better yarn**

Post-Consumer fibres lengths are **compatible** with Virgin Cotton fibres

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Mechanical Recycling Process - PETIT BATEAU

Step 1

- Pre-consumer feedstock Cotton
- Impact fraying conditions
- Yarn spinning
  - Yarn count: Nm 34
  - Recycled content: 30% & 70%
  - Rotor spinning investigation thanks virgin materials scientific approach

Step 2

- Pre-consumer feedstock Cotton
- Yarn Spinning
  - Yarn count: Nm 40 – 50 – 60
  - Recycled content: 50% & 60%
  - Rotor spinning investigation = Step 1 conditions
- Knittability trials

Step 3

- Pre-consumer optimization

Step 4

- Post-consumer optimization

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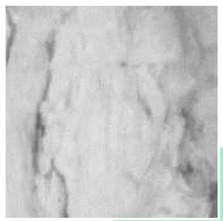
Step 2 - Mechanical Recycling Process

Pre-Consumers Trial Plan :



R-cotton content

- 50%
- 60%

Yarn Count

- Nm 40
- Nm 50
- Nm 60

Process conditions

- Technology: rotor spinning
- Conditions
  - Comber tools and speed
  - Rotor tools and speed
  - Adapter tools

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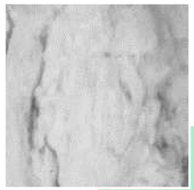
Step 2 - Mechanical Recycling Process



R-cotton content

- 50%
- 60%
- 70%
- 80%

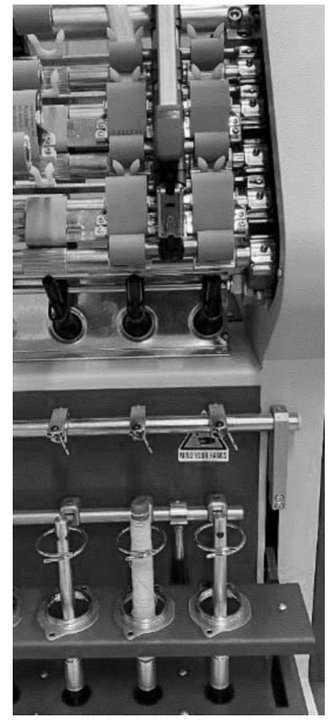
Virgin Cotton from TR (31 mm)

Yarn Count

- Finer yarn as possible with different recycled content

Process conditions

- Technology: Ring Spinning
- Rotor Spinning



Conclusions:

- Over 50% of recycled content, ring spinning not possible
- At 50% of recycled content, Nm 25 and coarser is possible (without regularity guarantee)

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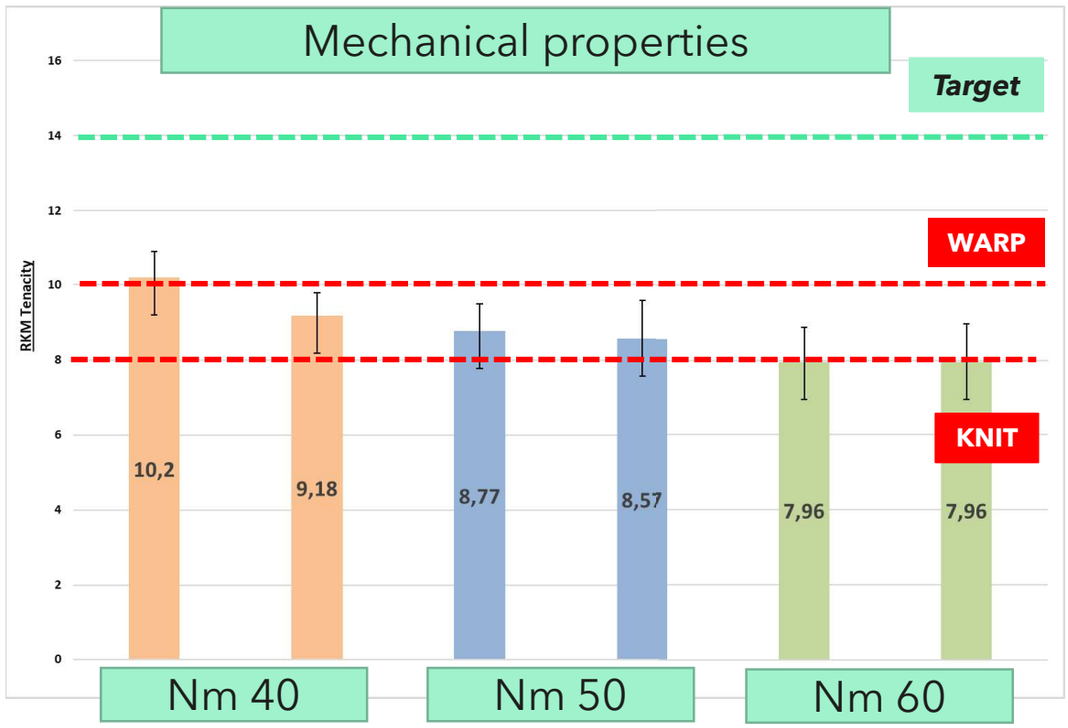
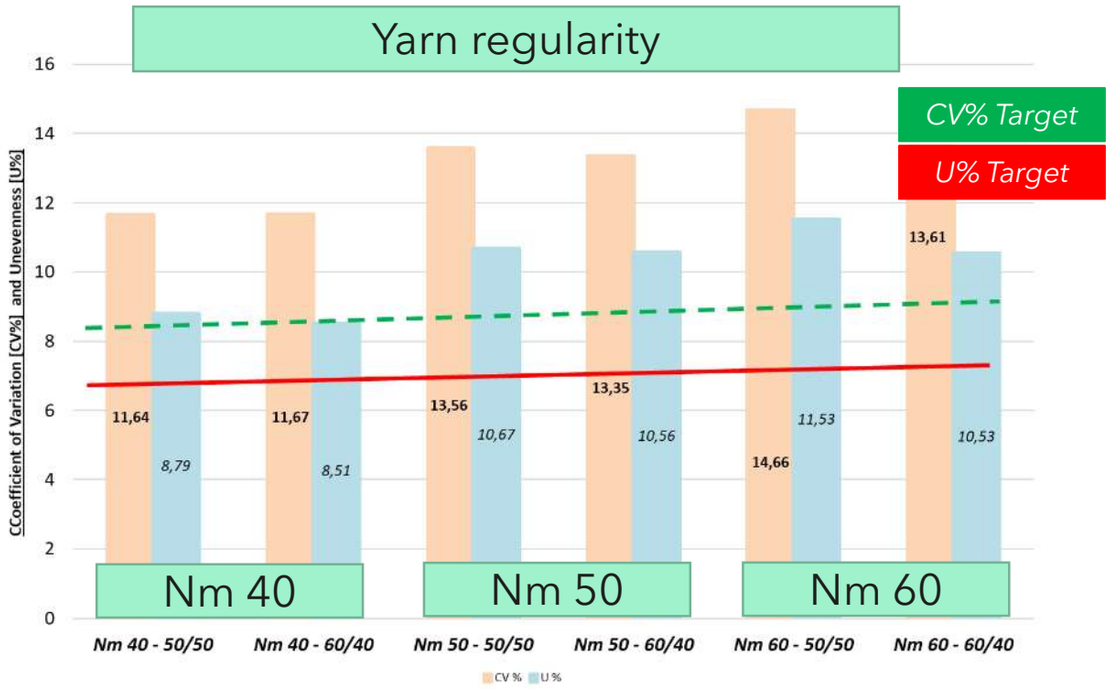
Step 2 - Mechanical Recycling Process





Targets specifications for Cotton yarn on Ring Spinning

RKM under the specifications

Low piecings during yarn spinning with 50% of recycled content

Loss of 30% of maximum force with recycled content

Increase of the recycled content ➔ Yarn is less regular

Finer yarn with samed recycled content ➔ Less good regularity

However, the number of piecing during the prototyping is more difficult by using the 60/40 ratio

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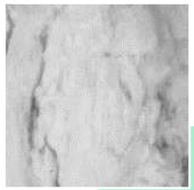
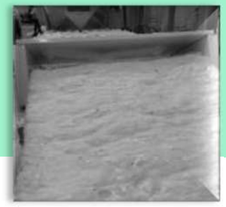
Step 3 - Mechanical Recycling Process



R-cotton content

- 20%
- 30%
- 40%

Virgin Cotton
from TR (31 mm)

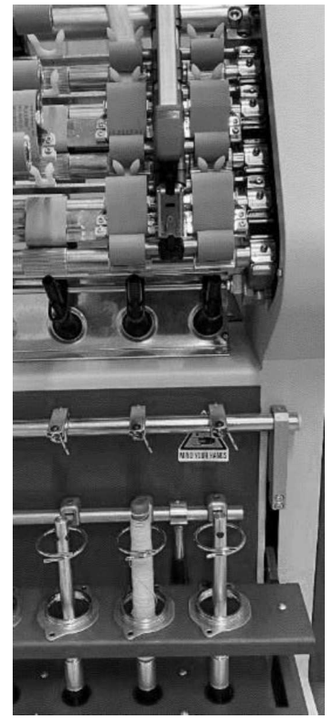


Yarn Count

- Nm 60

Process conditions

- Technology:
  Rotor Spinning
  Ring Spinning



Conclusions:

- Easier to create a regular sliver on carding step
- Higher resistance with a lower recycled amount on rotor yarn

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Step 3 - Mechanical Recycling Process

Comparison on Nm 60 yarns from Pre-Consumers cotton fibres

High virgin **content** → **Better resistance** of yarns

Knittability up to 40% recycled content

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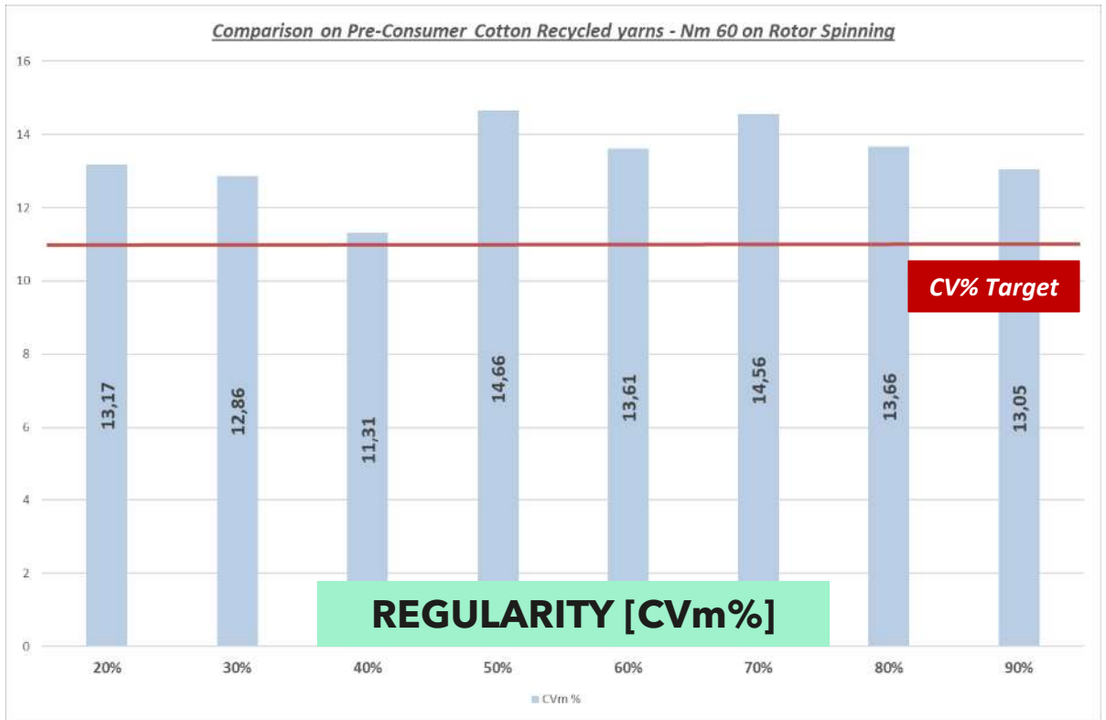
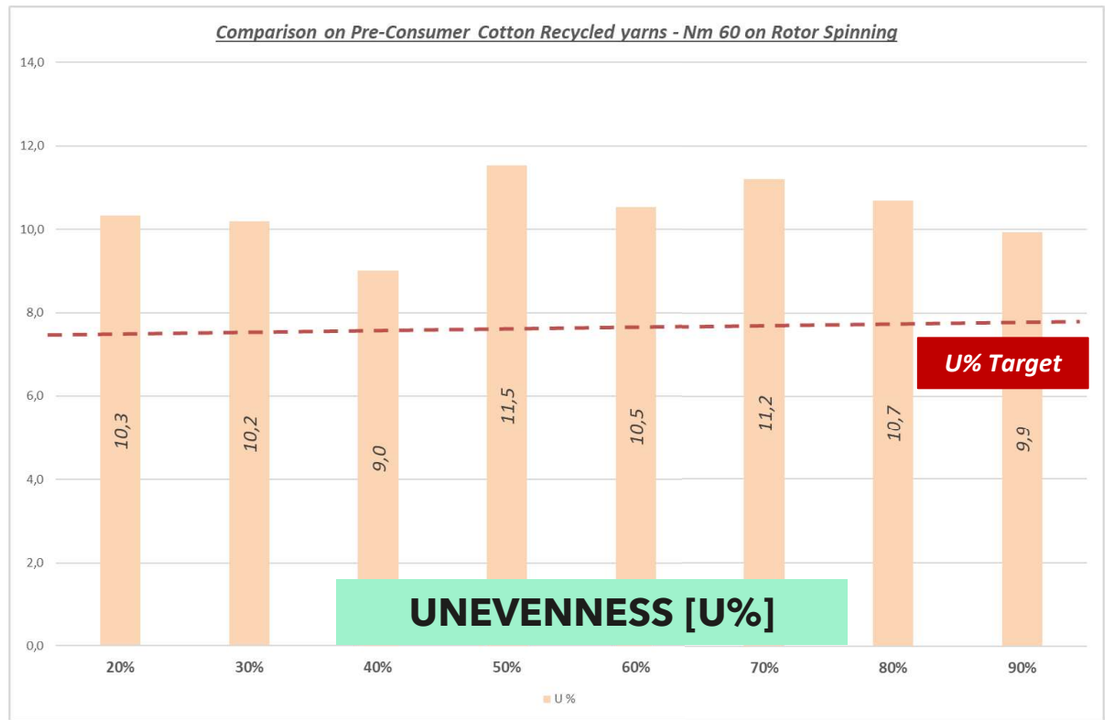
Step 3 - Mechanical Recycling Process

Comparison on Nm 60 yarns – Regularity and Unevenness





High virgin **content** → **Less regularity** on yarns

CVm% needs to be the lowest as possible

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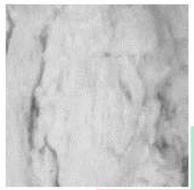
Step 4 - Mechanical Recycling Process



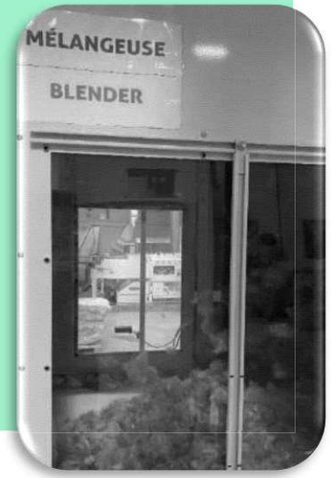
R-cotton content

- Technology
  - Carding
    - 50%

Virgin Cotton
from TR (31 mm)

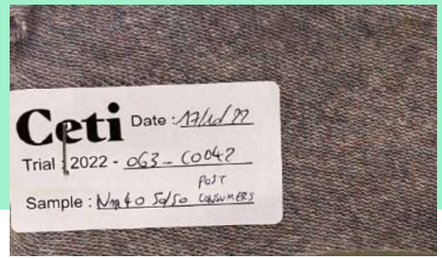
Yarn Count

- Nm 40



Process conditions

- Technology:
  Rotor
  Spinning
  Ring
  Spinning



Conclusions:

- Carding enables to open mostly the recycled yarns into the fibres blend
- Knittability had any issue by using this rotor yarn on Post-Consumers textile waste

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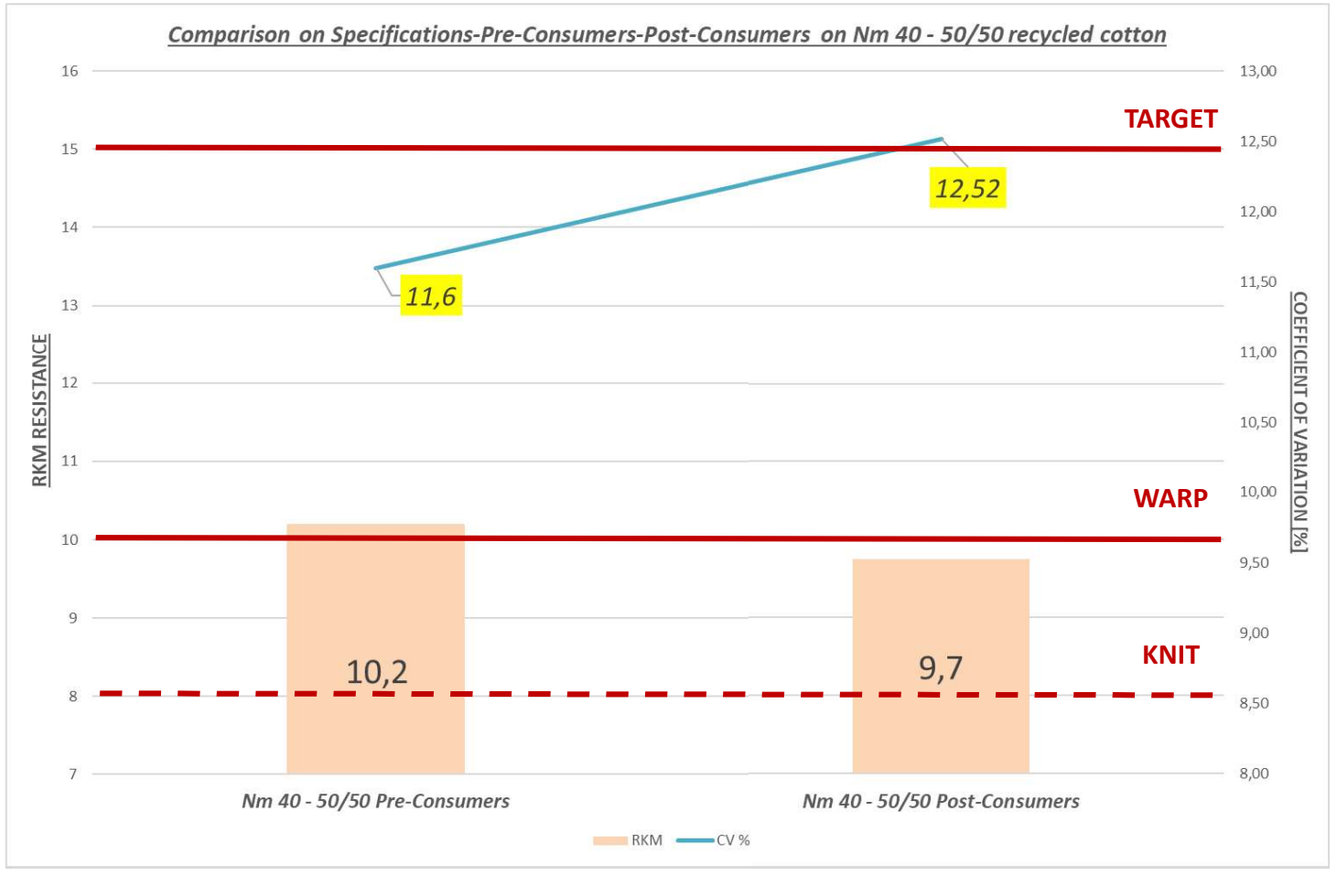
Step 4 - Mechanical Recycling Process

Comparison between specifications, Pre-Consumers and Post-Consumers yarns



RKM under the specifications, but **close to Pre-Consumers** value

Low piecings during yarn spinning with 50% of recycled content

Loss of 30% of maximum force with recycled content

Need to wait for the **fabric quality** through different equipments (Pilling test, Tensile strength…)

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Mechanical Recycling Process – Conclusions

Final comparisons – Pre-Consumers

Yarn Count	Nm 40	Nm 40	Nm 50	Nm 50	Nm 60	Nm 60
Yarn Technology	Ring Spinning	Rotor Spinning	Ring Spinning	Rotor Spinning	Ring Spinning	Rotor Spinning
Composition [%]	100% Combed Cotton	50 % R-cotton 50% Cotton	100% Combed Cotton	50 % R-cotton 50% Cotton	100% Combed Cotton	50 % R-cotton 50% Cotton
Elongation	6%	7%	5,65%	5,90%	5,8%	6,3%
Minimum force [cN]	300	207	250		215	
Average force [cN]	**375**	**243**	**300**	**174**	**250**	**131**
CV [%]	**7,0%**	**11,6%**	**6,4%**	**13,6%**	**6,6%**	**14,7%**
RKM	**15**	**10,2**	**15**	**8,8**	**>15**	**8,0**
Regularity [%]	8,4%	8,79%	8,9%	10,67%	8,8%	11,53%
CVm [%]	11,1%		11,1%		11%	
Thinness [/km]	1/1000	1/1000	1/1000	117/1000	1/1000	231/1000
Thickness [/km]	8/1000	6/1000	10/1000	7/1000	10/1000	3/1000
Neps 200% [km]	16/1000	171/1000	19/1000	655/1000	19/1000	798/1000

The final results obtained with recycled cotton and rotor spinning process are not for sure at the level of the ring spinning yarns due to:

- Technology: ring spinning gives better mechanical properties by using special virgin raw material
- High quality virgin cotton (removal of all short fibres)

But can nevertheless be used in knitting application with good final textile application

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Mechanical Recycling Process – Conclusions

Final comparisons – Pre-Consumers vs Post-Consumers

Yarn Count	TARGET - Nm 40	Nm 40 – Pre-Consumers	Nm 40 – Post-Consumers
Yarn Technology	Ring Spinning	Rotor Spinning	Rotor Spinning
Composition [%]	100% Combed Cotton	50 % R-cotton - 50% Cotton	50 % R-cotton - 50% Cotton
Elongation	6,3%	7%	5,6%
Minimum force [cN]	300	207	215
Average force [cN]	**375**	**243**	**239**
Average Force CV [%]	7,0%	7,0%	6,8%
RKM	**15**	**10,2**	**9,7**
U [%]	8,4%	8,8%	9,9%
CVm [%]	**11,1%**	**11,6%**	**12,5%**
Thinness [/km]	0	1	4
Thickness [/km]	8	6	8
Neps 200% [/km]	16	171	223

This investigation confirms there is no difference between a pre-consumer and post-consumer cotton in rotor spinning application.
The difference between spinning technologies comes from the raw material (special virgin cotton with short fibre removal) and final type of yarn (stronger in ring spinning).

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Mechanical Recycling Process – Conclusions

Technical data sheets of the process conditions for the obtention of the yarn with 50% of recycled content

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FRAYING Update: 26/10/2022

PARTNER

RAW MATERIAL Cotton from garments

FRAYING PROCESS

Size of cut raw materials	[mm]	
Inlet Speed 1	[mpm]	1,1
Inlet Speed 2	[mpm]	1,0
Loading Speed	[%]	7%
Sizing Ratio	[l/h]	60
Cleaning roll Speed	[%]	90%
First Cadette Speed roll 1	[mpm]	1700
First Cadette Speed roll 2	[mpm]	2280
Second Cadette Speed roll 1	[mpm]	2280
Second Cadette Speed roll 2	[mpm]	2200
Fan Speed	[%]	70%
Outlet Speed 1	[mpm]	1,6
Outlet Speed 2	[mpm]	1,7
Opening Cadette 1	[mm]	5
	[mm]	6
Opening Cadette 2	[mm]	8
	[mm]	9

ANALYSIS FIBER LENGTH

Span length SL 2,5 %	[mm]	22,4
Span length SL 50 %	[mm]	8,9
Uniformity ratio UR %	[mm]	39,7
Short fiber content SFC % (N), <9mm	[%]	25,4%
Mean Length ML	[mm]	13,5
Upper High Mean Length UHM	[mm]	20,1
Uniformity Index UI %	[%]	67,4%
Span length SL 66,7 %	[mm]	7
CV %	[%]	40,6%

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CARDING Update: 26/10/2022

PARTNER

RAW MATERIAL

		Ratio
Recycled Cotton	[%]	50%
Cotton GOTS 31mm - Turkey	[%]	50%

OPENING BLENDING CARDING

Equalizer	[rpm]	230
Vertical Conveyor	[mpm]	12
Breast Conveyor	[rpm]	230
Feeding Cylinder	[mpm]	3
Opening Cylinder	[rpm]	2300
Ribbon Weight	[g/m]	5
Feed Weight	[3->30]	650
Manual Calibration	[Menu C]	276
Sliver Tension	[2->29]	1,76
Outlet speed	[mpm]	40

ANALYSIS FIBER LENGTH

Span length SL 2,5 %	[mm]	27,3
Span length SL 50 %	[mm]	11,7
Uniformity ratio UR %	[mm]	43,2
Short fiber content SFC % (N), <9mm	[%]	7,9
Mean Length ML	[mm]	19,8
Upper High Mean Length UHM	[mm]	26,4
Uniformity Index UI %	[%]	75
Span length SL 66,7 %	[mm]	8,9
CV %	[%]	35,6

Ceti

SCIRT

SPINNING Update: 26/10/2022

PARTNER

		Ratio
RAW MATERIAL		
Recycled Cotton	[%]	50%
Cotton GOTS 31mm - Turkey	[%]	50%

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	40
Alpha Twist	[α]	160
Yarn Twist	[T/m]	1025
Rotor	T 640 BD	
Rotor Speed	[rpm]	60000
Opening roll	D 174 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/G	
Draft Ratio	[U.I.]	190
Piecings	[U.I.]	1
Clearer Cuts	[U.I.]	3
Outlet speed		
CV %	[%]	14,6%

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	0,96
RKM	[U.I.]	9,7
Elongation	[%]	5,6
Maximum Force	[cN]	239

ANALYSIS REGULARITY

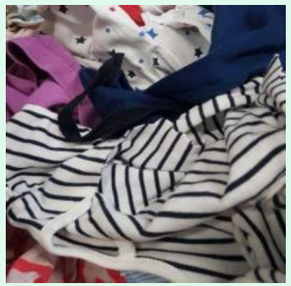
CV %	[%]	12,5	Thin -30%	[/km]	1936
U %	[%]	9,9	Thin -40%	[/km]	119
Hairiness	[H]	4,82	Thin -50%	[/km]	4
sH %	[sH]	0,91	Thin -60%	[/km]	0
Thick +35%	[/km]	137	Neps + 140%	[/km]	2637
Thick +50%	[/km]	8	Neps + 200%	[/km]	223
Thick +70%	[/km]	2	Neps + 280%	[/km]	21
Thick +100%	[/km]	0	Neps + 400%	[/km]	3

Ceti

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

SCIRT.

Summarize of the Investigation – update April 2023

Feedstock	Delivery	Fraying	Blending and Carding	Yarn spinning	Final Solution
Pre-consumer	300 kg 	265 kg 2 prototypes 	210 kg 14 prototypes 	24 kg 40 prototypes 	X
Post-consumer	250 kg 	188 kg 1 prototype 	10 kg 1 prototype 	2 kg 1 prototype 	1 yarn prototype 1kg 1 knit Proof of concept 1 complete process data sheet for industrial transfer

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

SCIRT.

D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Mechanical recycling

Recycled Viscose

Bel&Bo

CETI	22/02/2023

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Mechanical Recycling Process – Steps

Bel&Bo

Step 1

- Pre-consumer feedstock of Viscose
- Impact fraying conditions
- Carding of blend recycled content with Viscose and Lyocell
- Yarn spinning with Nm 40, 42

Step 2

- Yarn spinning with Nm 47
- Optimization of different parameters
- Alpha Twist - Comber tool - Adapter tool

- Post-consumer feedstock of Viscose
- Fraying with results from step 1
- Carding of blends
- Yarn spinning
  - Yarn count: Nm 47

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

SCIRT.

Step 2 - Mechanical Recycling Process

Pre-Consumers investigation:

Fraying

First path

(4 fraying drums)

- UHM: 21,8 mm
- SFC%: 29,9%
- Waste Ratio = 13%

Blend & Carding

Recycled content

- 50%
- 60%
- 70%
- 80%
- With Viscose fibre 1,7dtex/38mm
- With Lyocell fibre 1,3 dtex/38mm

Yarn count

Following garments analysis

- Nm 40
- Nm 42

2nd stage with Partner specification

- Nm 47

Yarn Spinning

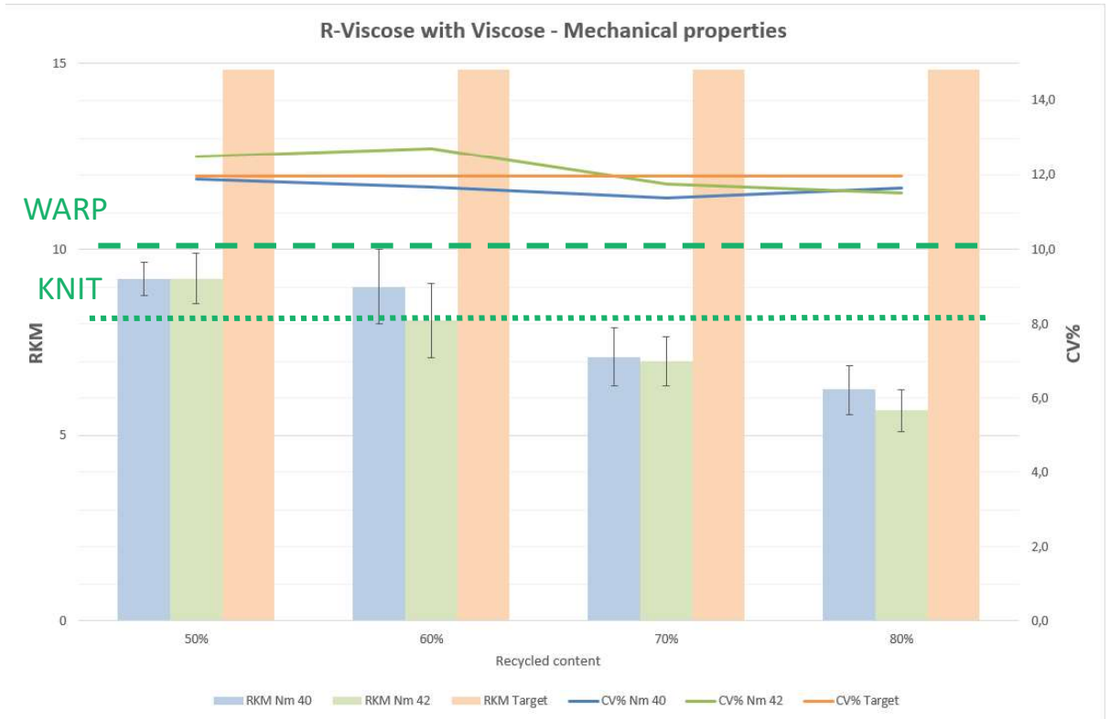
Similar approach than preliminary materials

Optimization of the yarn spinning process for the

Nm 47

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process



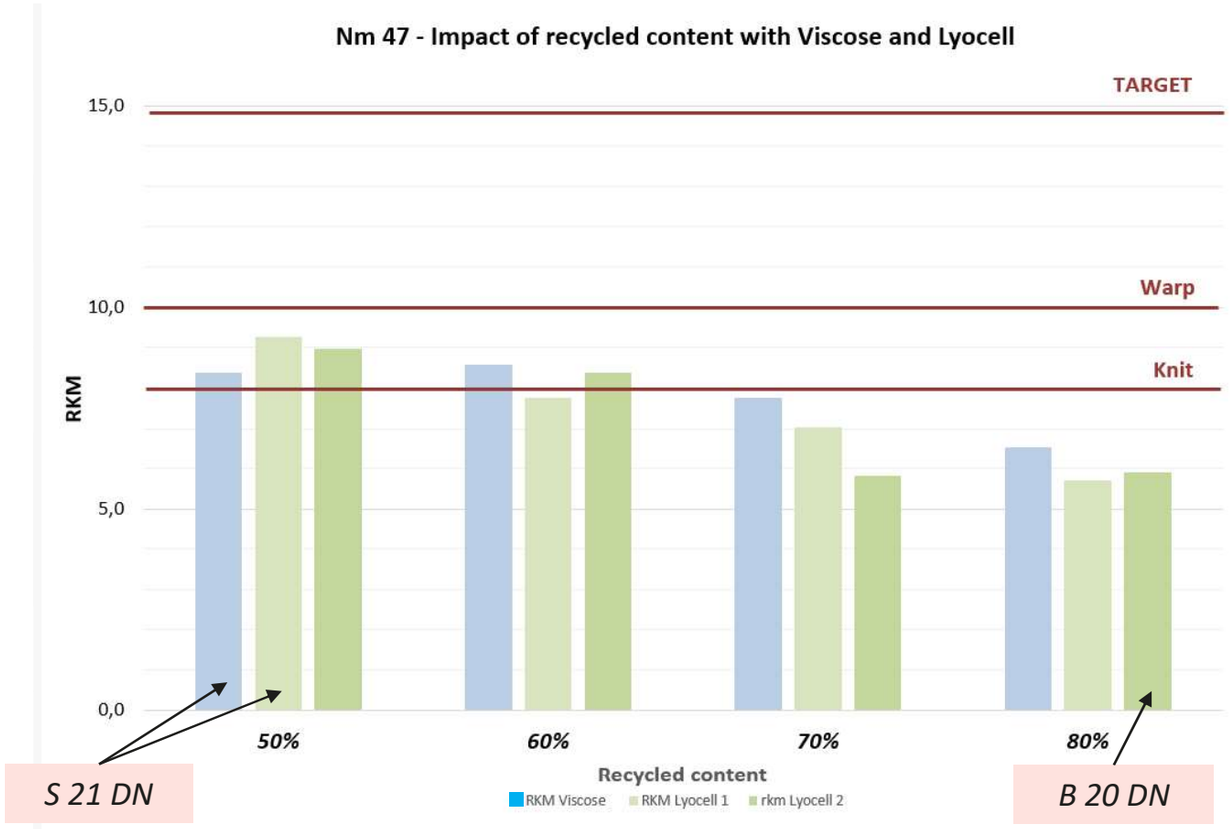
Improvement of the yarn spinning process on Nm 42			
Alpha Twist	145	150	155
Opening roll	S 21 DN		B 20 DN
Adapter type	KSK4A	K4A	KSK6A

Impact of the recycled content on Nm 47 with		
Alpha Twist	**160**	
Opening roll	S 21 DN	B 20 DN
Adapter type	KSK4A	

- The high recycled content (>50%) reduces the RKM of min 30%
- Yarn regularity is answering to the target

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process



Recycled content

- RKM reduction while recycled content increases

Lyocell vs Viscose

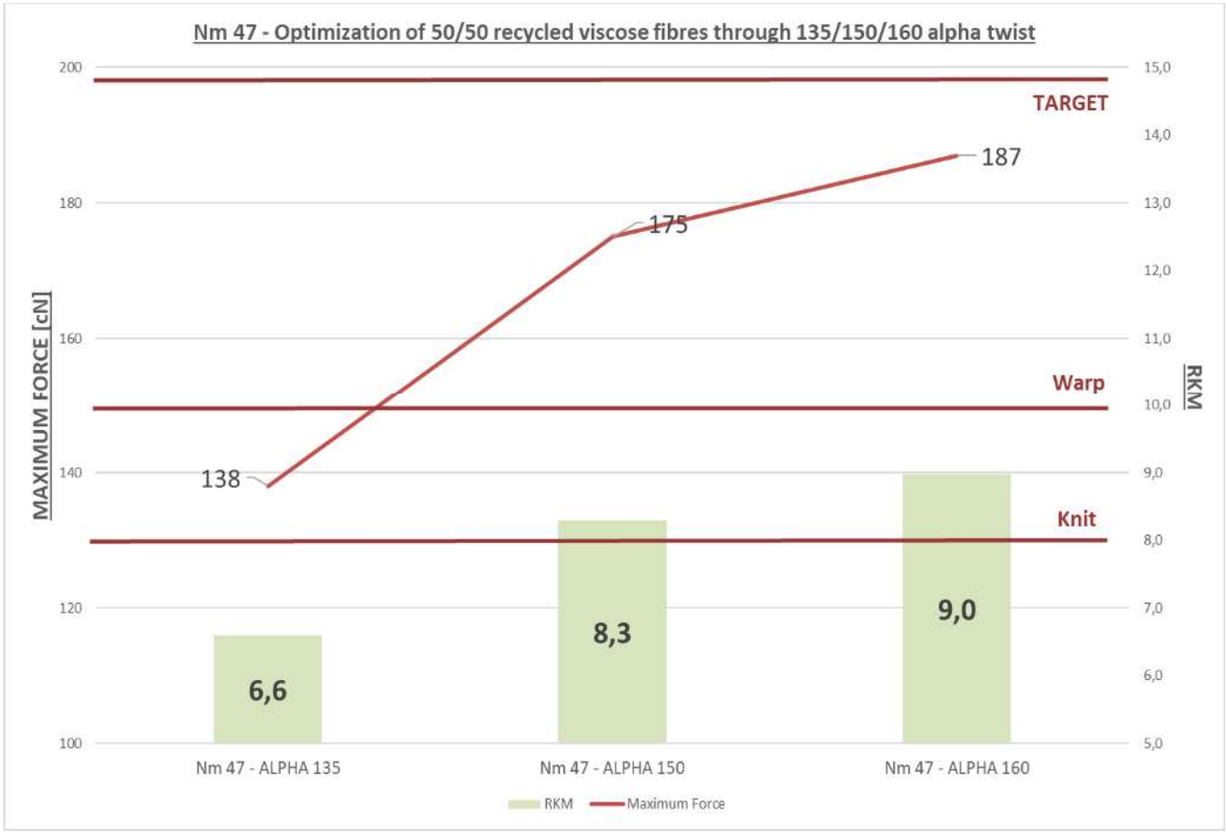
- Alpha torsion impact (100% viscose Nm 50 ➔ RKM better with alpha 135 than 150)

Opening Roll type

- S21DN opening roll is the most convenient reference in terms of resistance
- B20DN is more convenient for piecings

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process



Alpha Twist

- High value ➔ High resistance
- 160 is better to apply

Opening roll type

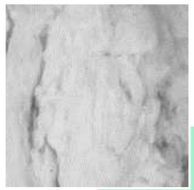
- B 20 DN convenient for low piecings

Knittability

- Feasible on alpha 160 and 150
- Break on knitting with alpha 135 ➔ Weaker

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process



R-viscose content

- 50%
- 60%
- 70%
- 80%

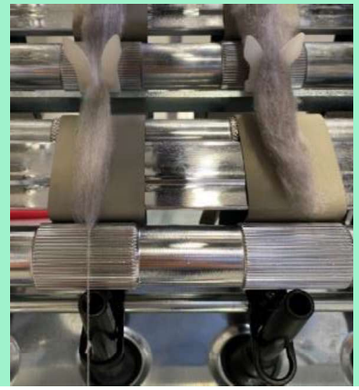
Lyocell fibre
1,3 dtex/38mm

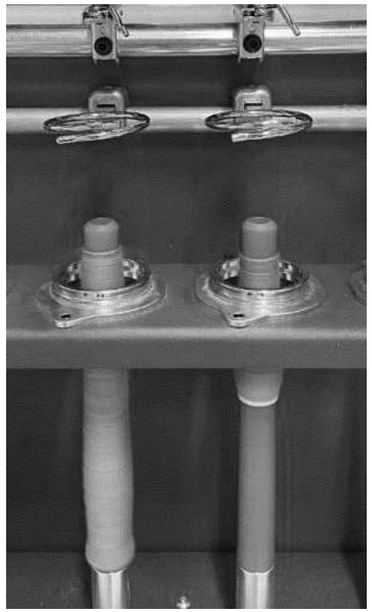
Yarn Count

- Finer yarn as possible with different recycled content

Process conditions

- Technology: Ring Spinning





Conclusions:

- Over 50% of recyled content, ring spinning is not possible
- At 50% of recycled content, Nm 35 and less is possible (without regularity guarrantee)

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 3 - Mechanical Recycling Process

Post-Consumers investigation:

Fraying

First path

(4 fraying drums)

- UHM: 22,5 mm
- SFC%: 19,4 %
- Waste ratio : 6 %

Blend & Carding

Recycled content

- 50%
- With Lyocell fibre 1,3 dtex/38mm

Yarn count

Optimization

- Nm 47
- Alpha 160

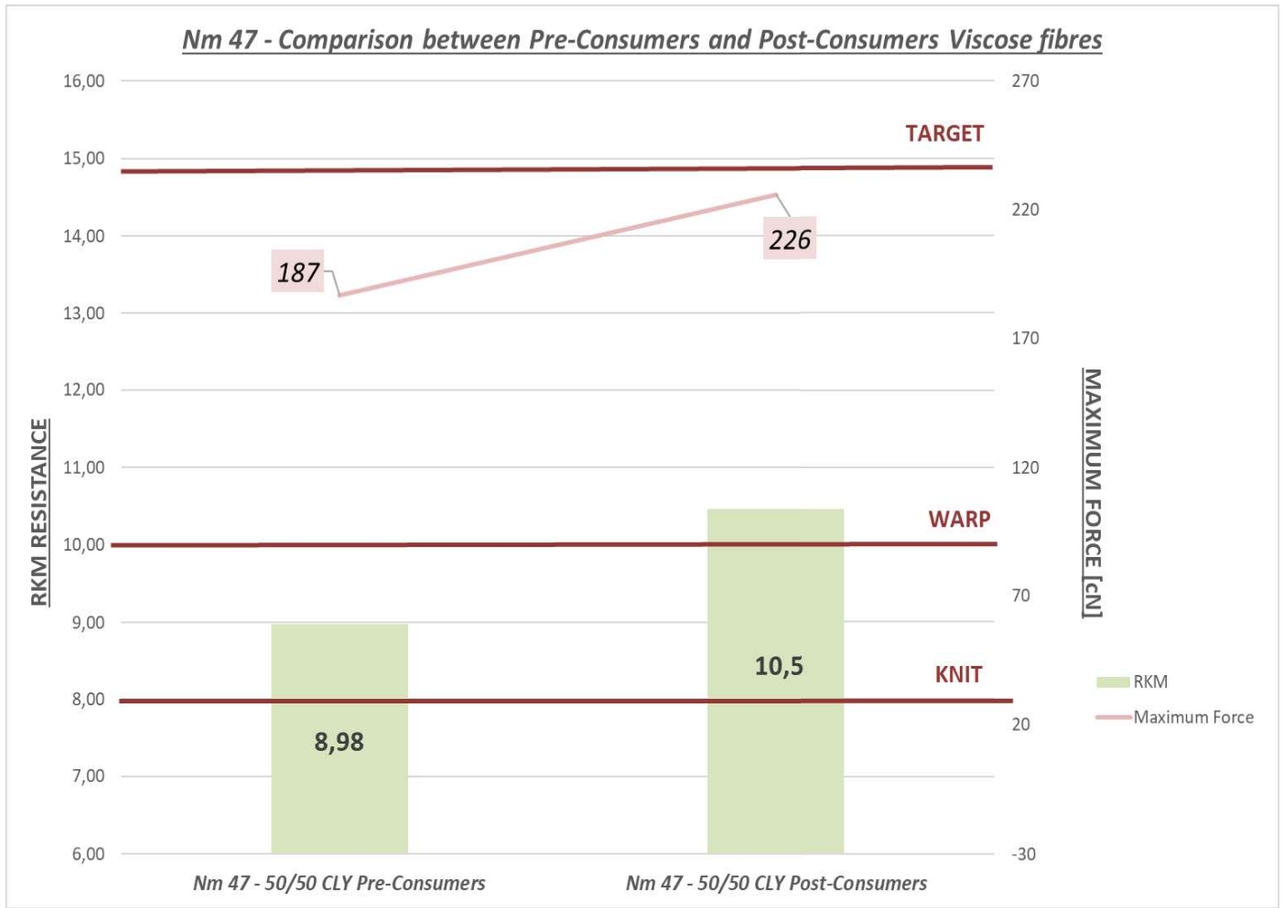
Yarn Spinning

Similar approach than preliminary materials

Optimization of the yarn spinning process for Nm 47

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 3 - Mechanical Recycling Process



Yarn Process

- Good cohesion with Post-Consumer fibres blend (Recycled + Lyocell)
- Stabilization of the process

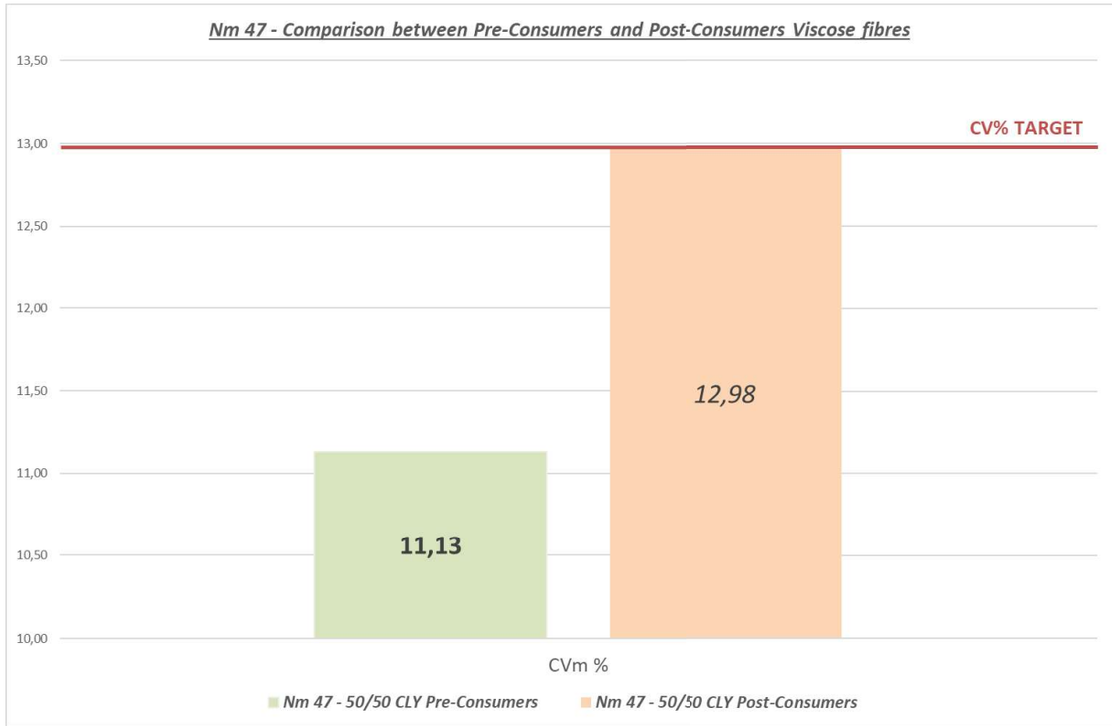
Knit Process

- Feasible on Post-Consumers

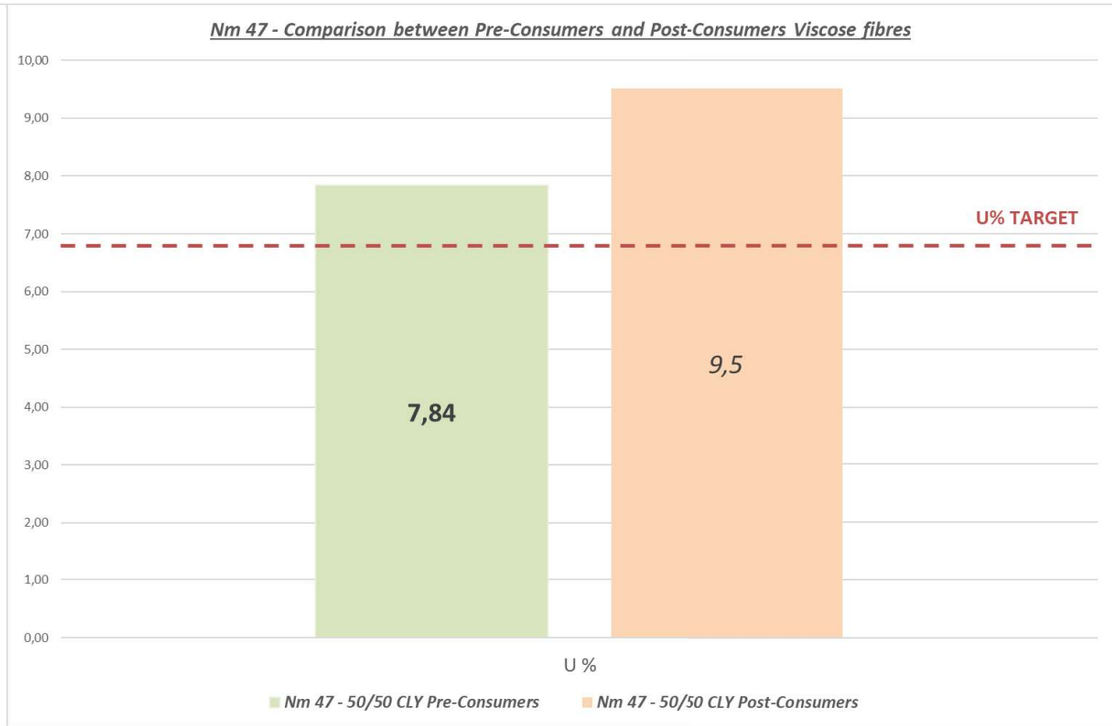
This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 3 - Mechanical Recycling Process

YARN REGULARITY



UNEVENNESS



CV% lower than target → **Better** quality

Post-Consumers materials give **less regularity** than Pre-Consumers materials

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Mechanical Recycling Process – Conclusions

Technical data sheets of the process conditions for the obtention of the yarn with 50% of recycled content

SCIRT. SYSTEM CIRCULARITY & INNOVATIVE RECYCLING OF TEXTILES

FRAYING Update: 26/10/2022

PARTNER Bel&Bo

RAW MATERIAL Viscose from dresses

FRAYING PROCESS

Size of cut raw materials	[mm]	40
Inlet Speed 1	[mpm]	1,0
Inlet Speed 2	[mpm]	1,0
Loading Speed	[%]	8%
Sizing Ratio	[l/h]	70
Cleaning roll Speed	[%]	95%
First Cadette Speed roll 1	[mpm]	1700
First Cadette Speed roll 2	[mpm]	2300
Second Cadette Speed roll 1	[mpm]	2350
Second Cadette Speed roll 2	[mpm]	2150
Fan Speed	[%]	55%
Outlet Speed 1	[mpm]	1,5
Outlet Speed 2	[mpm]	1,6
Opening Cadette 1	[mm]	3
	[mm]	6
Opening Cadette 2	[mm]	8
	[mm]	8

ANALYSIS FIBER LENGTH

Span length SL 2,5 %	[mm]	24,4
Span length SL 50 %	[mm]	9,9
Uniformity ratio UR %	[mm]	40,8
Short fiber content SFC % (N), <9mm	[%]	19,4%
Mean Length ML	[mm]	15,8
Upper High Mean Length UHM	[mm]	22,5
Uniformity Index UI %	[%]	70,4%
Span length SL 66,7 %	[mm]	7,6
CV %	[%]	40,7%

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SCIRT. SYSTEM CIRCULARITY & INNOVATIVE RECYCLING OF TEXTILES

CARDING Update: 26/10/2022

PARTNER Bel&Bo

RAW MATERIAL

		Ratio
Recycled Viscose	[%]	50
Lyocell 1,3dtex/38mm	[%]	50

OPENING BLENDING

Equalizer	[rpm]	200
Vertical Conveyor	[mpm]	10
Breast Conveyor	[rpm]	220
Feeding Cylinder	[mpm]	2
Opening Cylinder	[rpm]	1800
Ribbon Weight	[g/m]	5
Feed Weight	[3->30]	745
Manual Calibration	[Menu C]	230
Sliver Tension	[2->29]	1,85
Outlet speed	[mpm]	40

ANALYSIS FIBER LENGTH

Span length SL 2,5 %	[mm]	34,3
Span length SL 50 %	[mm]	14
Uniformity ratio UR %	[mm]	40,8
Short fiber content SFC % (N), <9mm	[%]	8,6
Mean Length ML	[mm]	23,9
Upper High Mean Length UHM	[mm]	35,4
Uniformity Index UI %	[%]	67,5
Span length SL 66,7 %	[mm]	10,2
CV %	[%]	45,2

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SCIRT. SYSTEM CIRCULARITY & INNOVATIVE RECYCLING OF TEXTILES

SPINNING Update: 26/10/2022

PARTNER Bel&Bo

RAW MATERIAL		Ratio
Recycled Viscose	[%]	50
Lyocell 1,3dtex/38mm	[%]	50

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	**47**
Alpha Twist	[α]	160
Yarn Twist	[T/m]	1097
Rotor	T 640 BD	
Rotor Speed	[rpm]	60000
Opening roll	B 20 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/G	
Draft Ratio	[U.I.]	240
Outlet speed	[mpm]	40
CV %	[%]	12,5%

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	1,0
RKM	[U.I.]	10,5
Elongation	[%]	7,9
Maximum Force	[cN]	226

ANALYSIS REGULARITY

CV %	[%]	12,98	Thin -30%	[/km]	1427
U %	[%]	9,51	Thin -40%	[/km]	69
Hairiness	[H]	4,94	Thin -50%	[/km]	1
sH %	[sH]	0,94	Thin -60%	[/km]	0
Thick +35%	[/km]	127	Neps + 140%	[/km]	2613
Thick +50%	[/km]	9	Neps + 200%	[/km]	263
Thick +70%	[/km]	2	Neps + 280%	[/km]	46
Thick +100%	[/km]	0	Neps + 400%	[/km]	13

Ceti

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

SCIRT.

Summarize of the Investigation – update April 2023

Feedstock	Delivery	Fraying	Blending and Carding	Yarn spinning	Final Solution
Pre-consumer	200 kg	187 kg 1 prototype 	80 kg 8 prototypes	22 kg 43 prototypes	X
Post-consumer	XXX kg 	XXX kg 2 prototypes 	10 kg 1 prototype	2 kg 1 prototype 	1 yarn prototype 1 kg 1 knit Proof of concept 1 complete process data sheet for industrial transfer

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

SCIRT.

D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Mechanical recycling

hnst

Recycled Denim

CETI	22/02/2023

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Mechanical Recycling Process - Steps

Step 1

- Post-consumer feedstock of frayed Denim
- Carding of blend recycled content with Lyocell
- Yarn spinning with Nm 12,8

Step 2

- Pre-consumer analysis (sweaters)
- Carding of blend cotton recycled content with virgin cotton
- Yarn spinning with Nm 17 and 20

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 1 - Mechanical Recycling Process

Post-Consumers investigation:

Fraying

First path

(4 fraying drums)

- UHM: 17,9 mm
- SFC%: 32,3 %
- Waste ratio: 16 %

Partner feedstock:

- UHM: 16,9 mm
- SFC%: 54 %

Blend & Carding

Recycled content

- 50%
- 60%
- 70%
- 80%

- Lyocell fibre 1,3 dtex/38mm
- Cotton recycled slivers

Yarn count

ESG Specifications

- Nm 12,8
- Nm 17 – 20

Analyse of one ESG yarn with CETI lab capacity (Nm 20)

Yarn Spinning

Similar approach than preliminary materials

Comparison of both feedstocks and fraying quality

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 1 - Mechanical Recycling Process

Fraying investigation:

Raw Materials	VALVAN Lot 1	VALVAN Lot 2	ALTEX Denim Fibres
UHM (mm)	17,9 mm	18,8 mm	16,9 mm
SFC (%)	32,3 %	34,2 %	54,0 %
Waste Ratio	16 %	19 %	X

Same CETI fraying process ➔ Same results

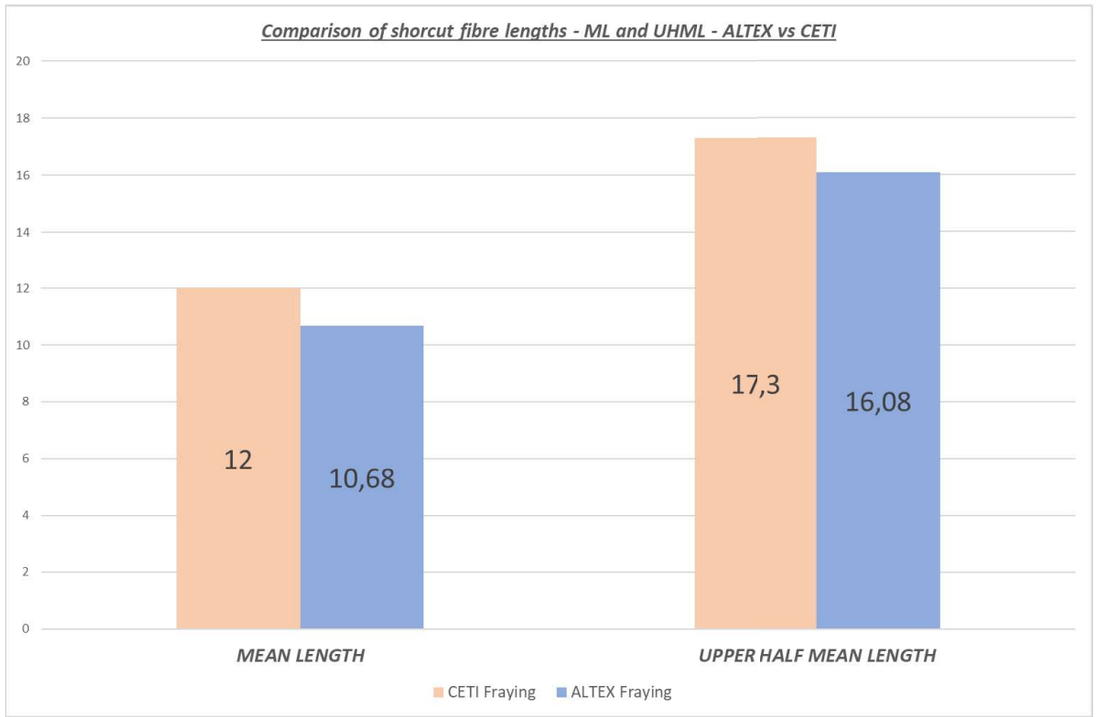
ALTEX feedstock less opened than CETI fibres

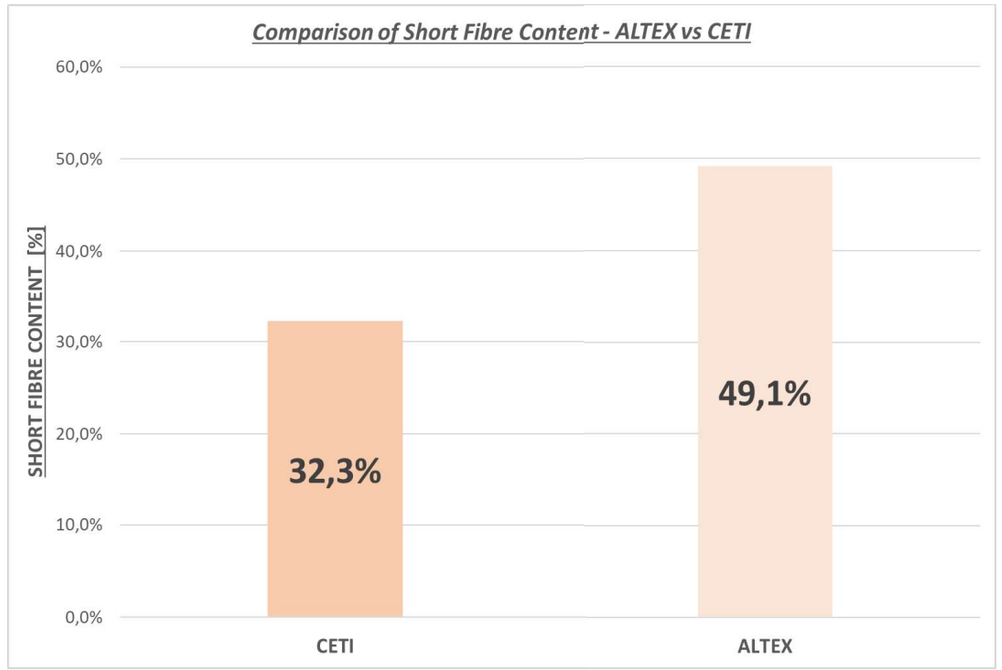
ALTEX

CETI

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 1 - Mechanical Recycling Process





Better fraying quality on CETI facility

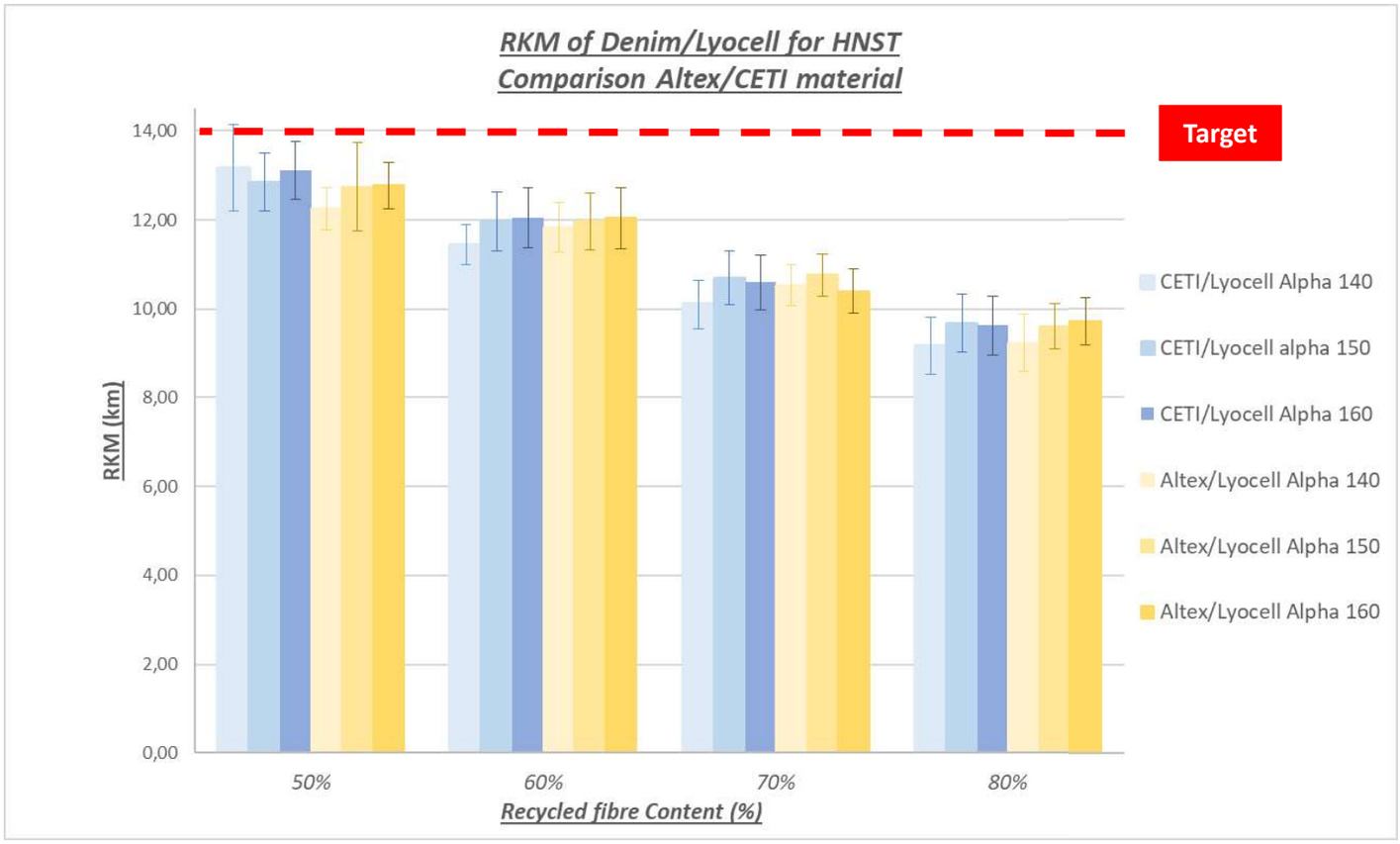
Higher fibre length ➔ Better cohesion with virgin cotton

More opened fibres and yarns with CETI ability

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 1 - Mechanical Recycling Process

Comparison on recycled yarns :



No influence on Nm 12,8
for two different materials

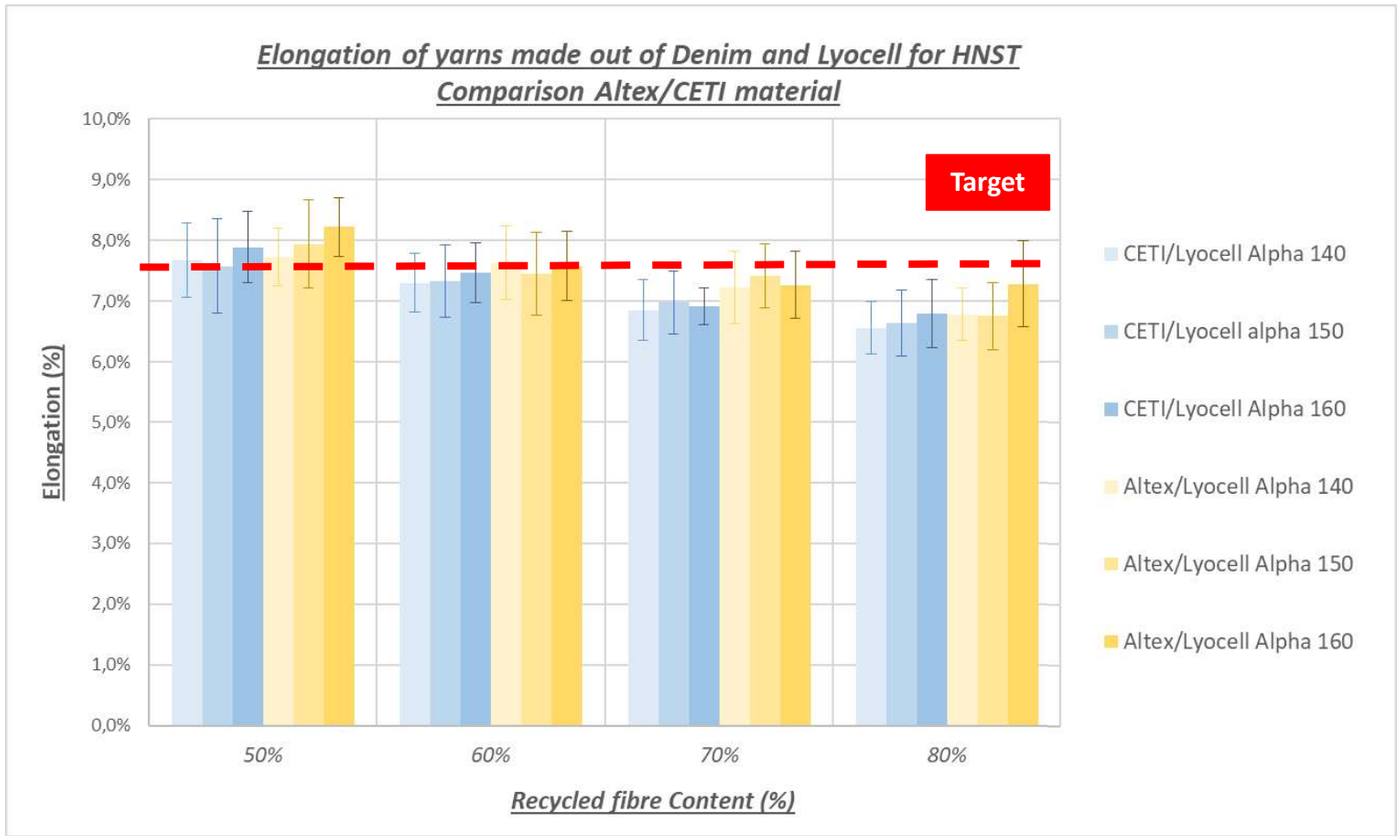
Higher fibre length into the blend
➔ **Better cohesion** with virgin lyocell

Higher alpha twist on yarns
➔ **Recommended** for high recycled content

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 1 - Mechanical Recycling Process

Comparison on recycled yarns :

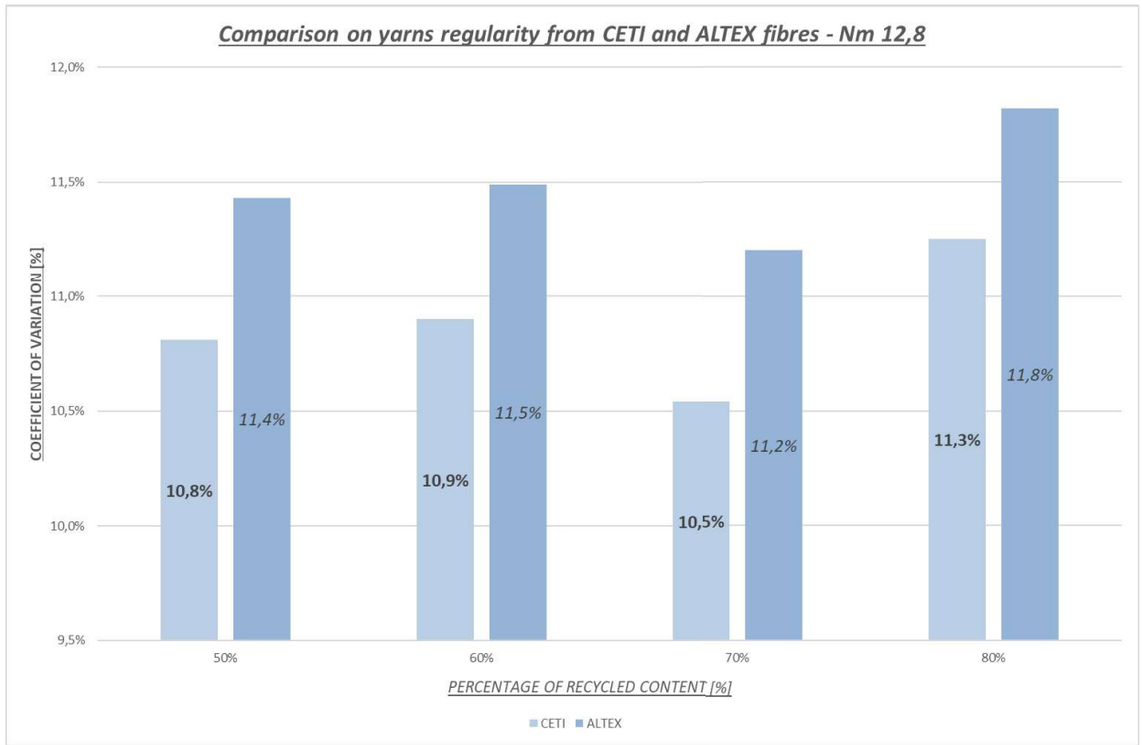


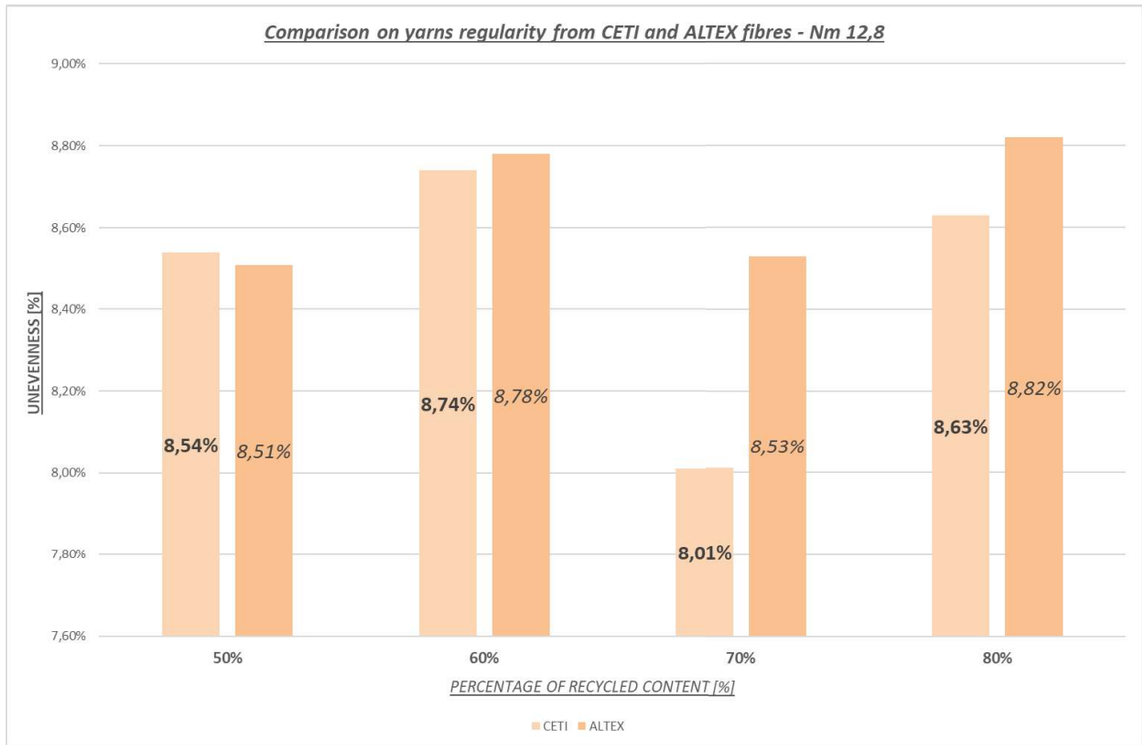
No visual impact on Nm 12,8
➔ Finer yarn to proceed for observing impact

Higher alpha twist on yarns
➔ Higher elongation on yarns

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 1 - Mechanical Recycling Process





CETI frayed fibres vs ALTEX frayed fibres

- **Lower CV% ➔ Better regularity**
- CV% values are validated

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Summarize of the Investigation – update April 2023

Feedstock	Delivery	Fraying	Blending and Carding	Yarn spinning	Final Solution
Denim from ALTEX	187 kg 		40 kg 4 prototypes	12 kg 12 prototypes	1 yarn prototype 1 knit Proof of concept 1 complete process data sheet for industrial transfer
Post-consumer Denim	200 kg	160 kg 10 prototypes 	40 kg 4 prototypes	12 kg 12 prototypes	1 yarn prototype 1kg 1 knit Proof of concept 1 complete process data sheet for industrial transfer

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process

Pre-Consumers investigation:

Fraying

Pre-consumer feedstocks coming from another project partner

Blend & Carding

Recycled content

- 50%
- 60%
- 70%
- 80%

Lyocell

1,3dtex / 38mm

Yarn count

Nm 17

Nm 20

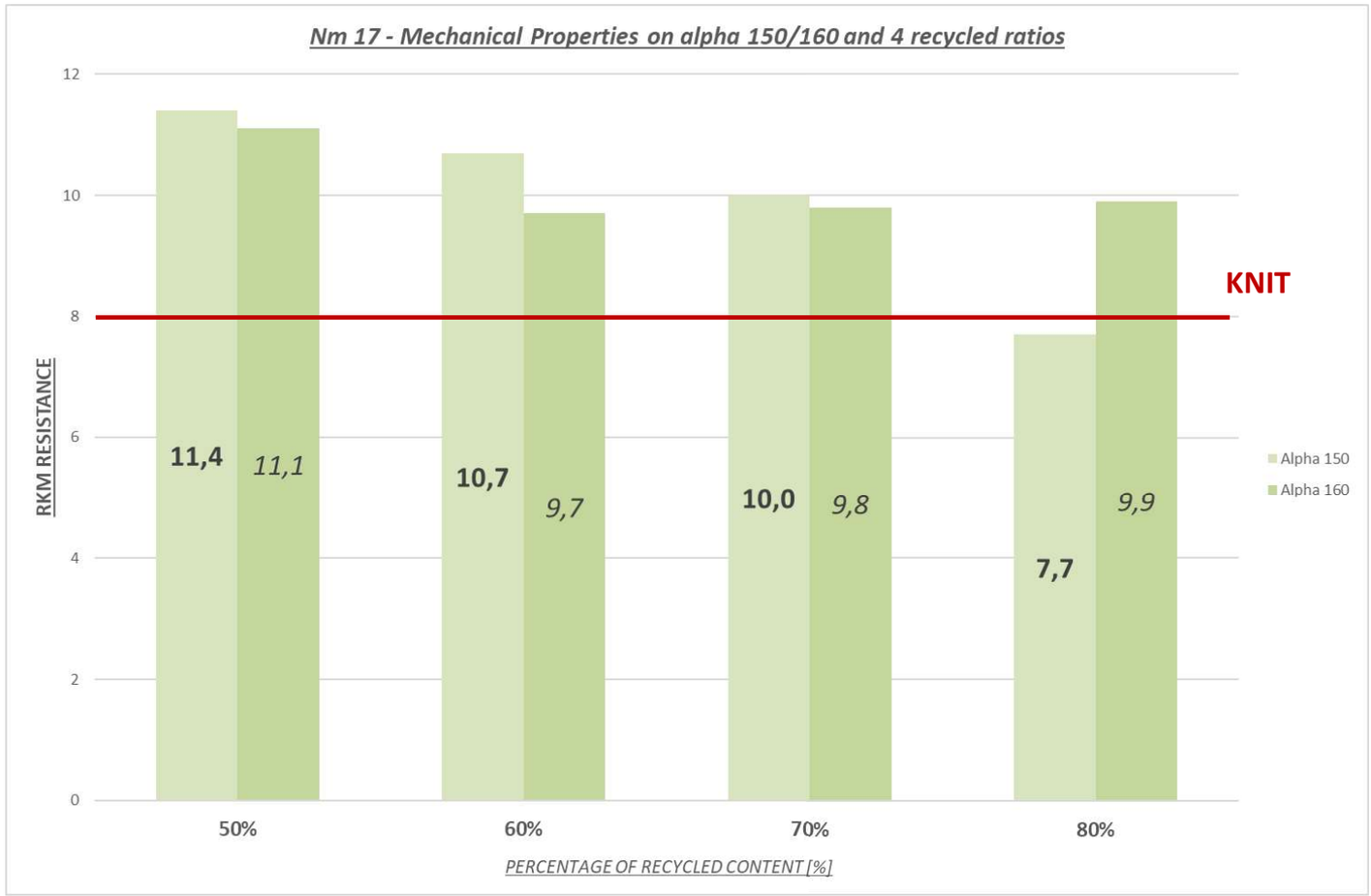
Yarn Spinning

Similar approach than preliminary materials

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process

Nm 17 – Mechanical Properties :



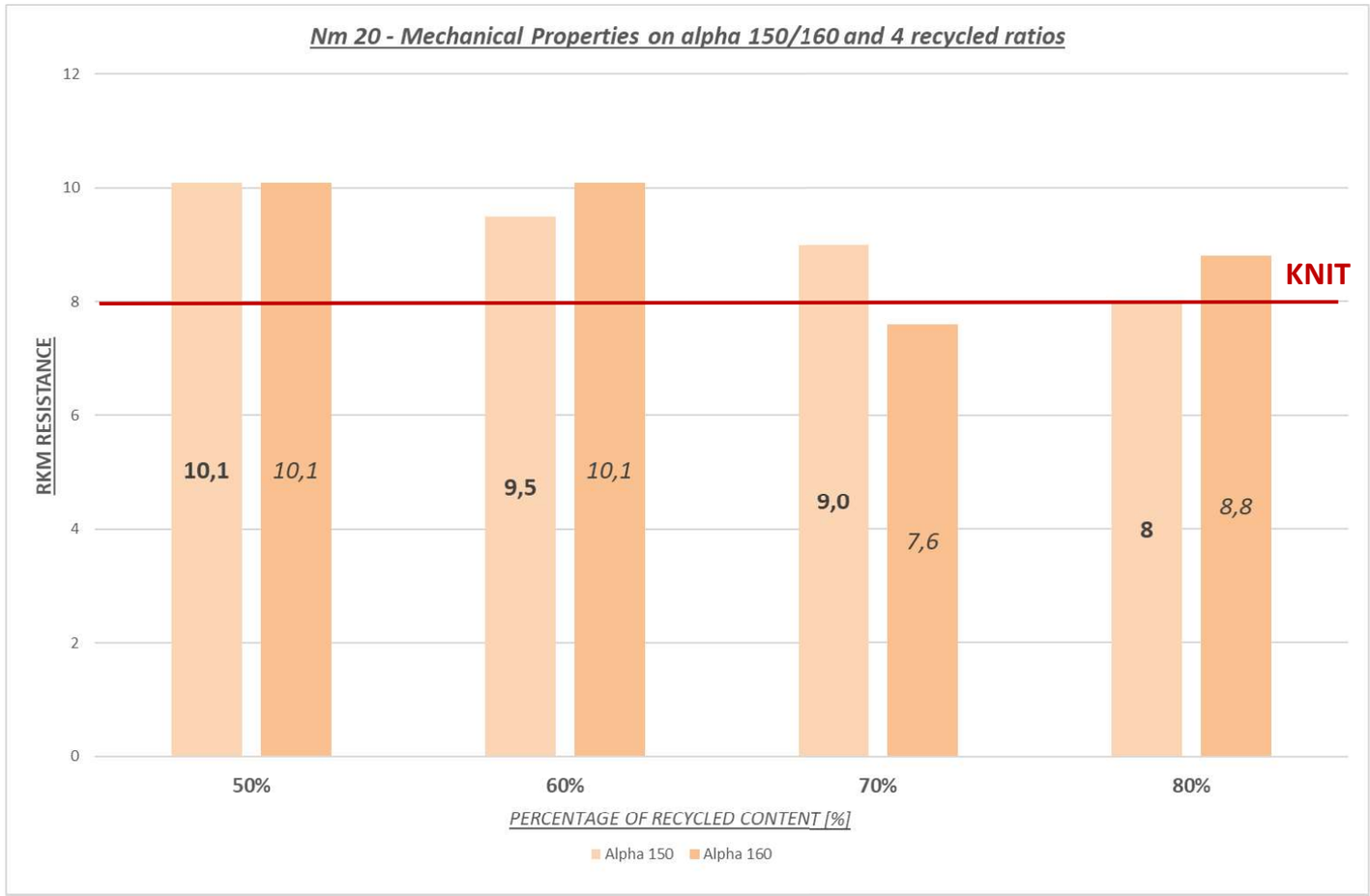
Adding **10% of recycled** cotton fibres on **yarn**
➔ **Decrease of 10% in resistance**

Alpha 160 for 70% of recycled fibres
➔ **More cohesion** with recycled fibres
➔ **Short fibres** → use of **higher alpha twist**

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process

Nm 20 – Mechanical Properties :



Finer rotor yarn (from Nm 17 to Nm 20)
➔ Decrease of 10% in resistance

Alpha 160 for more than 70% of recycled fibres
➔ More cohesion with recycled fibres

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Mechanical Recycling Process – Conclusions

Technical data sheets of the process conditions for the obtention of the yarn with 50% of recycled content

SCIRT

FRAYING Update: 26/10/2022

PARTNER hnst

RAW MATERIAL Denim Cotton

FRAYING PROCESS

Size of cut raw materials	[mm]	
Inlet Speed 1	[mpm]	1,0
Inlet Speed 2	[mpm]	1,1
Loading Speed	[%]	6%
Sizing Ratio	[l/h]	70
Cleaning roll Speed	[%]	80%
First Cadette Speed roll 1	[mpm]	1700
First Cadette Speed roll 2	[mpm]	2300
Second Cadette Speed roll 1	[mpm]	2350
Second Cadette Speed roll 2	[mpm]	2150
Fan Speed	[%]	40%
Outlet Speed 1	[mpm]	1,5
Outlet Speed 2	[mpm]	1,6
Opening Cadette 1	[mm]	2
	[mm]	6
Opening Cadette 2	[mm]	8
	[mm]	8

ANALYSIS FIBER LENGTH

Span length SL 2,5 %	[mm]	20,9
Span length SL 50 %	[mm]	8,2
Uniformity ratio UR %	[mm]	39,1
Short fiber content SFC % (N), <9mm	[%]	34,2%
Mean Length ML	[mm]	12
Upper High Mean Length UHM	[mm]	18,8
Uniformity Index UI %	[%]	63,5%
Span length SL 66,7 %	[mm]	6,5
CV %	[%]	41,9%

Ceti

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CARDING Update: 26/10/2022

PARTNER hnst

RAW MATERIAL

		Ratio
Recycled Denim Cotton	[%]	50%
Lyocell 1,3dtex/38mm	[%]	50%

OPENING BLENDING CARDING

Equalizer	[rpm]	230
Vertical Conveyor	[mpm]	18
Breast Conveyor	[rpm]	230
Feeding Cylinder	[mpm]	5
Opening Cylinder	[rpm]	2300
Ribbon Weight	[g/m]	5,27
Feed Weight	[3->30]	740
Manual Calibration	[Menu C]	268
Sliver Tension	[2->29]	1,8
Outlet speed	[mpm]	40

ANALYSIS FIBER LENGTH

Span length SL 2,5 %	[mm]	35,7
Span length SL 50 %	[mm]	15,3
Uniformity ratio UR %	[mm]	43
Short fiber content SFC % (N), <9mm	[%]	6,9
Mean Length ML	[mm]	26,7
Upper High Mean Length UHM	[mm]	37,2
Uniformity Index UI %	[%]	71,9
Span length SL 66,7 %	[mm]	11,1
CV %	[%]	44,4

Ceti

SCIRT

SPINNING Update: 26/10/2022

PARTNER hnst

RAW MATERIAL

		Ratio
Recycled Denim Cotton	[%]	50%
Lyocell 1,3dtex/38mm	[%]	50%

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	**12,8**
Alpha Twist	[α]	160
Yarn Twist	[T/m]	1025
Rotor	T 640 BD	
Rotor Speed	[rpm]	60000
Opening roll	D 174 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/G	
Draft Ratio	[U.I.]	190
Outlet speed	[mpm]	
CV %	[%]	14,6%

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	1,28
RKM	[U.I.]	13,1
Elongation	[%]	7,9
Maximum Force	[cN]	1026

ANALYSIS REGULARITY

CV %	[%]	10,81	Thin -30%	[/km]	1301
U %	[%]	8,54	Thin -40%	[/km]	26
Hairiness	[H]	5,21	Thin -50%	[/km]	0
sH %	[sH]	0,97	Thin -60%	[/km]	0
Thick +35%	[/km]	169	Neps + 140%	[/km]	1612
Thick +50%	[/km]	18	Neps + 200%	[/km]	22
Thick +70%	[/km]	5	Neps + 280%	[/km]	2
Thick +100%	[/km]	1	Neps + 400%	[/km]	0

Ceti

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Summarize of the Investigation – update April 2023

hnst

Feedstock	Delivery	Fraying	Blending and Carding	Yarn spinning	Final Solution
Pre-consumer For sweater	187 kg 		40 kg 8 prototypes	16 kg 32 prototypes	yarn prototype 1 knit Proof of concept 1 complete process data sheet for industrial transfer
Post-consumer For sweater		From partner Petit Bateau	40 kg 8 prototypes	16 kg 32 prototypes	1 yarn prototype 1 kg 1 knit Proof of concept 1 complete process data sheet for industrial transfer

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Mechanical recycling

Recycled Wool/PET

XANDRES
BELGIUM

CETI	22/02/2023

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Mechanical Recycling Process - Steps

XANDRES
BELGIUM

Step 1

- Pre-consumer feedstock (PET/Wool/Elastane)
- Impact fraying conditions
- Carding of blend recycled content with PET
- Alternative of yarns : **nonwovens**

Step 2

- Post-consumer feedstock of PET and Wool
- Fraying with results from step 1
- Carding of blends
- Yarn spinning
- Yarn count: Nm 29

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Step 1 - Mechanical Recycling Process

XANDRES BELGIUM

Pre-Consumers investigation:

Fraying

First path

(4 fraying drums)

- UHM: 17 mm
- SFC%: 42%

Second path

(+2 finer fraying drums)

- UHM: 21mm
- SFC%: 36%

Feedstock yarn composition ➔ twisted yarn good for abrasion resistance but very difficult to fray and separate the fibres from yarn
➔ High waste ratio and not enough opening of frayed fibres (>25%)

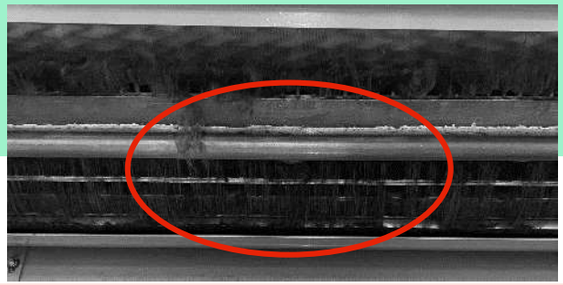
Blend & Carding

At CETI

Recycled content

- 64,4%
- 73,1%
- 80,9%
- 87,9%
- PET fibre 1,7dtex/38mm

NOT SUCCESSFUL



The high content of frayed fibres and specifically wool into the blend creates carding selection and high loss ratio (>30%)

Alternative of Yarns

Nonwoven Substitute

- 100%
- Airlay
- Needlepunching
- Thermal Bonding
- 500 gsm

The Wool/Polyester feedstock does not fulfill the process and rentability criteria for a yarn spinning use.
The type of yarn (twisted) and blend improves the textile durability and not recyclability for yarn, a nonwoven application is therefore more adapted (padding).

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Mechanical Recycling Process

XANDRES BELGIUM

Pre-Consumers :

Fibres Preparation

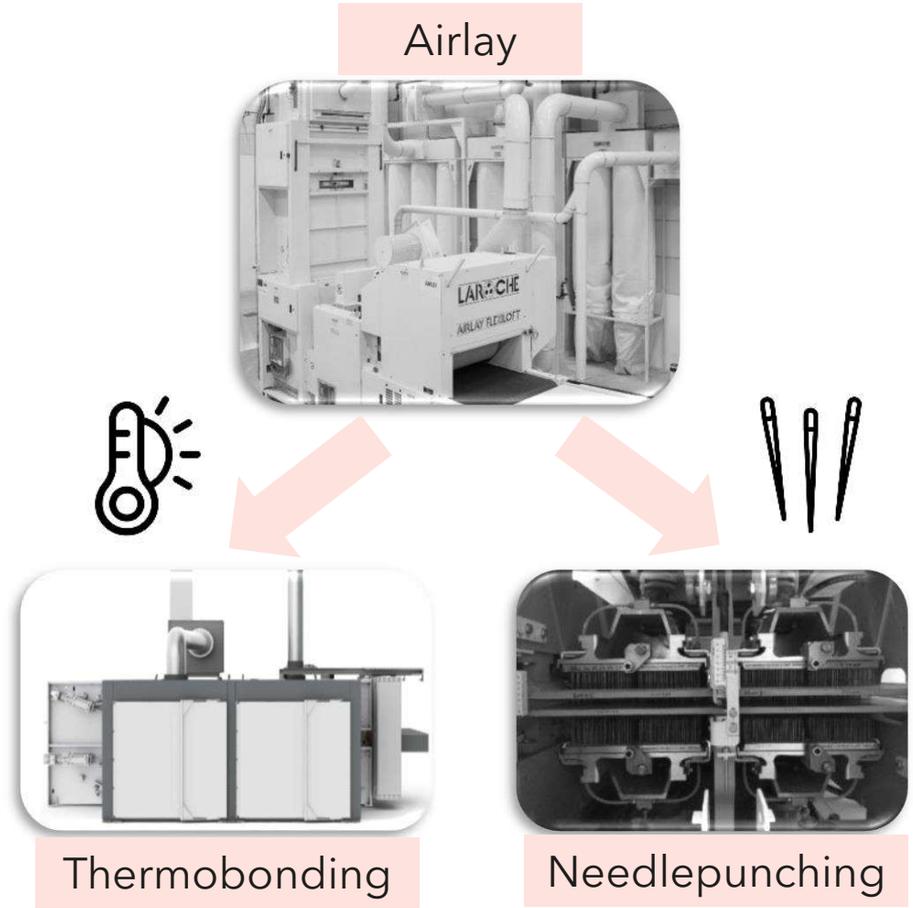
- Recycled fibres
  - PET/Wool/EA
- PET/CoPET
  - 2,2 dtex
  - 32 mm
- PET
  - 6,7 dtex
  - 60 mm

Airlaying

- **Ratio 1**
  - 100% recycled
- **Ratio 2**
  - 85% recycled
  - 15% PET/CoPET
- **Ratio 3**
  - 85% recycled
  - 15% PET

Web Bonding

- 500 gsm
- Thermal bonding
- Needlepunching



This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Step 1 - Mechanical Recycling Process

XANDRES
BELGIUM

Pre-Consumers :

Sample N°	Recycled Fibres	PET/CoPET 2,2/32	PET 6,7/60	Web Bonding	BW [gsm]	Thickness [mm]	MD Strength	CD Strength
1	85%		15%	Thermal	507	14,3	3,1	16,2
2	85%		15%	Thermal	496	13,3	3,6	10,4
3	85%		15%	Thermal	501	13,6	6,8	14,3
4	**85%**		**15%**	**Thermal**	**490**	**7,0**	**15,8**	**13,1**
5	100%			Needlepunching	591	10,7	1,5	1,2
6	100%			Needlepunching	514	9,7	2,3	1,8
7	100%			Needlepunching	448	9,0	1,6	1,9
8A	85%	15%		Needlepunching	478	12,5	3,4	2,4
8B	85%	15%		Needlepunching	491	11,4	1,3	2,4
8C	**85%**	**15%**		**Needlepunching**	**493**	**9,1**	**3,7**	**3,3**
8D	85%	15%		Needlepunching	473	10,3	2,3	2,4

Pre-Consumers materials are suitable for nonwoven process

- Thermal bonding → **Rigid** nonwovens
- Mecanical bonding → **Soft** nonwovens

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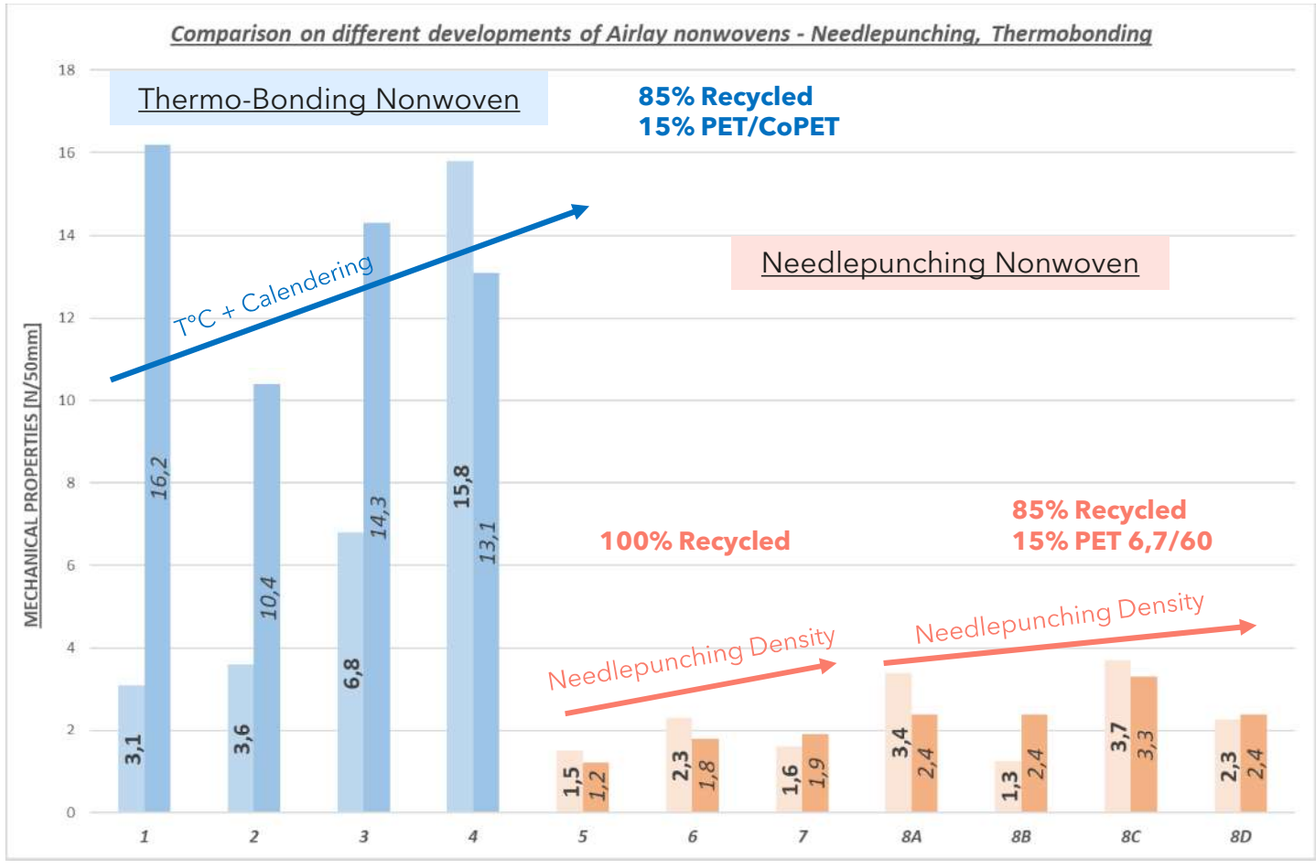
Step 1 - Mechanical Recycling Process

XANDRES BELGIUM

Pre-Consumers :



Thermo-Bonding

- High temperature ➔ Better bonding
- High Calendering ➔ Better resistance, density

Needlepunching

- High bonding ➔ Less cohesion with 100% recycled

PET staple fibres

- Give **more cohesion** in blends with recycled

Applications

- Padding

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Step 2 - Mechanical Recycling Process

XANDRES BELGIUM

Post-Consumers investigation:

Fraying

Valvan garments

- **100% Wool**
  - UHM = 19 mm
  - SFC = 32,9 %
  - Waste = 17 %

- **100% PET**
  - UHM = 22,3 mm
  - SFC = 17,8 %
  - Waste = 9 %

Blend & Carding

Recycled content

- **RATIO 1 :**
  - 45% Recycled Wool
  - 55% Virgin PET
- **RATIO 2 :**
  - 45% Recycled Wool
  - 55% rPET
- **RATIO 3 :**
  - 30% Recycled Wool
  - 15% Recycled PET
  - 55% Virgin PET

Rotor Spinning

Recycled content

Optimization of the yarn spinning process

Nm 29

The content of frayed wool can not exceed 30%, due to the fact the fibre is coarser than Polyester ones and contaminate the carding sliver and yarn.
The polyester feedstock is not a fibre feedstock but contains textiles made of filaments, the frayed filaments are longer than fibres but filaments are thinner and more fragile than a polyester fibre, creating more loss during carding process and therefore yarn spinning process.

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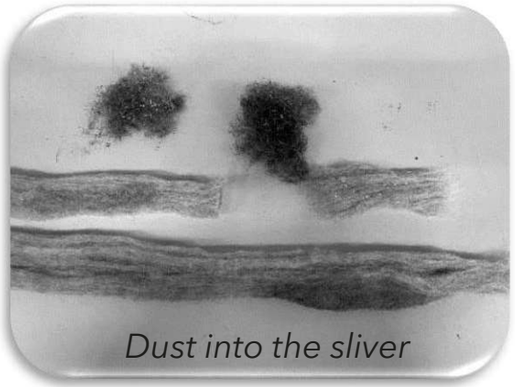
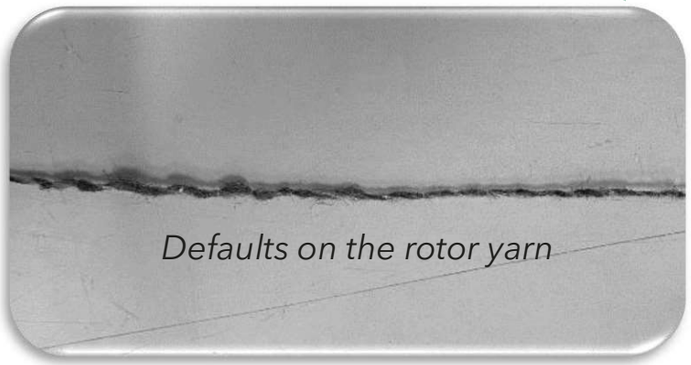
Step 2 - Mechanical Recycling Process

Post-Consumers investigation:

Carding



Spinning



Yarn Process

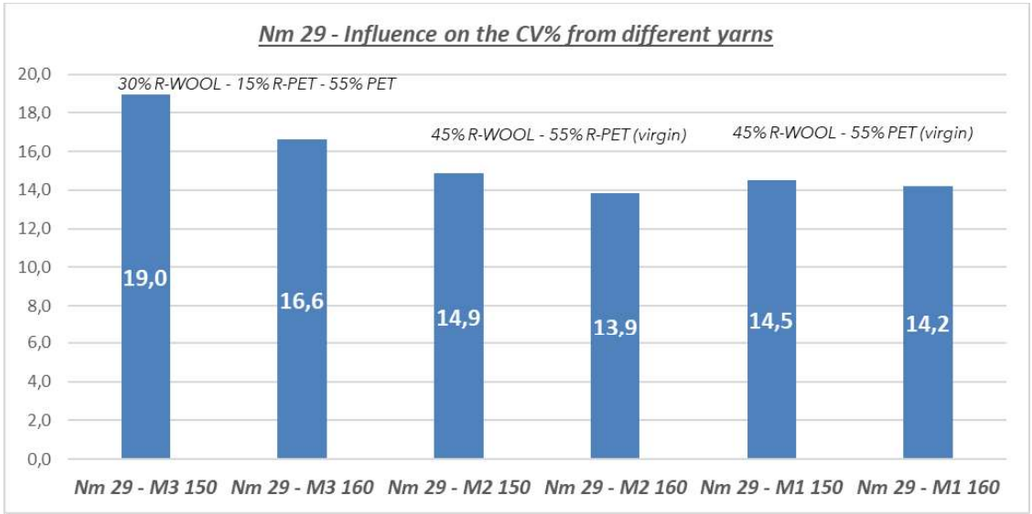
- Sliver defaults from wool fibres (>30%)
- Opening roll unable to remove wool impurities
- Fibres spinning difficulties
  - Rotor Speed of 70 000 rpm → More cohesion
  - B 20 DN opening roll → Enhance breaking of sliver

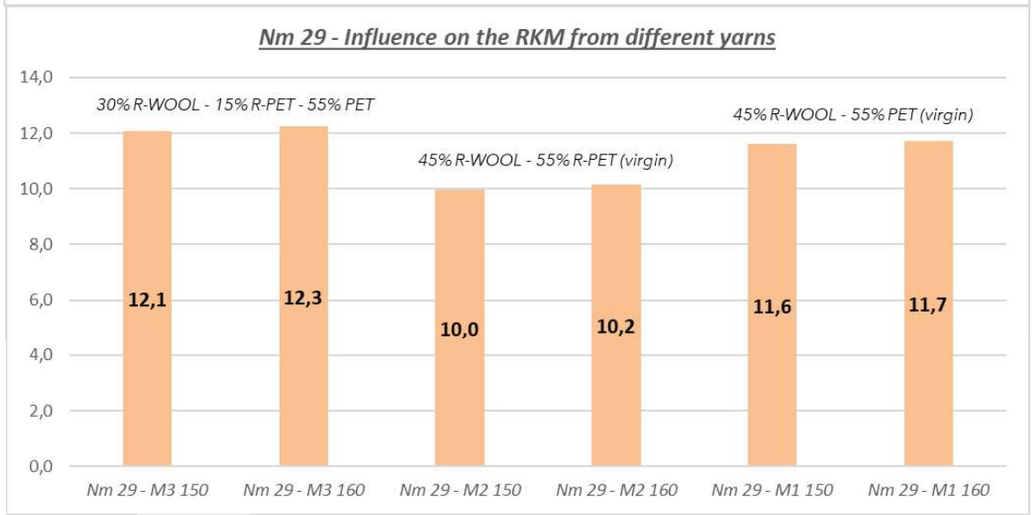
Alternative

- 30% R-Wool – 70% PET

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Step 2 - Mechanical Recycling Process





Alpha Twist

- High value ➔ High resistance
- **160** is better to apply on recycled

Resistance

- PET filaments ➔ More strength on yarns

Regularity

- Tri-component yarns are not suitable
- Alpha 160 ➔ More regularity

Alternative

- 30% R-Wool / 70% Virgin PET

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Summarize of the Investigation – update April 2023

XANDRES BELGIUM

Feedstock	Delivery	Fraying	Blending and Carding	Yarn spinning	Final Solution
Pre-consumer	200 kg 	140 kg 1 prototype	40 kg 4 prototypes	X	X
Post-consumer	200 kg wool 200 kg Polyester	166 & 182 kg 2 prototypes 	30 kg 3 prototypes	6 kg 6 prototypes 	

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T2.2.3 – Rotor Spinning yarns data from Post-Consumers for industrialization

Brand concerned	PETIT BATEAU	BEL & BO	HNST	XANDRES
Recycled Fibres	50% Cotton	50% Viscose	70% Denim	30% Wool – 15% PET
Virgin Fibres	50% Cotton	50% Lyocell 1,3/38	30% Lyocell 1,3/38	55% PET
Yarn Count	**Nm 40**	**Nm 47**	**Nm 12,8**	**Nm 29**
Yarn Technology	Rotor Spinning	Rotor Spinning	Rotor Spinning	Rotor Spinning
Elongation	5,6%	7,9%	7%	14,1%
Average force [cN]	**239**	**226**	**810**	**414**
Average Force CV [%]	6,8%	10,3%	5,8%	11,3%
RKM	**9,7**	**10,5**	**10,7**	**12,3**
U [%]	9,9%	9,5%	8%	11,3%
CVm [%]	**12,5%**	**12,9%**	**10,5%**	**16,6%**
Thinness [/km]	4	9	13	281
Thickness [/km]	8	1	5	494
Neps 200% [/km]	223	263	0	144
Hairiness [%]	4,82	4,94	5,49	5,99
Quantity [m]	15 000	15 000	4 000	5 000

The textile to textile recycling investigation through different feedstocks confirms the following:
For a single material feedstock, the 50% frayed content is possible by adapting the process – depends of the final yarn specifications, the textile process needs to be adapted (knitting instead of weaving or weaving possible by using the recycled yarn in weft)
For a 2 material feedstock such as wool and polyester, types of fibres have a big impact on the process and yarns specification – final content can not follow the original one.

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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T2.2.3 – Rotor Spinning yarns data – PETIT BATEAU Industrialization

PARTNER

RAW MATERIAL		Ratio
Recycled Cotton	[%]	50%
Cotton GOTS 31mm - Turkey	[%]	50%

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	**40**
Alpha Twist	[α]	160
Yarn Twist	[T/m]	1025
Rotor	T 640 BD	
Rotor Speed	[rpm]	60000
Opening roll	D 174 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/G	
Draft Ratio	[U.I.]	190
Outlet speed	[mpm]	59,3
CV %	[%]	14,6%
Quantity	[m]	15000

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	0,96
RKM	[U.I.]	9,7
Elongation	[%]	5,6
Maximum Force	[cN]	239

ANALYSIS REGULARITY

CV %	[%]	12,5
U %	[%]	9,9
Hairiness	[H]	4,82
sH %	[sH]	0,91

Thick +35%	[/km]	137
Thick +50%	[/km]	8
Thick +70%	[/km]	2
Thick +100%	[/km]	0

Thin -30%	[/km]	1936
Thin -40%	[/km]	119
Thin -50%	[/km]	4
Thin -60%	[/km]	0

Neps + 140%	[/km]	2637
Neps + 200%	[/km]	223
Neps + 280%	[/km]	21
Neps + 400%	[/km]	3

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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T2.2.3 – Rotor Spinning yarns data – BEL & BO Industrialization

PARTNER

Bel&Bo

RAW MATERIAL		Ratio
Recycled Viscose	[%]	50%
Lyocell 1,3dtex/38mm	[%]	50%

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	**47**
Alpha Twist	[α]	160
Yarn Twist	[T/m]	1097
Rotor	T 640 BD	
Rotor Speed	[rpm]	60000
Opening roll	B 20 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/G	
Draft Ratio	[U.I.]	240
Outlet speed	[mpm]	54,7
CV %	[%]	12,5%
Quantity	[m]	15000

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	1,0
RKM	[U.I.]	10,5
Elongation	[%]	7,9
Maximum Force	[cN]	226

ANALYSIS REGULARITY

CV %	[%]	12,98
U %	[%]	9,51
Hairiness	[H]	4,94
sH %	[sH]	0,94

Thick +35%	[/km]	127
Thick +50%	[/km]	9
Thick +70%	[/km]	2
Thick +100%	[/km]	0

Thin -30%	[/km]	1427
Thin -40%	[/km]	69
Thin -50%	[/km]	1
Thin -60%	[/km]	0

Neps + 140%	[/km]	2613
Neps + 200%	[/km]	263
Neps + 280%	[/km]	46
Neps + 400%	[/km]	13

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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T2.2.3 – Rotor Spinning yarns data – HNST Industrialization

PARTNER hnst

RAW MATERIAL		Ratio
Recycled Denim Cotton	[%]	70%
Lyocell 1,3dtex/38mm	[%]	30%

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	**12,8**
Alpha Twist	[α]	150
Yarn Twist	[T/m]	1025
Rotor	T 640 BD	
Rotor Speed	[rpm]	60000
Opening roll	D 174 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/G	
Draft Ratio	[U.I.]	190
Outlet speed	[mpm]	104,8
CV %	[%]	12,5%
Quantity	[m]	4000

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	1,05
RKM	[U.I.]	10,7
Elongation	[%]	7
Maximum Force	[cN]	810

ANALYSIS REGULARITY

CV %	[%]	10,54
U %	[%]	8,01
Hairiness	[H]	5,49
sH %	[sH]	1,08

Thick +35%	[/km]	142
Thick +50%	[/km]	13
Thick +70%	[/km]	5
Thick +100%	[/km]	0

Thin -30%	[/km]	909
Thin -40%	[/km]	14
Thin -50%	[/km]	0
Thin -60%	[/km]	0

Neps + 140%	[/km]	1221
Neps + 200%	[/km]	14
Neps + 280%	[/km]	1
Neps + 400%	[/km]	0

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T2.2.3 – Rotor Spinning yarns data – XANDRES Industrialization

PARTNER

XANDRES BELGIUM

RAW MATERIAL

		Ratio
Recycled Wool	[%]	30%
Recycled PET	[%]	15%
PET 1,7dtex/38mm	[%]	55%

ROTOR SPINNING PROCESS

Yarn Count	[Nm]	**29**
Alpha Twist	[α]	160
Yarn Twist	[T/m]	862
Rotor	T 646 BD	
Rotor Speed	[rpm]	70000
Opening roll	B 20 DN	
Opening roll Speed	[rpm]	8000
Adapter Tool	KS K4 A	
Torque	TS 30 O/W	
Draft Ratio	[U.I.]	155
Outlet speed	[mpm]	81,2
CV %	[%]	17,5%
Quantity	[m]	5000

ANALYSIS STRENGTH

Tenacity	[cN/dtex]	1,2
RKM	[U.I.]	12,3
Elongation	[%]	14,1
Maximum Force	[cN]	414

ANALYSIS REGULARITY

CV %	[%]	16,6
U %	[%]	11,3
Hairiness	[H]	5,99
sH %	[sH]	1,09

Thick +35%	[/km]	1836
Thick +50%	[/km]	494
Thick +70%	[/km]	143
Thick +100%	[/km]	2

Thin -30%	[/km]	5983
Thin -40%	[/km]	1313
Thin -50%	[/km]	281
Thin -60%	[/km]	54

Neps + 140%	[/km]	6238
Neps + 200%	[/km]	2529
Neps + 280%	[/km]	756
Neps + 400%	[/km]	144

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Task 2.2 : Increased value recycling of clothing and spinning

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D.2.1: Lab-scale (0,1 – 1 kg/batch) samples for (re-)spinning trials after (bio)chemical recycling of multi-material fibre/textile blends

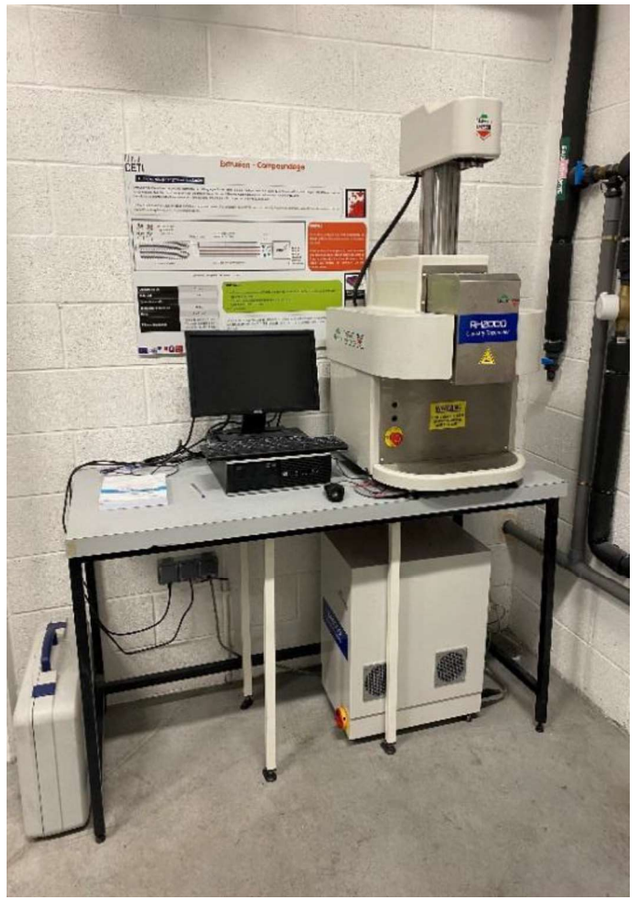
TU WIEN

Sustainable Innovation Institute

CETI	November 2022

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

MACHINE and MATERIALS TESTED



MATERIALS TESTED

1. PET separated from **WOOL**
2. PET separated from **ELASTANE**
3. PET separated from **WOOL AND ELASTANE**

SAMPLE: MILLING

SAMPLE EXPANSION

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

CONCLUSIONS

PET from Wool

- Although two tests were conducted, unfortunately, data was not collected from low sensor sensitivity. However, sample helped CETI team to calibrate machine for further testing

PET from Elastane

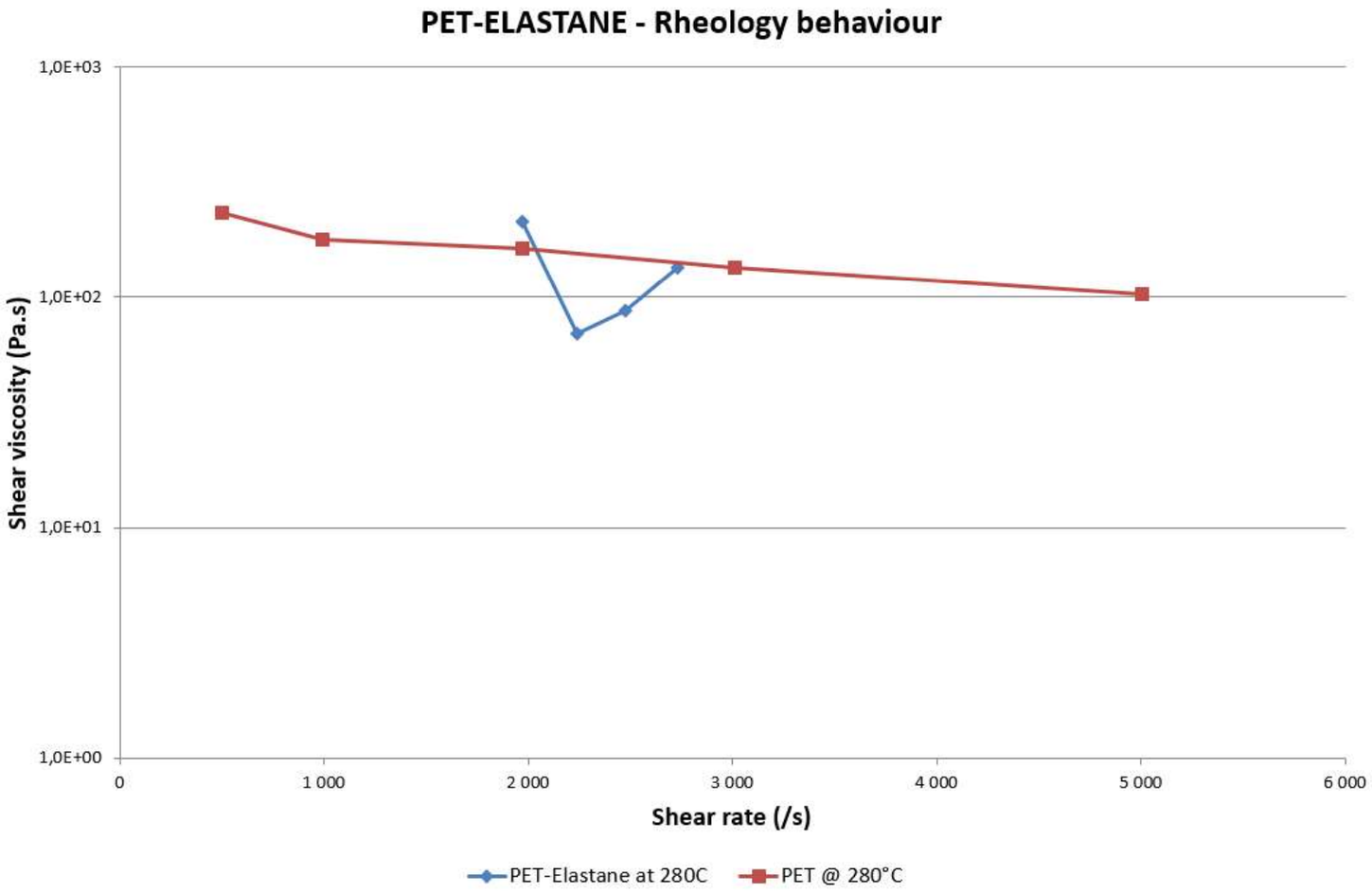
- Elastic recovery noticed. This suggests that elastane has not been fully removed. Further discussions with TU WIEN should take place

PET from Elastane and Wool

- Sample shows viscoelasticity that makes it suitable for use in melt spinning applications

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

RHEOLOGY: PET from ELASTANE



OUTCOMES

- Overall, pressure is not constant through the test; rubbery behaviour
- Elastane seems to be not fully separated

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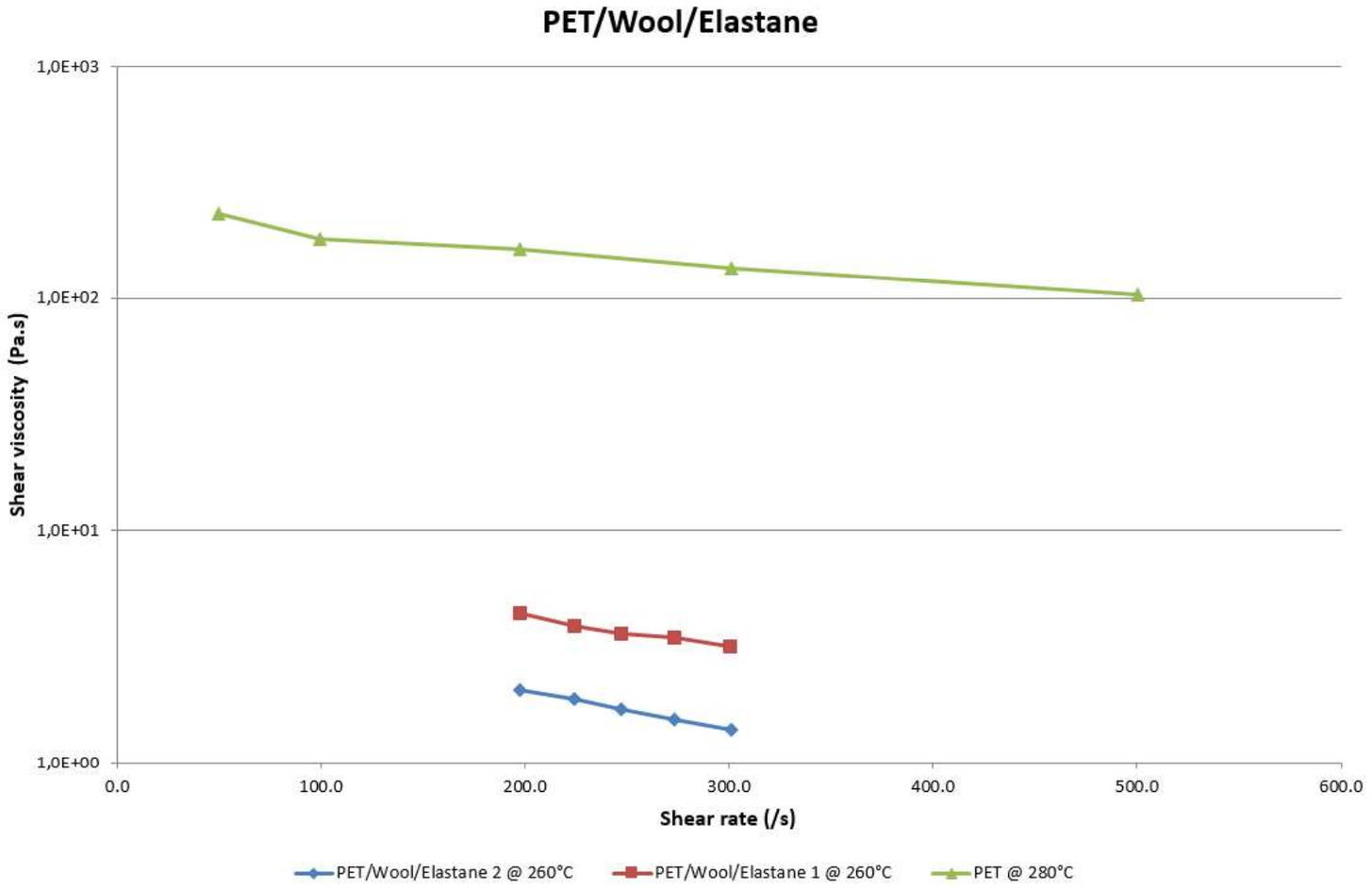
PET from Elastane and Wool



OUTCOMES

- PET shows typical/standard viscous behaviour
- At 250°C, this PET might be used for melt spinning applications ➔ low limit of melting point
- PET highly sensitive to temperature: degradation might occur

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Task 2.2 : Increased value recycling of clothing and spinning

D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50%

Thermo-mechanical recycling

DECATHLON

CETI	November 2022

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Thermo-mechanical Recycling Process - Plan

Situation of the recycling process investigation

Thermomechanical recycling process and primary material scientific approach

Thermomechanical recycling process on pre-consumer NEGOMBO

- Thermo-mechanical process and Results
- Rheology
- Melt-spinning Process and Results

Thermomechanical recycling on post-consumer polyster

- Thermo-mechanical process and Results
- Rheology
- Melt-spinning Process and Results

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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Your CETI team

SCIRT.

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MINES Paris –
KEDGE - IFM

Simon
Textile Engineer
ENSAIT

Marie
Textile Engineer
ENSAIT

Javier
Chemistry
Engineer, PhD
Boston University

Technicians team: Charles, Ludovic

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Thermo-Mechanical recycling process - Situation

Research topics	Status	To realize
Scientific approach on thermo-mechanical recycling	Pre-consumer on different feedstocks investigation Thermo-mechanical recycling process methodology	PET degradation analysis through the pellet to filament process
Preconsumer Negombo	Feedstock delivery mid-May 2022	Negombo melt spinning investigation of blends with virgin PET
	Thermomechanical recycling – July 2022	
	Melt spinning: Specific spinpack delivery (July 2022) 100% r-Negombo in 75 deniers/36 filaments - July 2022	
Negombo 2 (with accessories)	Waiting for feedstock	Complete thermo-mechanical process
Patmos	Waiting for feedstock	Complete thermo-mechanical process

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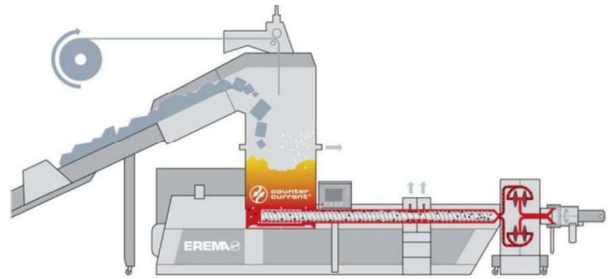
Experimental Program


Textile feedstock

Thermomechanical recycling

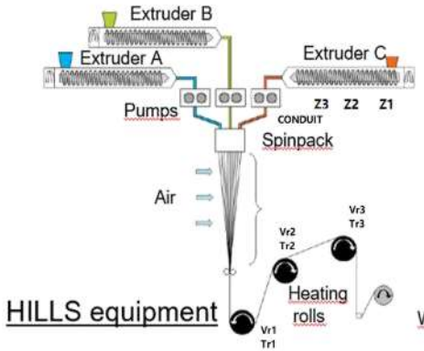


Compound ***(optional)***

Pellets

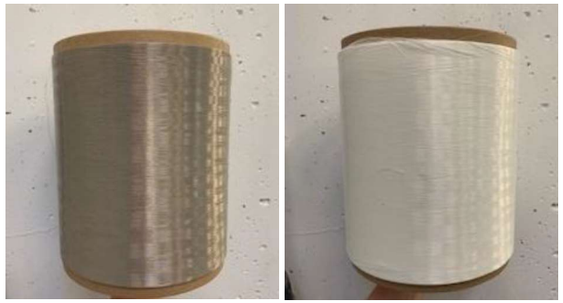
Rheology


Meltspinning



Multifilament

Measurement of mechanical and thermal properties



This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50% Thermo-mechanical recycling Primary materials – Scientific approach

CETI	November 2022

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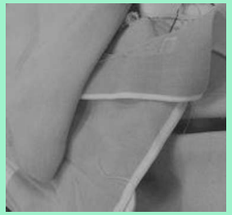
Thermo-mechanical investigation with pre-consumers materials – Investigation plan

Raw Materials

- Pre-consumer PET fibres

- Pre-consumer PET fabrics (knits)



Erema Process

- Densification

- Extrusion
- Filtration
- Pelletizing

Rheology & Compound

- Liquid viscosity and behavior of the recycled resin under different pressures
- Comparison with different virgin resin
- Blend of r-PET & PET through compound

Melt spinning

- Extrusion defined by rheology results
- Investigation and comparison through:
  - Capillary throughput
  - Filament drawing
  - …

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Thermo-mechanical investigation with pre-consumers materials – Results

PET fibres

PET knitted fabrics

Thermo-mechanical recycling process

Fibre rPET

Knitted fabrics rPET

Melt-spinning process

Fibres rPET

Knitted fabrics rPET

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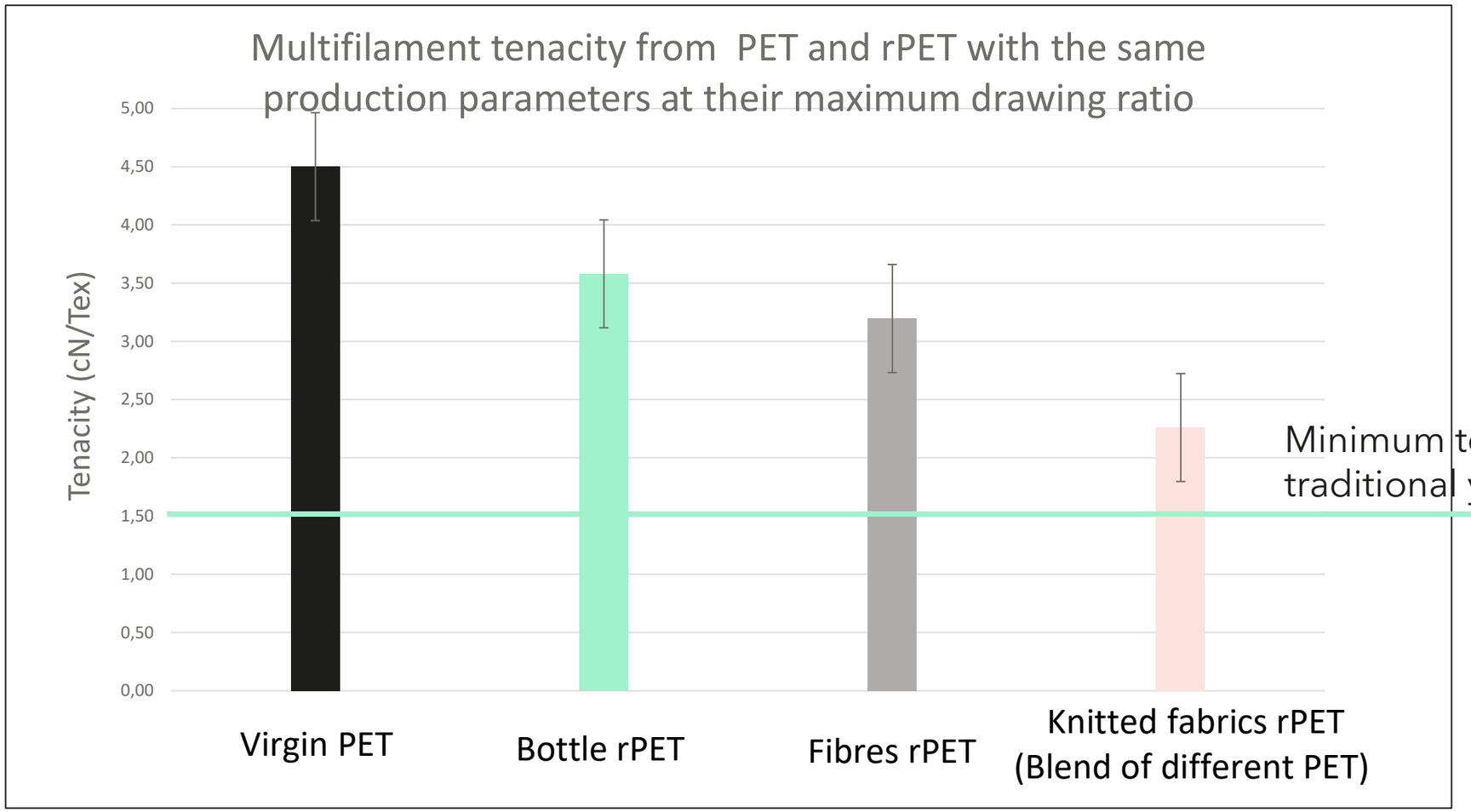
Thermo-mechanical investigation with pre-consumers materials – Results



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D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50% Thermo-mechanical recycling Negombo

DECATHLON

CETI	November 2022

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Thermo-mechanical Process – NEGOMBO

DECATHLON

Step 1

- Pre-consumer feedstock Negombo
- Thermo-mechanical recycling
- Rheology
- Compound with virgin PET
  - Recycling content: 30% & 70%
- Melt-spinning process
  - 50d/72 DTY
  - 75d/72 DTY
  - 75d/36 DTY

Step 2

- Post-consumer feedstock Negombo
- Thermo-mechanical recycling
- Rheology
- Compound with virgin PET
  - Recycling content: step 1
- Melt-spinning process
  - 50d/72 DTY
  - 75d/72 DTY
  - 75d/36 DTY

Step 3

- PATMOS investigation

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Thermo-mechanical Process – NEGOMBO

Raw Materials

- Pre-consumer Negombo farbics

Erema Process

- Feedstock preparation
- Densification
- Extrusion
- Filtration
- Pelletizing

Rheology & Compound

- Liquid viscosity and behavior of the recycled resin under different pressures
- Compound with recycled content:
  - 100%
  - 70%
  - 30%

Melt spinning

- Process thankss to scientific approach
- Multi-filaments:
  - 85-90 dtex [50d/72 DTY]
  - 130-135 dtex [75d/72]
  - 130-135 dtex [75d/36]
- Specifications:
  - Elongation: 120 -140%
  - Tenacity:1.94-2.21 cN/dtex

Conclusions

Negombo thermomechanical is possible but problem of contamination (filtration clogging)

R-Negombo suitable for melt spinning process thanks to positive rheology behavior

100% r-Negombo extrusion and filament spinning are stable

Multi-filament for final application 75d/36 DTY under the specifications and not possible to texturizing.

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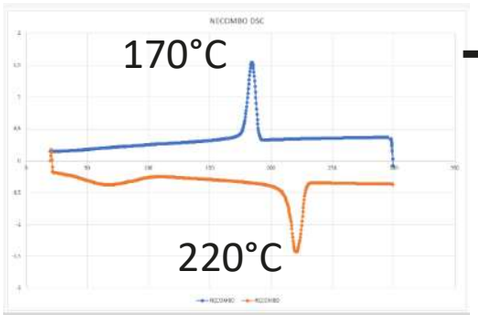
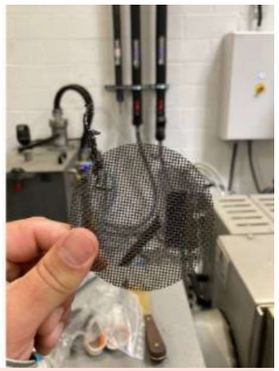
NEGOMBO - Thermo-mechanical recycling



DSC Analysis



Not continuous process ➔ filter tended to clog, due to the NEGOMBO contamination

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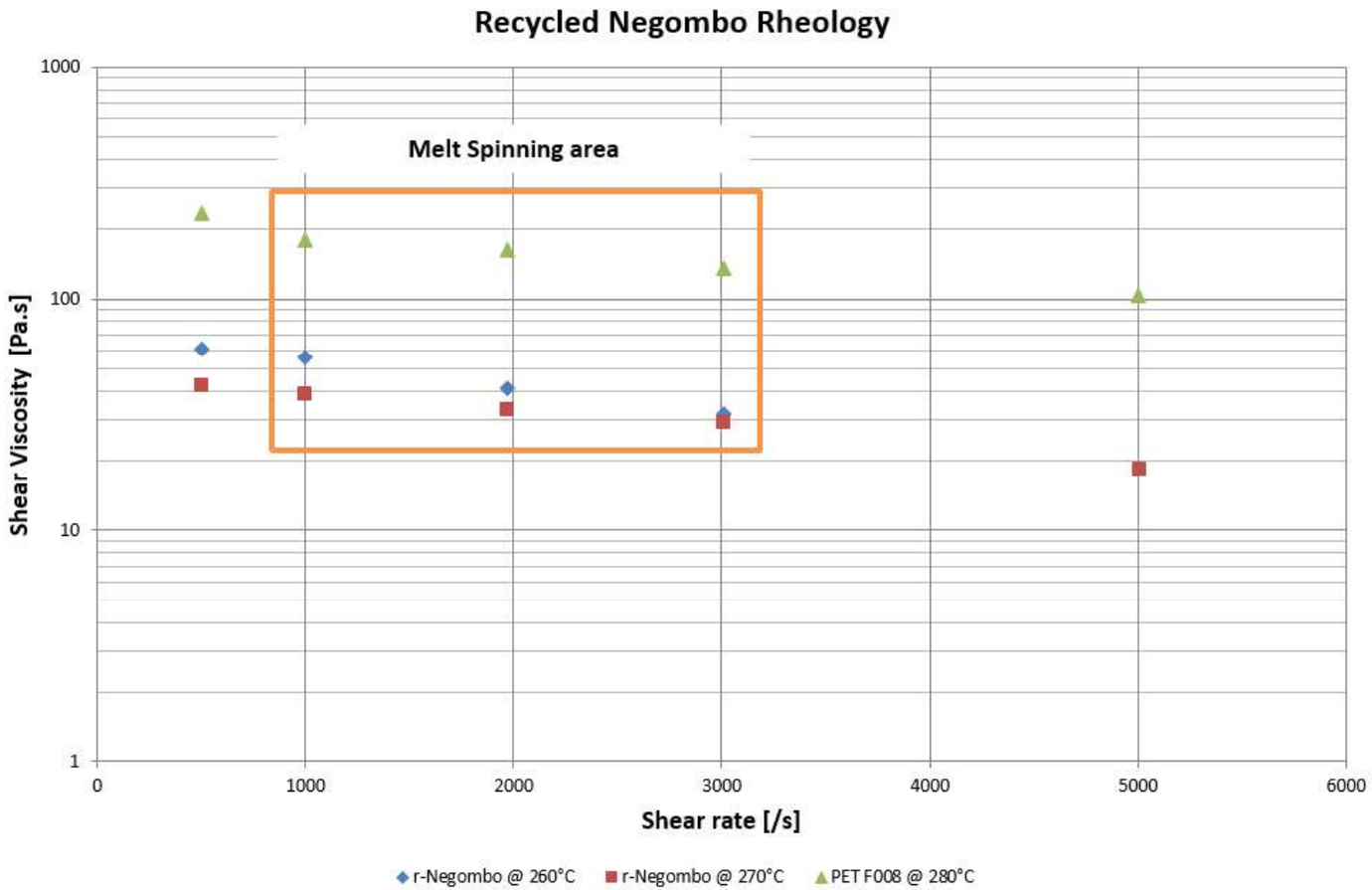
NEGOMBO - Rheology



R-Negombo

- Good viscosity at 270°C

R-Negombo vs PET

- Less viscous means sheared macromolecules due to recycling

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NEGOMBO - Melt-Spinning – Process investigation

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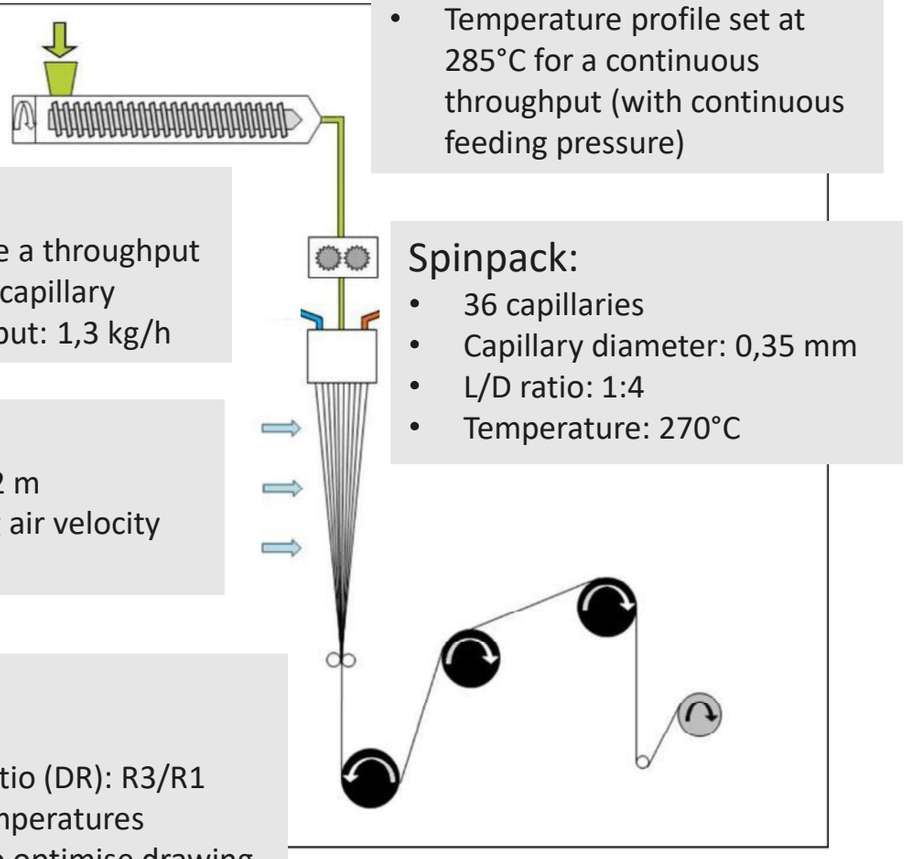

Extruder
- Temperature profile set at 285°C for a continuous throughput (with continuous feeding pressure)

Spin pump
- Set to achieve a throughput of 0,6 g/min/capillary
- Line throughput: 1,3 kg/h

Spinpack:
- 36 capillaries
- Capillary diameter: 0,35 mm
- L/D ratio: 1:4
- Temperature: 270°C

Quenching:
- Length: 1,2 m
- Quenching air velocity set at 0

Drawing:
- 3 godets
- Drawing ratio (DR): R3/R1
- Godets temperatures adjusted to optimise drawing

Recycled Negombo at 100%

Final product: 75den/36 filaments DTY means 130-135 dtex/36 filaments POY

	R1	R2	R3	DR	R1	R2	R3	Multi filament
	[m/min]				[°C]			[dtex]
1	1 480	1 490	1 500	1.00	70	75	37	140
2	1 000	1 510	1 520	1.49	70	75	37	149
3	**750**	**1 510**	**1 520**	**1.98**	**70**	**75**	**37**	**140**
4	750	1 610	1 620	2.13	70	75	37	133

Melt spinning process

- Extrusion and filament spinning are stable

Filament drawing investigation

- The conditions #3 are the best

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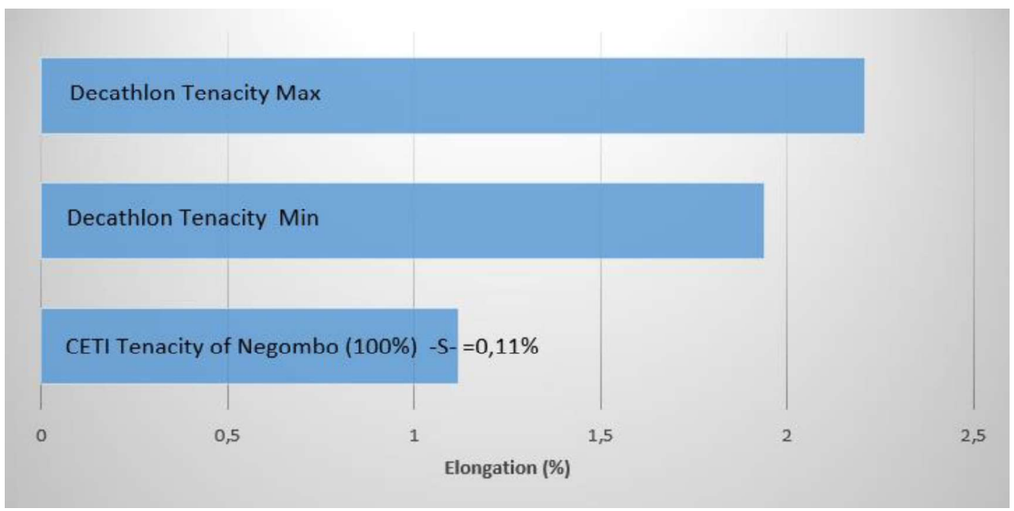
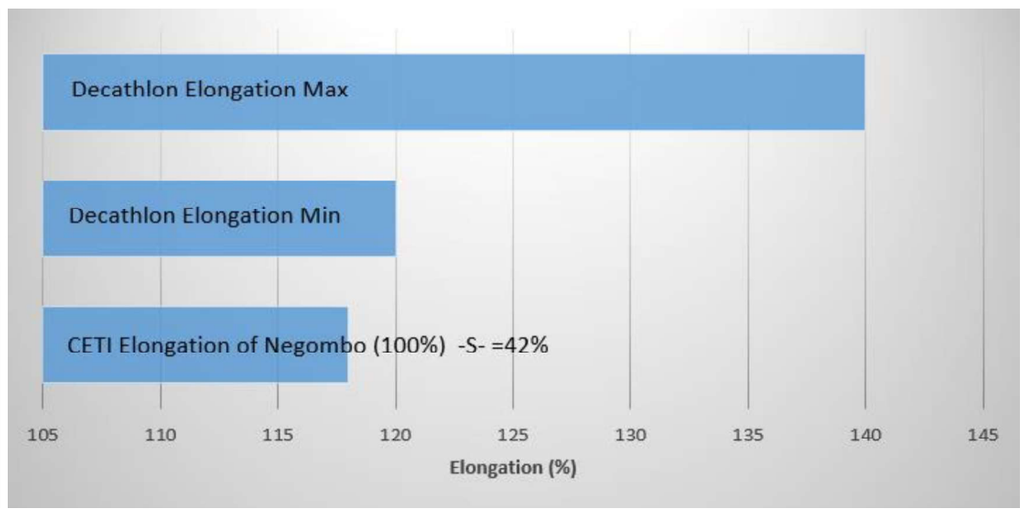
NEGOMBO - Melt-Spinning - Results

	R1	R2	R3	DR	R1	R2	R3	Multi filament	Tenacity	Elongation
	[m/min]				[°C]			[dtex]	[cN/dtex]	[%]
1	1 480	1 490	1 500	1.00	70	75	37	140	0,92	205
2	1 000	1 510	1 520	1.49	70	75	37	149	1,03	161
3	**750**	**1 510**	**1 520**	**1.98**	**70**	**75**	**37**	**140**	**1,12**	**118**
4	750	1 610	1 620	2.13	70	75	37	133	1,19	111





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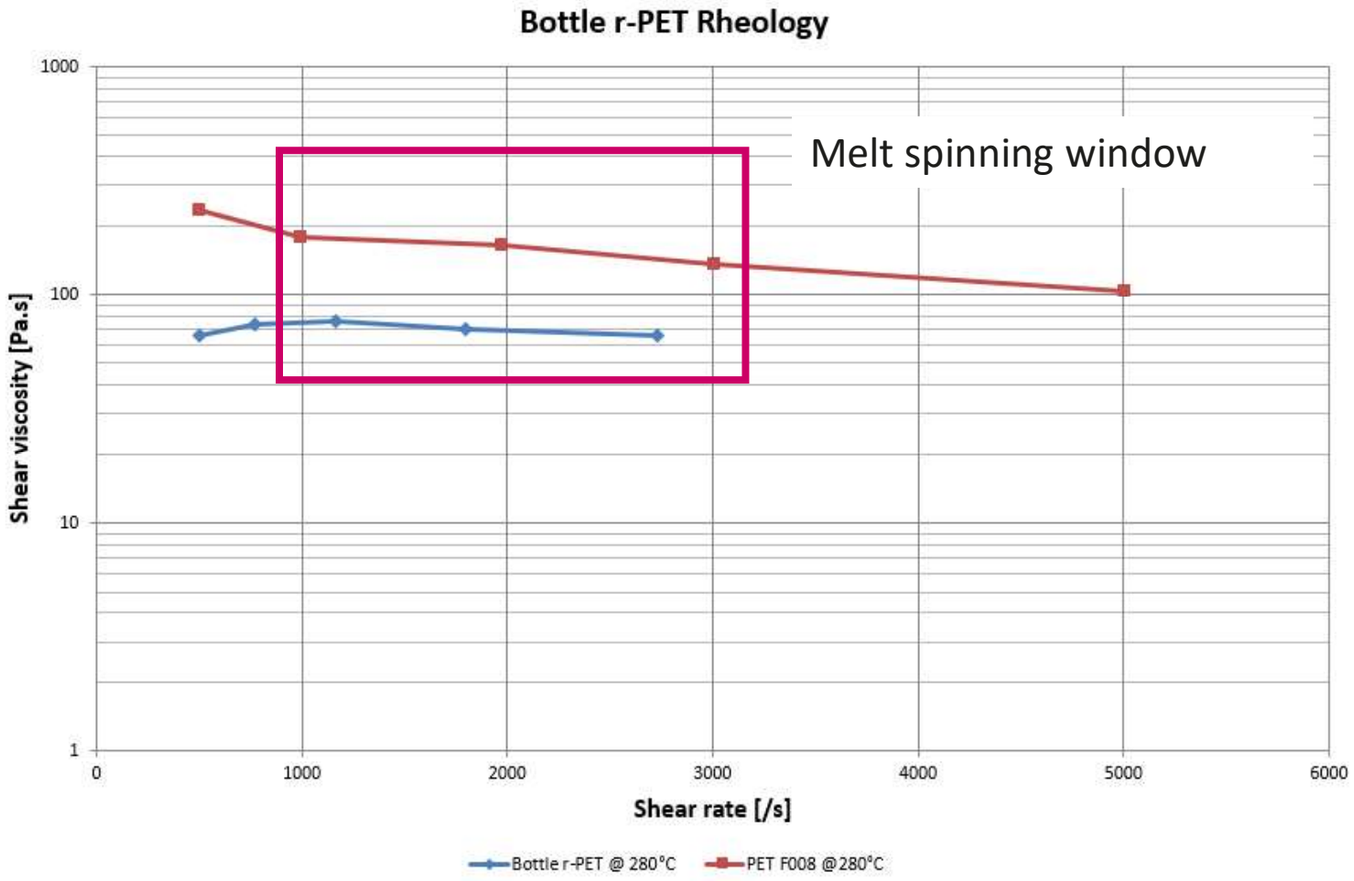
Bottle r-PET vs PET Rheology



Bottle r-PET less visquous than standard PET

- Recycled product with higher shearing
- Lower possible final mechanical proeperties

Bottle r-PET has good viscosity for filament application

- Resin is still visquous to be processed through melt spinning process

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NEGOMBO - Polymers blending through compounding

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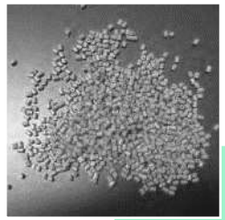
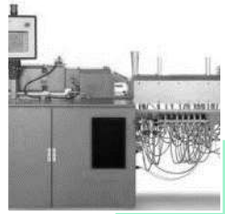
Raw materials

- Recycled Negombo
- Bottle r-PET



Blending

- R-Negombo: 50% and 75%
- Bottle r-PET: 50% and 25%



Compound extrusion

- Profile: 260°C
- Throughput: 20 kg/h
- Torque: 63%

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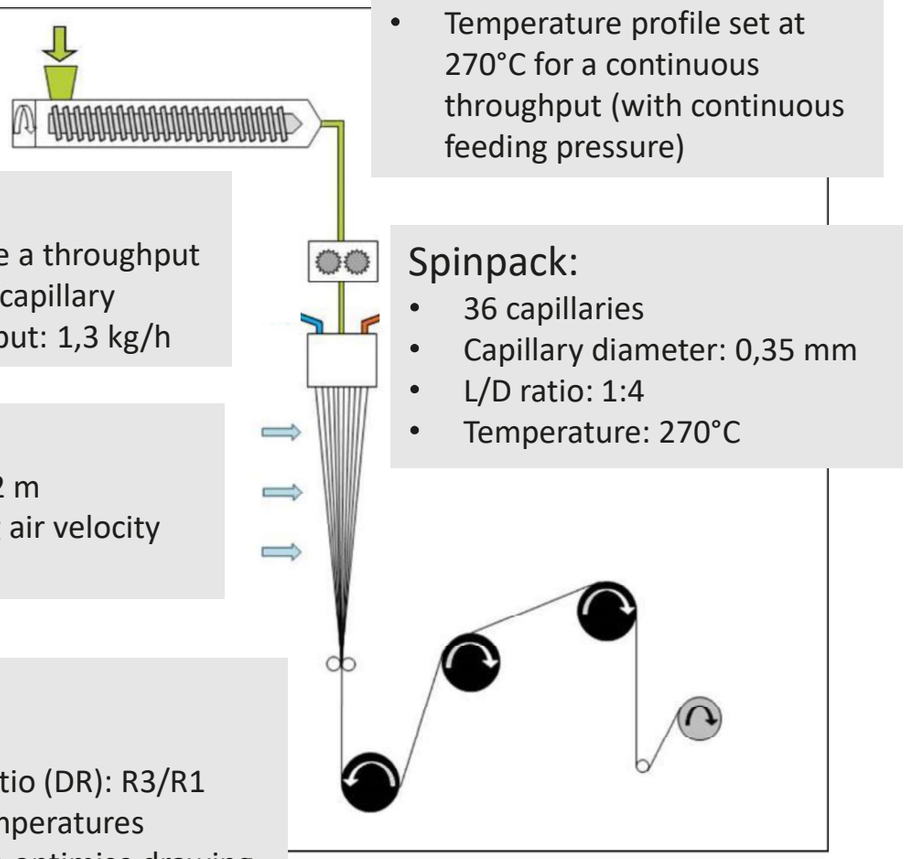
NEGOMBO - Melt-Spinning – Process investigation Step 2



Extruder
- Temperature profile set at 270°C for a continuous throughput (with continuous feeding pressure)

Spin pump
- Set to achieve a throughput of 0,6 g/min/capillary
- Line throughput: 1,3 kg/h

Spinpack:
- 36 capillaries
- Capillary diameter: 0,35 mm
- L/D ratio: 1:4
- Temperature: 270°C

Quenching:
- Length: 1,2 m
- Quenching air velocity set at 0

Drawing:
- 3 godets
- Drawing ratio (DR): R3/R1
- Godets temperatures adjusted to optimise drawing

Process is not reproductible

- Comparison with previous trials – difficulties to apply exactly same parameters settings

R-Negombo viscosity variations

- Despite of equivalent process conditions, the final viscosity of the r-Negombo ensures variations of results

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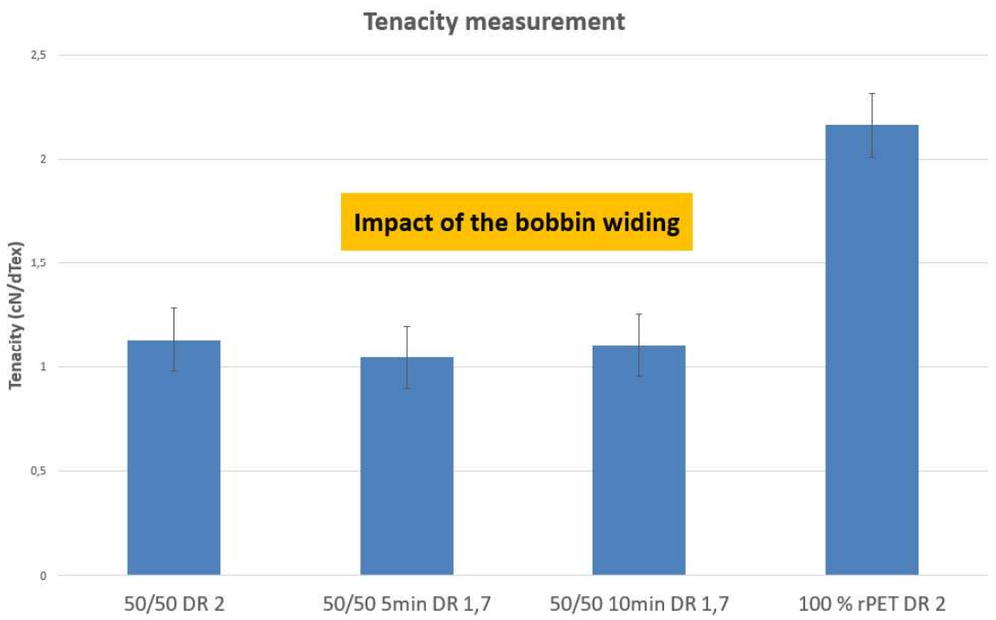
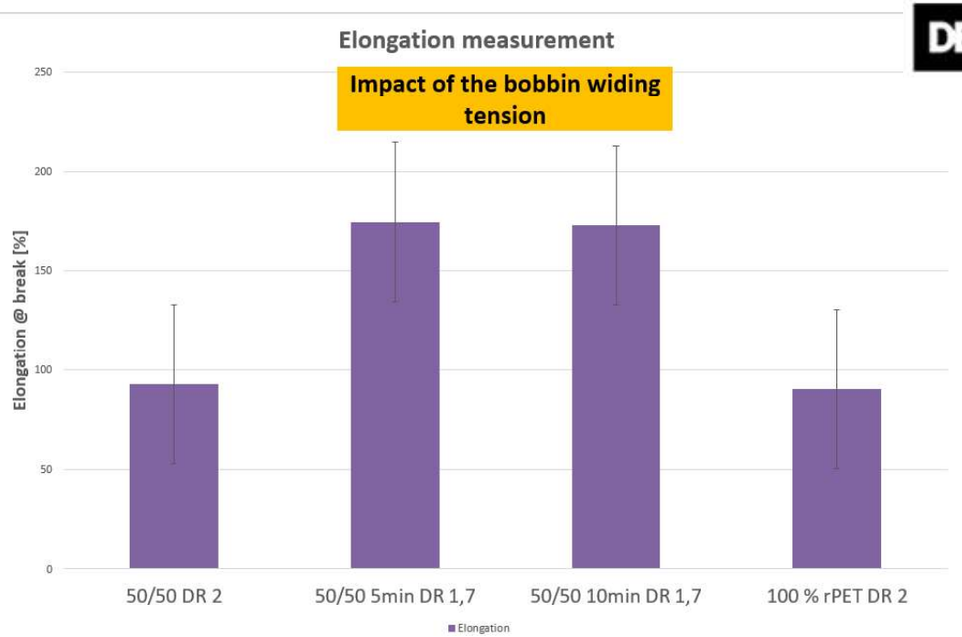
NEGOMBO - Melt-Spinning – Process investigation Step 2





- Bottle r-PET resin fulfills the requirements of final mechanical properties (>2 cN/dtex, 120%).
- The r-Negombo content reduces by 2 the final tenacity.
- Drawing ratio (DR) and godet temperatures are the key to achieve an high filament elongation.

➔ **Coloured r-Negombo and consequent potential contamination can impact negatively the final filament mechanical properties. By investigating with a post-production Negombo without treatment (dying and finishing), a better understanding of the recycling process can be achieved**

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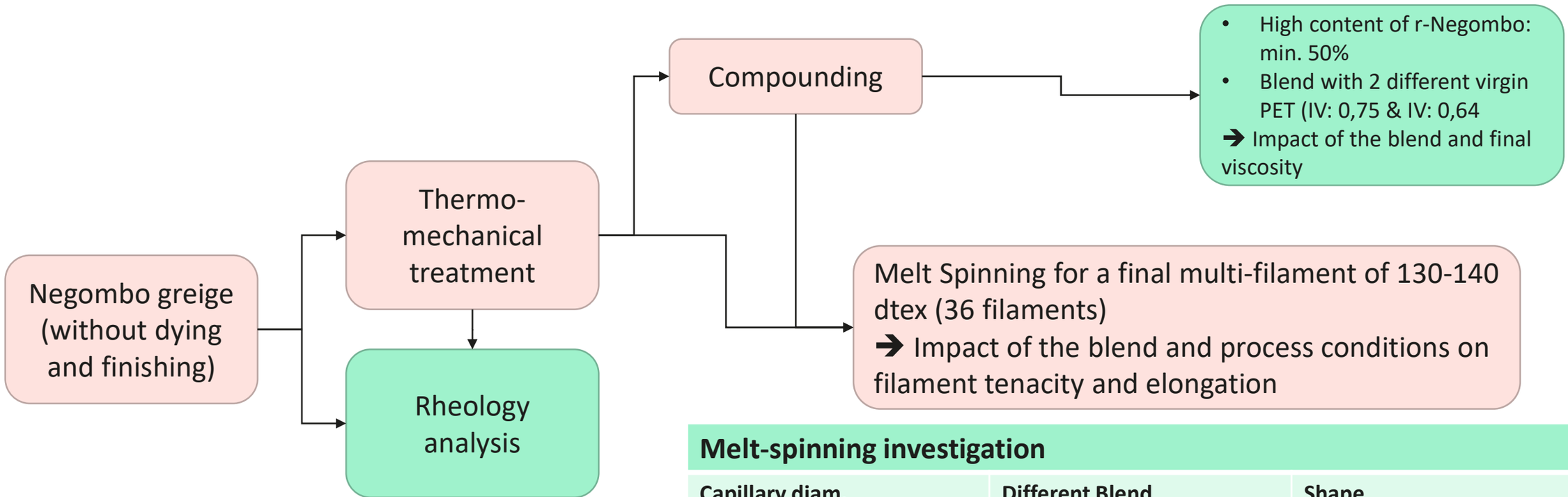
NEGOMBO – Thermo-mechanical recycling – further steps



Melt-spinning investigation

Capillary diam.	Different Blend	Shape
0,35 and 0,60 mm	Recycled material content from 50% to 100%	• Mono-component • Bi-component (Core/Sheath)
Impact of the resin shearing	Impact of the blend viscosity	Better configuration to achieve high recycled content

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

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D2.2: Prototypes of yarn from task 2.1 with a recycled content > 50% Thermo-mechanical recycling PET Post-consumer feedstock

valvan baling systems

CETI	November 2022

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Thermo-mechanical Process – Post-consumer PET

valvan baling systems

Step 1

- Post-consumer feedstock
- Thermo-mechanical recycling
- Rheology
- Compound with virgin PET
  - Recycling content: 50% & 75%

Step 2

- Post-consumer feedstock
- Melt-spinning process with different blends with two kind of virgin PET

Step 3

- Post-consumer feedstock
- Melt-spinning process with sheath/core cross section

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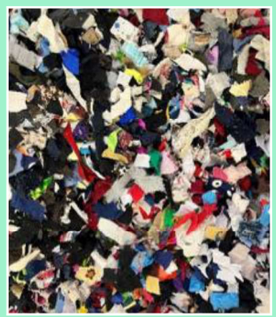
Thermo-mechanical Process – Post-consumer PET

Raw Materials

- Post consumer cutted textile > 98% PET



Erema Process

- Feedstock preparation
- Densification
- Extrusion
- Filtration
- Pelletizing

Rheology & Compound

- Liquid viscosity and behavior of the recycled resin under different pressures
- Compound with recycled content:
  - 50%
  - 75%

Melt spinning

- Process thanks to scientific approach
- Multi-filaments:
- Monocomposant from the obtained blends
- Specifications:
  - Elongation: 120 -140%
  - Tenacity:1.94-2.21 cN/dtex
  - Count : 140 dtex

Conclusions

Post-consumer thermomechanical is possible but problem of contamination (filtration clogging : filter changement each 30 min)

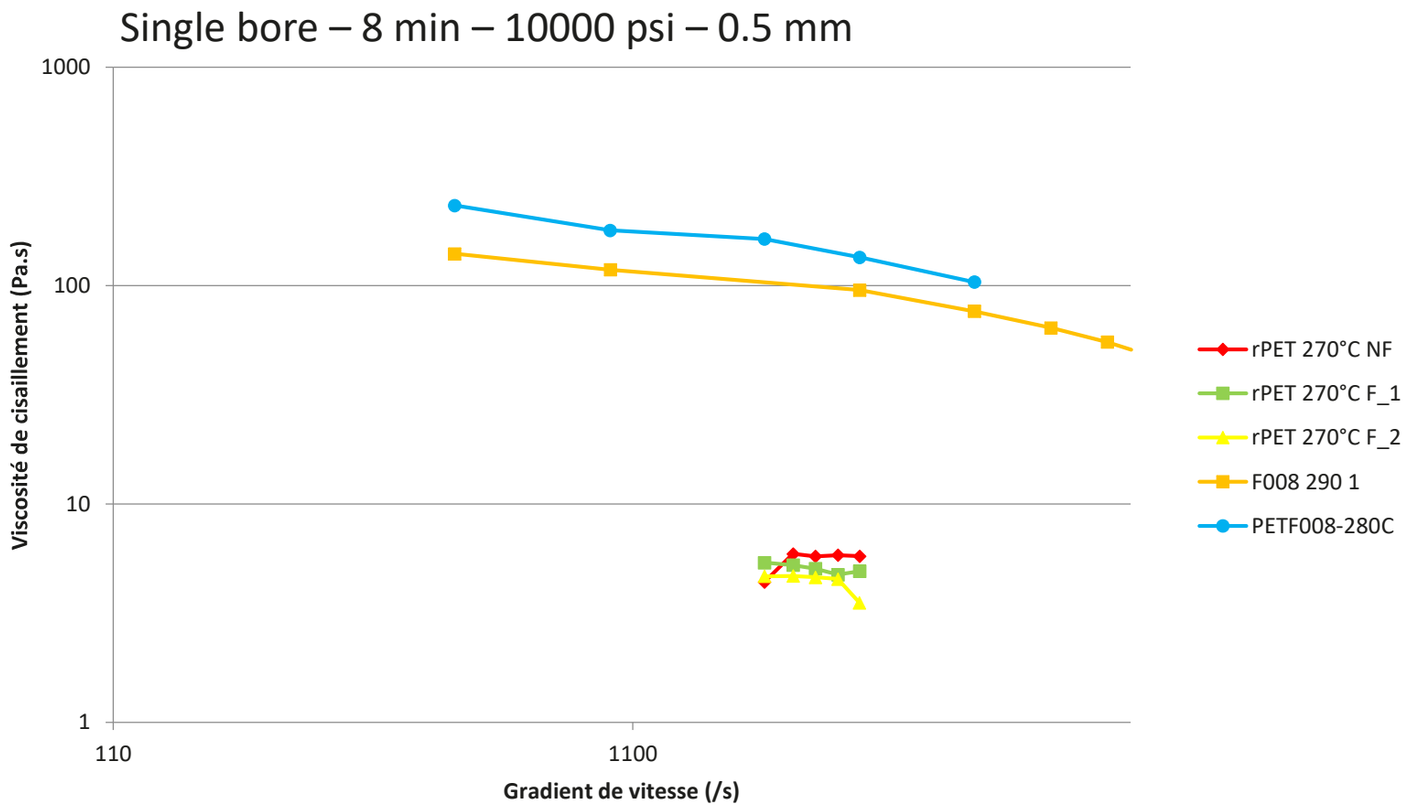
100% Post-consumer is not suitable for melt spinning process due to negative rheology behavior

Extrusion and filament spinning are not stable

Multi-filament for final application 75d/36 DTY under the specifications and not possible for texturizing.

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

Rheology of the rPET obtain



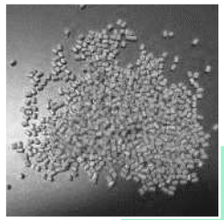
- Very low viscosity (270°C is the lower temperature possible)
- Blending are mandatory to a good processing
- The unfiltered material have a lower viscosity due to fewer contamination

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

POSTCONSUMER - Polymers blending through compounding

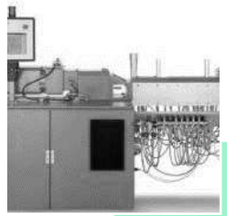
Raw materials

- R-Post consumer cutted textile > 98% PET pellets
- Virgin PET F008
- Virgin PET 5140
  → These two references don't have the same macromolecule characteristic, they will not interract the same way with the recycled material



Blending

- R-Post consumer: 50% and 75%
- Virgin PET F008 **and** 5140: 50% and 25%



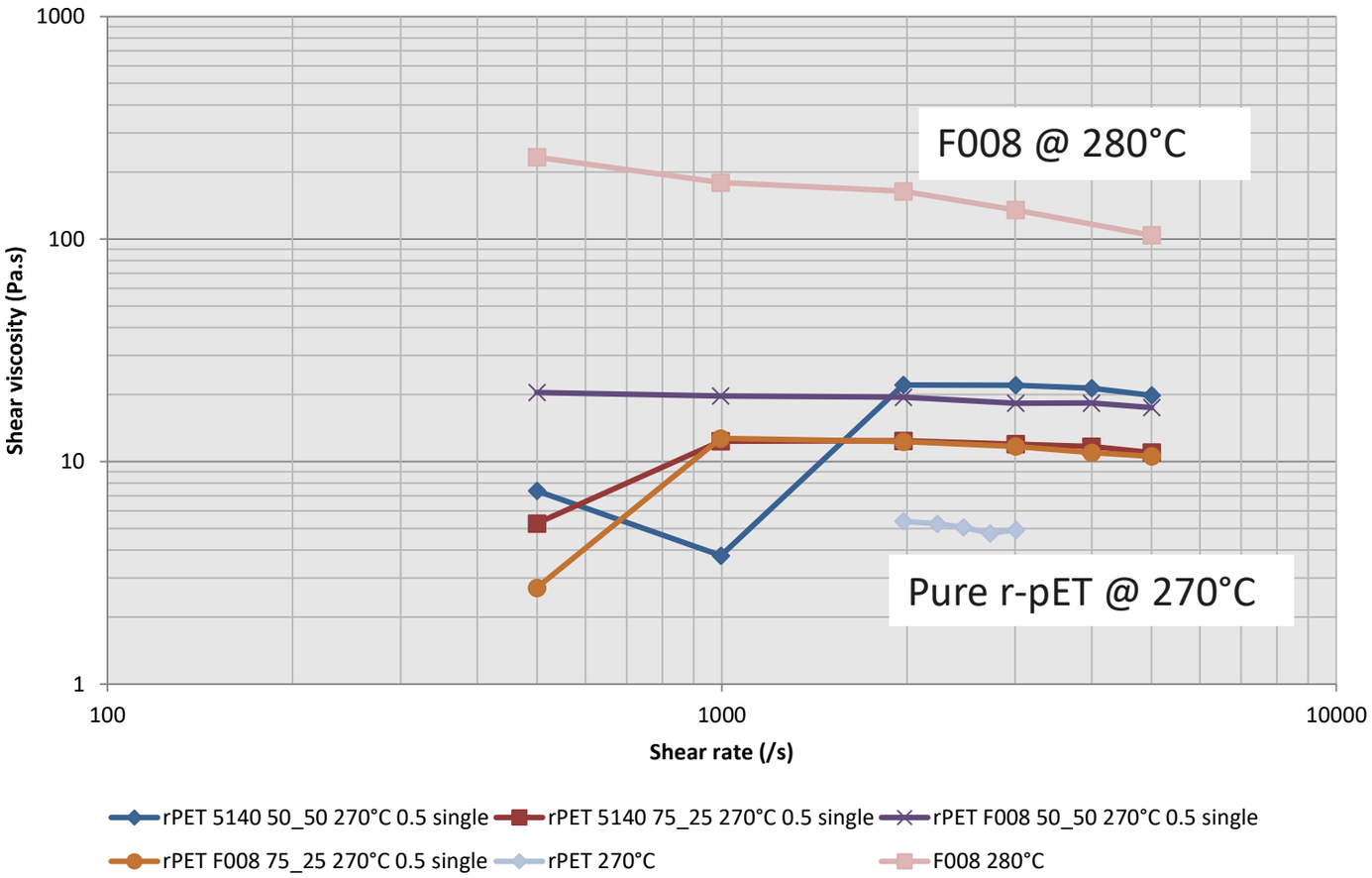
Compound extrusion

- Profile: 260°C
- Throughput: 20 kg/h
- Torque: 63%

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

POSTCONSUMER - Rheology of the rPET blends

Single bore – 8 min – 10000 psi – 0.5 mm



Blends improve viscosity behaviour

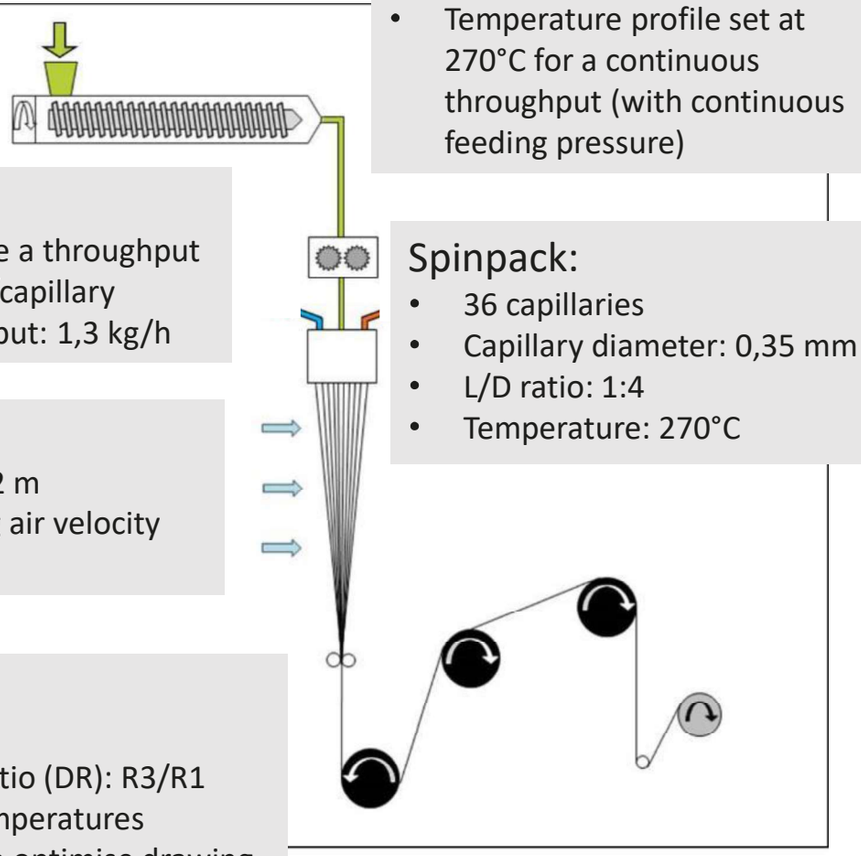
- Still below standard F008
- Viscosity seems to be under melt spinning standards

Blends 50/50 with RT 5140 and F008 seems to be similar blend

- Blends viscosity are closer to pure r-PET than virgin material
- The impact of IV of virgin material is under expectations

This project has received funding from the Horizon 2020 Programme under grant agreement n°101003906.

POSTCONSUMER - Melt-Spinning – Process investigation Step 2



Extruder
- Temperature profile set at 270°C for a continuous throughput (with continuous feeding pressure)

Spin pump
- Set to achieve a throughput of 0,6 g/min/capillary
- Line throughput: 1,3 kg/h

Spinpack:
- 36 capillaries
- Capillary diameter: 0,35 mm
- L/D ratio: 1:4
- Temperature: 270°C

Quenching:
- Length: 1,2 m
- Quenching air velocity set at 0

Drawing:
- 3 godets
- Drawing ratio (DR): R3/R1
- Godets temperatures adjusted to optimise drawing

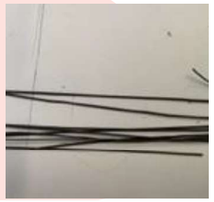
Process is not reproductible

- Difficulties to apply exactly same parameters settings a bobine to another

Extrusion conditions change

- To adapt a good spin-ability of the resins blends, extrusion profile needs to be increased to 280 and then 290°C

High contamination level



- Contamination clogs the spinneret capillary and filter decreasing the flow of material causing filament breaks

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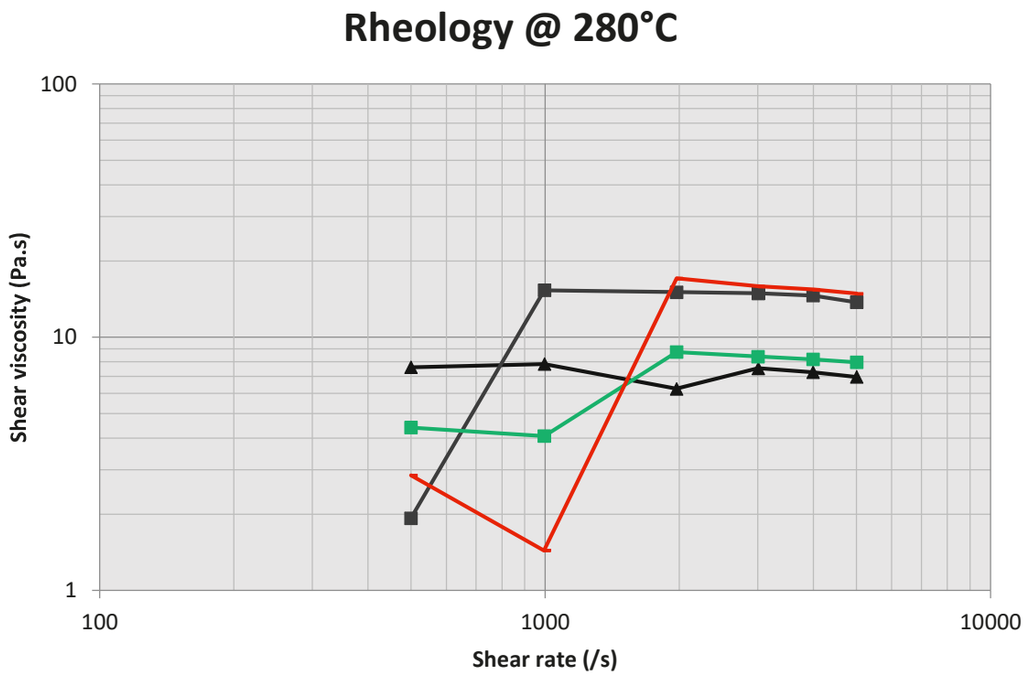
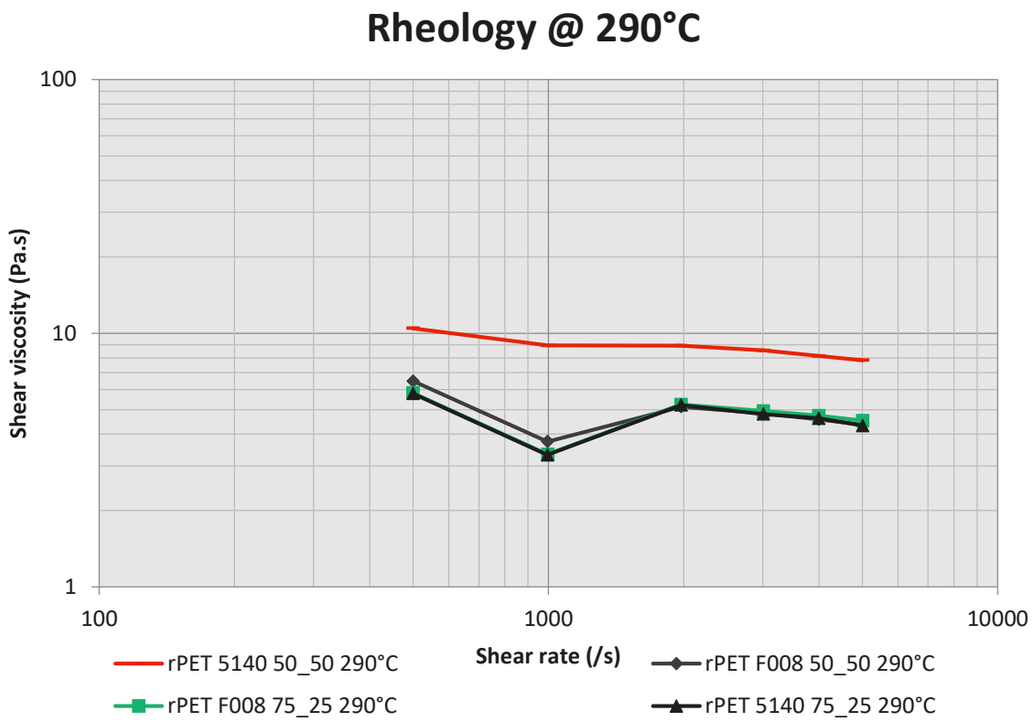
POSTCONSUMER - Thorough Rheology of the rPET blends

valvan baling systems





Single bore – 8 min – 10000 psi – 0.5 mm

- **During the melt spinning trial, extrusion profil had to be increased to improve the stability and the good processing of the material, more rheology analysis have been done with higher temperature**
- **PET 5140 seems to have a positive impact on the recycled material, futher work will include more investigation with this combination**

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POSTCONSUMER – Thermo-mechanical recycling – further steps

R-PET → Melt Spinning for a final multi-filament of 130-140 dtex (36 filaments)
➔ Impact of the cross section and process conditions on filament tenacity and elongation

Melt-spinning investigation		
Capillary diam.	**Different Blend**	**Shape**
0,35 and 0,60 mm	Recycled material content from 50% to 100%	**Bi-component (Core/Sheath)**
Impact of the resin shearing	Impact of the blend viscosity	Increase recycled material content

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Project Partners

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Thank you.

Let’s keep in touch.

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