A SOLUTION FOR THE CRUCIAL CHALLENGE OF TEXTILE RECYCLING: CHEMICAL REMOVAL OF FINISHES FROM ACRYLIC FABRICS

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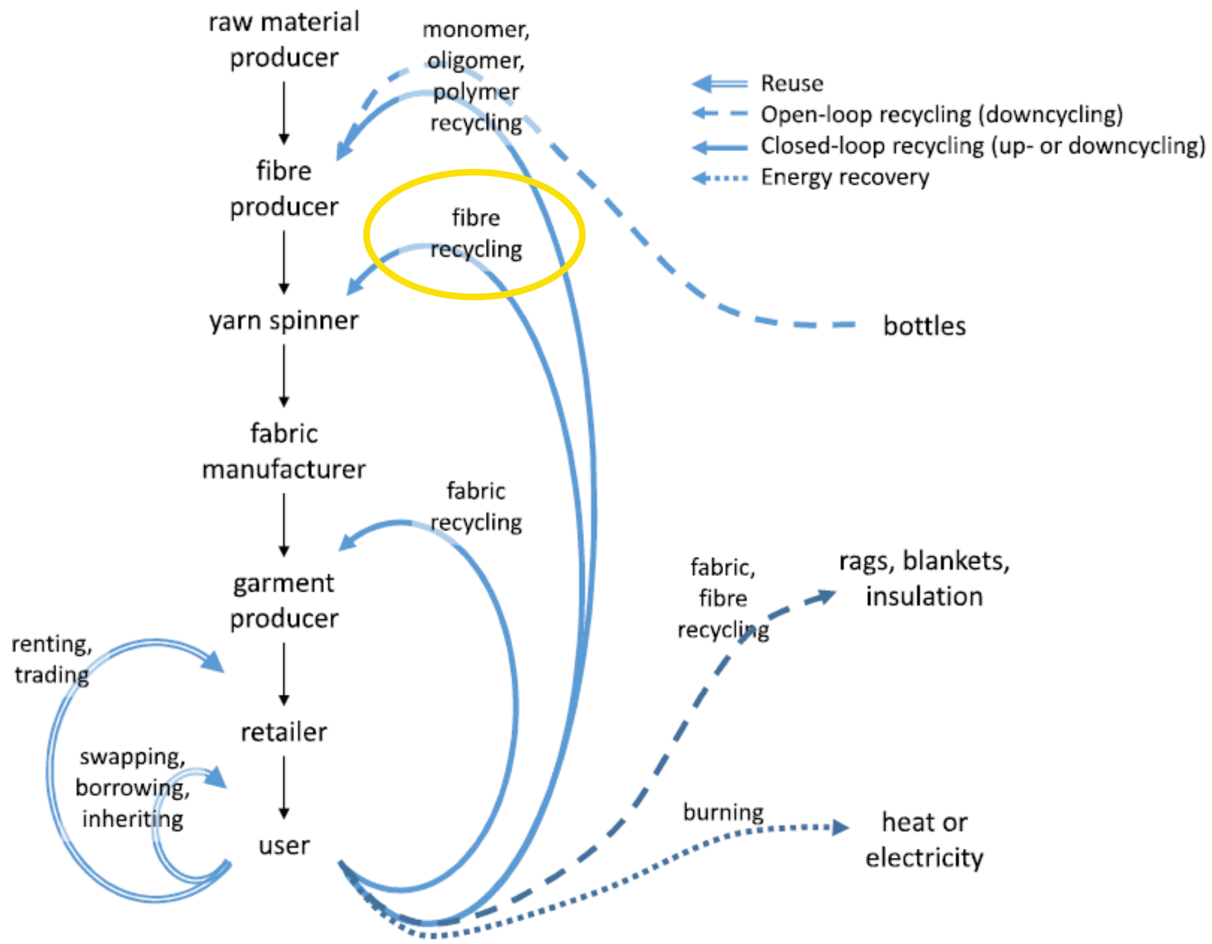
REACT webinar October 29, 2020

GOAL: RECYCLING OF WASTE ACRYLIC TEXTILES

PROCESS: MECHANICAL FIBRE RECYCLING



[1] G. Sandin and G. Peters, "Environmental impact of textile reuse and recycling – A review", *Journal of Cleaner Production*, vol. 184, pp. 353-365, Feb 2018.

WHY RECYCLE?

MECHANICAL RECYCLING – ECOLOGICAL BENEFIT [2]

Midpoint I	% reduction reached
Climate change	8
Particulate matter	8
Ionising radiation	12
Terrestrial acidific	8
Fossil depletion	8
Urban land occupa	7
Freshwater ecotox	10
Marine ecotoxicity	9
Metal depletion	7
Human toxicity	10
Freshwater eutrop	31
Marine eutrophica	18
Agricultural land c	24
Water depletion	25
Natural land trans	12
Ozone depletion	9
Photochemical oxi	8
Terrestrial ecotoxi	45

Phase	Option	ENDPOINTS		
		Human health	Ecosystem diversity	Resource availability
Production	Reducing agrochemical use	0.7	3.7	0.4
	Replacing cotton with hemp or flax	0.3	5.8	0.7
	Reducing consumption of sizing chemicals	0.2	0.3	0.2
	Replacing chemicals with enzymes	0.03	0.11	0.03
	Using alternative knitting techniques	1.2	2.0	4.0
	Using dye controllers and low liquor ratio dyeing machines	0.1	0.8	0.1
	Water recycling	0.6	11.3	0.6
Distribution	Reducing air freight	3.9	1.9	4.5
Use	Reducing washing temperature	4.7	2.1	4.3
	Optimising the load of appliances	3.9	2.4	3.3
	Reducing tumble drying	1.6	0.7	1.5
	Improvement of washing/drying appliances efficiency	3.8	1.7	3.6
End-of-life	Promotion of reuse and recycling	8.1	5.7	7.7

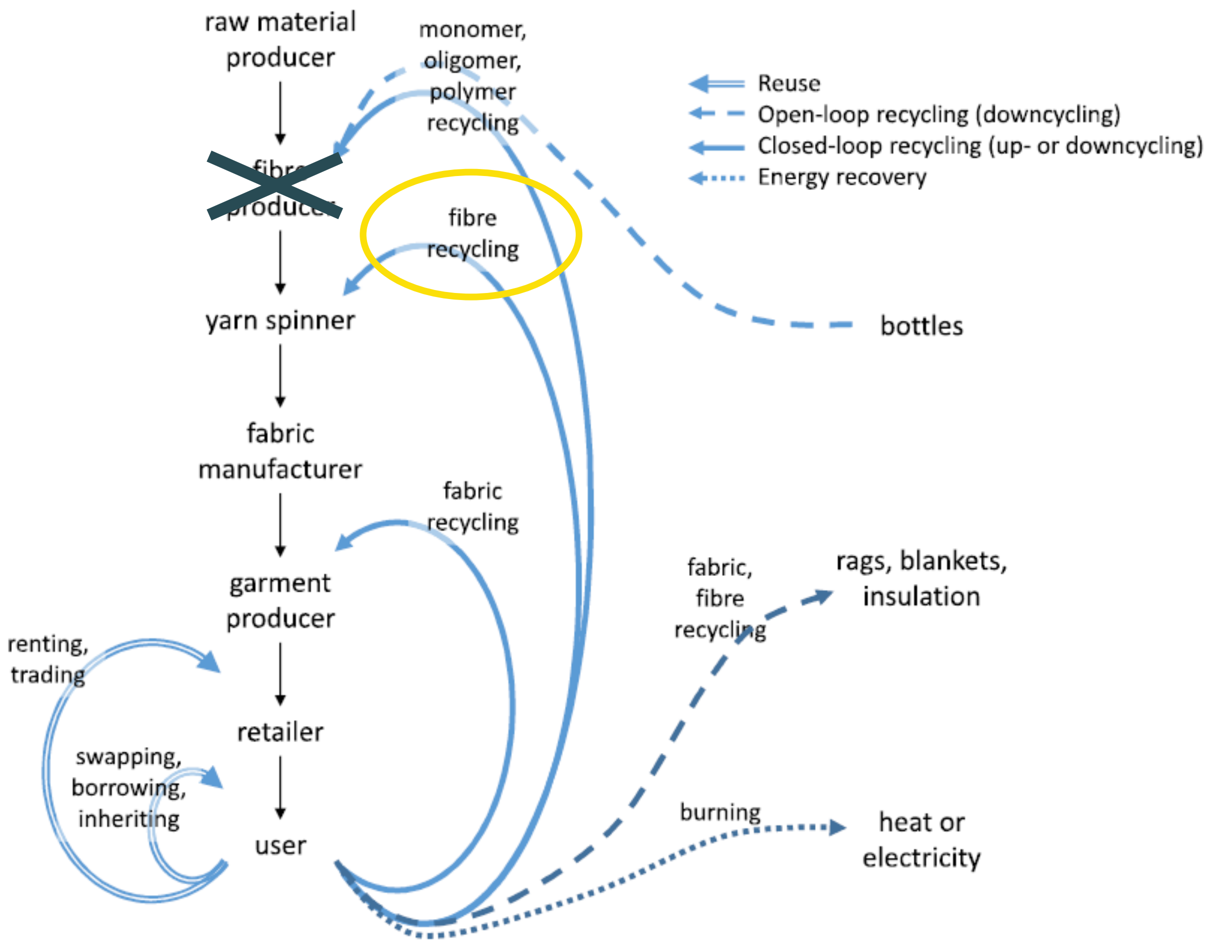
[2] A. Beton et al., *Environmental improvement potential of textiles (IMPRO Textiles)*. Luxembourg, 2014.

MECHANICAL RECYCLING – ECONOMICAL BENEFIT

- Energy yields (per kg)
  - 0 MJ gained from landfill
  - 2.4 MJ gained from incineration [3]
  - 19.4 MJ conserved by recycling [3]
- Recycling potential index [3]
  1. PET fibres
  2. PP fibres
  3. PE fibres
  4. **Acrylic fibres**

[3] S. Muthu, Y. Li, J. Hu and P. Mok, "Recyclability Potential Index (RPI): The concept and quantification of RPI for textile fibres", *Ecological Indicators*, vol. 18, pp. 58-62, 2012.

MECHANICAL RECYCLING – HEALTH BENEFIT [1]



- Melting temperature > 300°C
- Degradation temperature ≈ 280°C

→ Extruded and solution spun in highly polar organic solvents (e.g. ~~DMF, DMSO~~)

[1] G. Sandin and G. Peters, "Environmental impact of textile reuse and recycling – A review", *Journal of Cleaner Production*, vol. 184, pp. 353-365, Feb 2018.

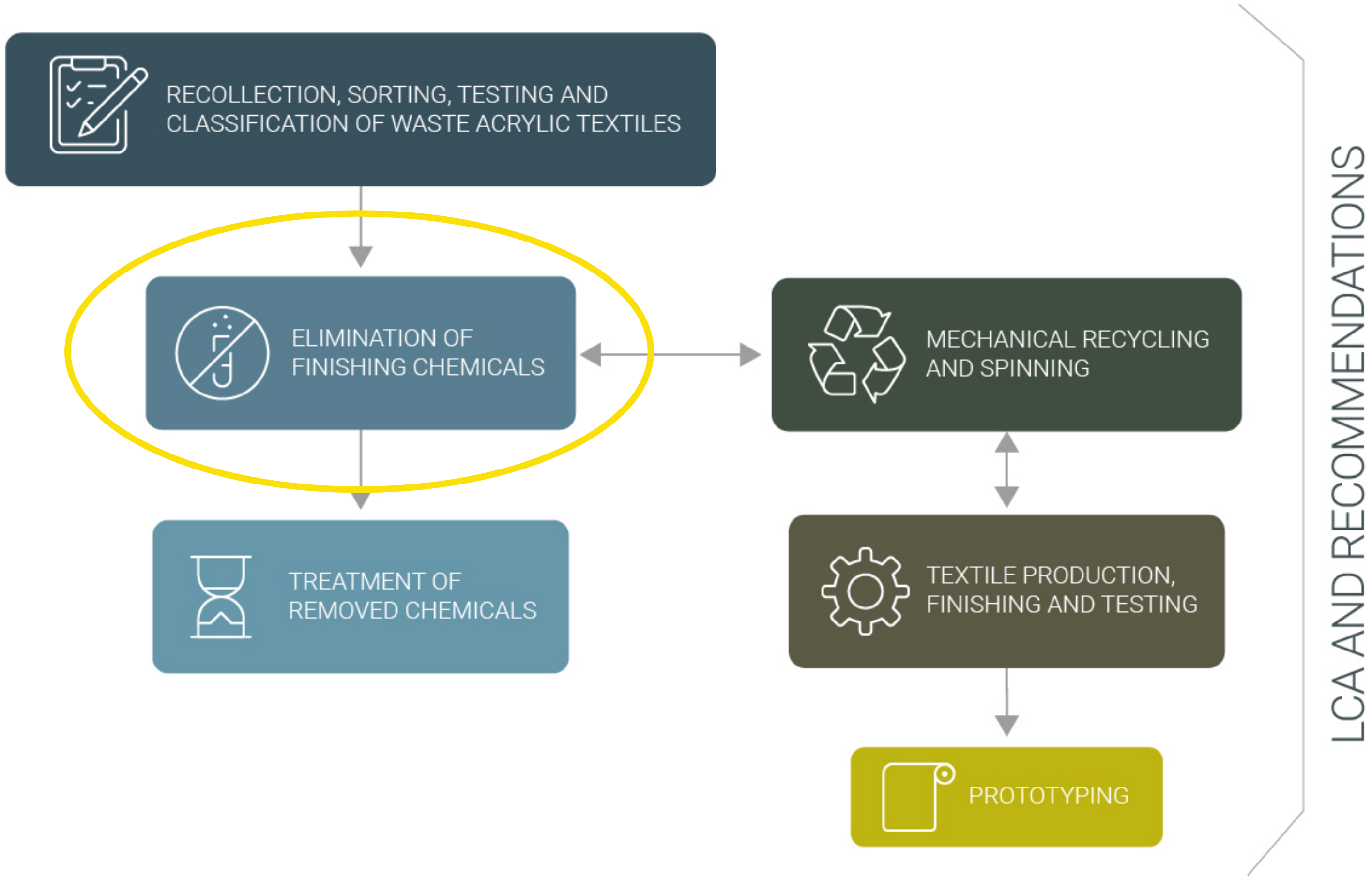
THERE IS ALMOST NO RECYCLING

Fibre material	Annual production (million tonnes) [4]
Synthetic	50
Cotton	20
Other	53

- Clothing (67% of the textile market in 2015) [4]
  - Only 1% closed-loop recycling!
  - Up to 12% cascaded recycling (downcycling)
- Outdoor acrylic fabrics
  - Not recycled at all

[4] Ellen MacArthur Foundation, "A new textiles economy: Redesigning fashion's future", Dec 2017.

REACT METHODOLOGY



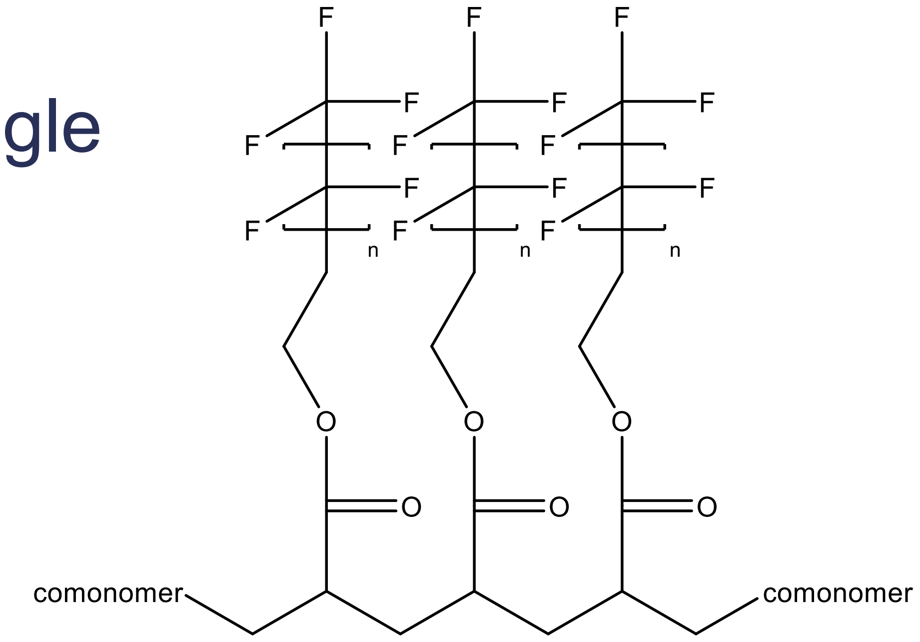
WHAT IS THE PROBLEM?

ACRYLIC FIBERS ARE CHEMICALLY FINISHED

- Awning finish
  - Thermosetting resin
  - Fluorocarbons

FLUOROCARBONS

- Most used water, oil and dirt repellent because lowest γ_c (10-20 mN/m)
- If the critical textile surface tension γ_c is lower than the liquid surface tension γ_l (internal cohesive interaction): contact angle is finite → prevents wetting and dirt from adhering to the surface [13]
  - γ_l, water = 72.75 mN/m at 20ºC
  - γ_l, oils = 20-40 mN/m at 20ºC



[13] D. Heywood, *Textile finishing*. Bradford: Society of Dyers and Colourists, 2003.

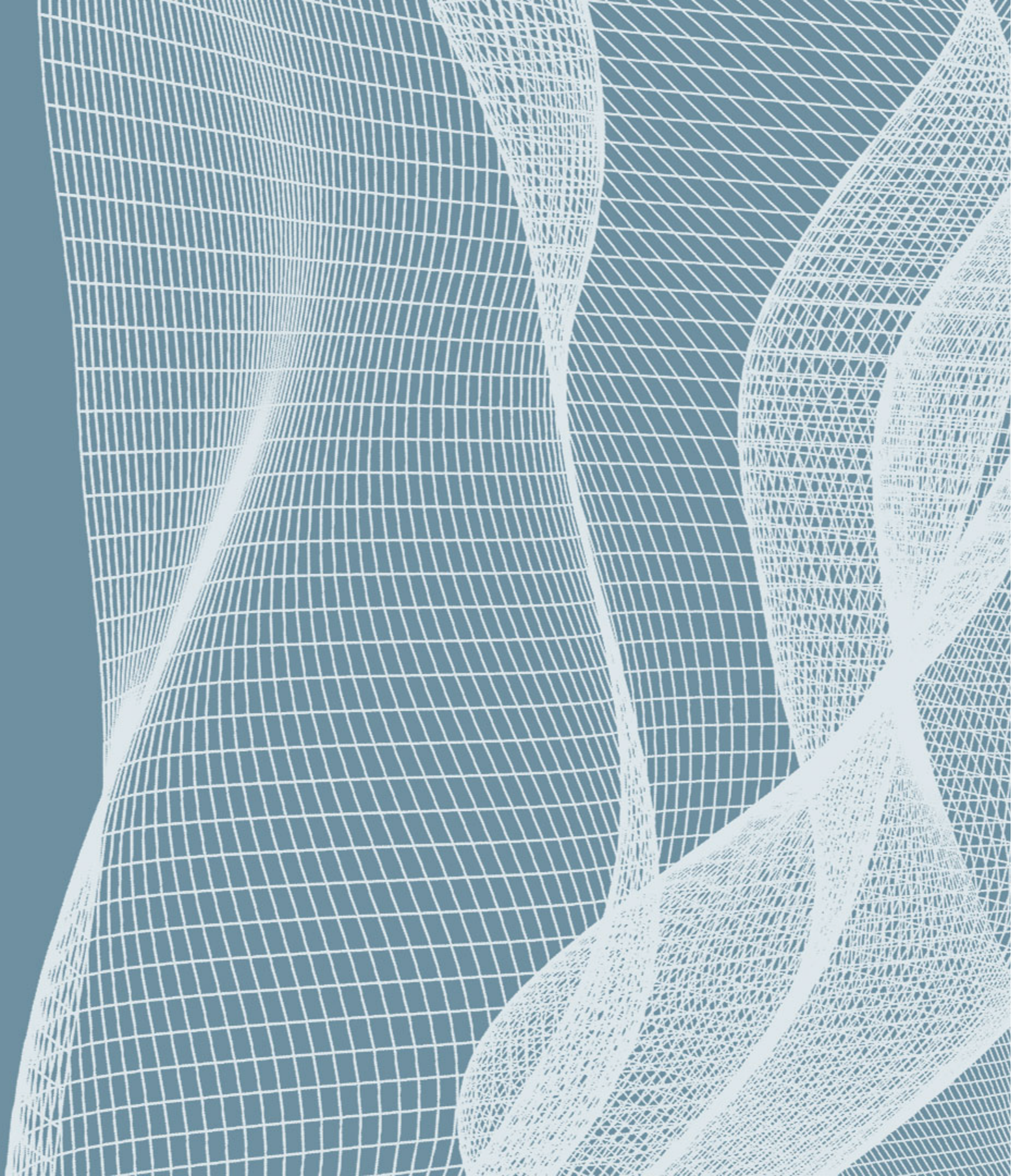
THERMOSETTING RESIN

- Improve dimensional stability/heat resistance and wash fastness
- Physically surround the fibre surface
- Bind the fluorocarbons to the fibre
- Cross-linked resin is insoluble in any solvent

→ Reverse the reactions!?

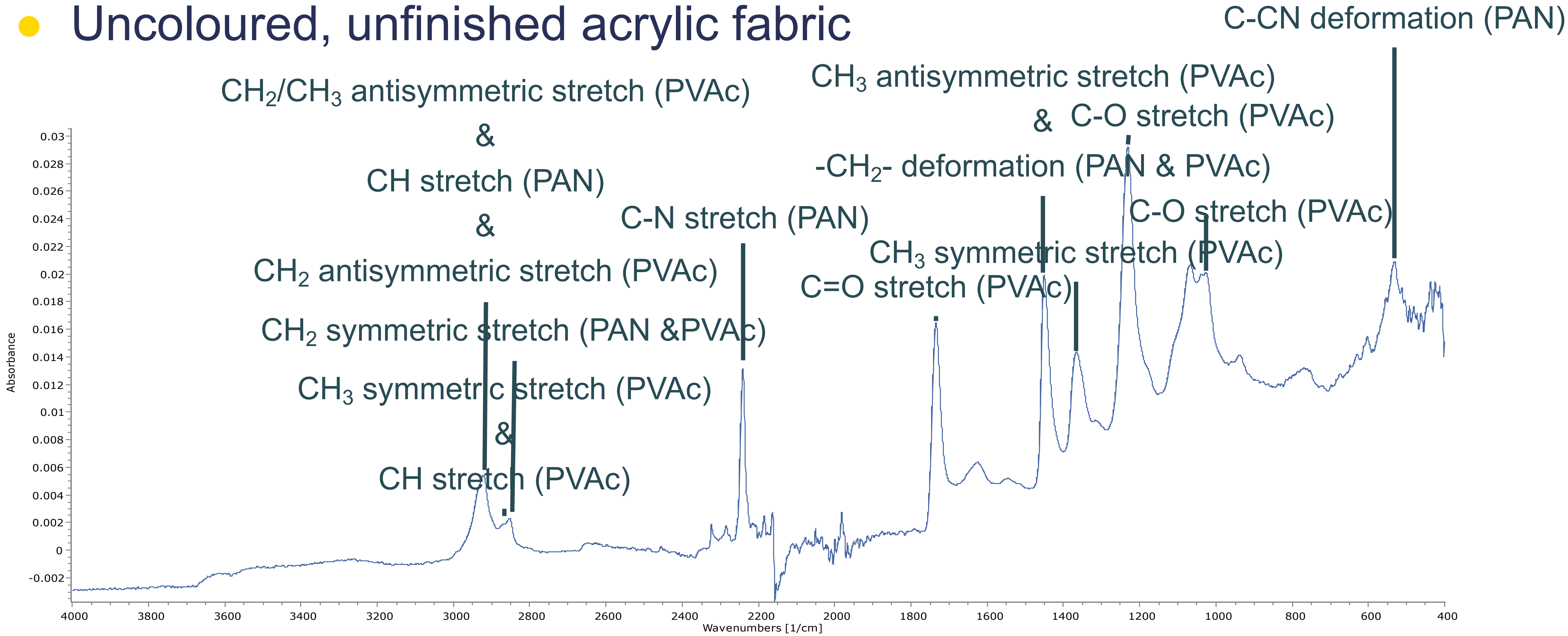
[5] "Melamine", *Polymerdatabase.com*, 2015. [Online]. Available: https://polymerdatabase.com/polymer%20classes/MelamineFormaldehyde%20type.html.

EVALUATION OF THE FINISH REMOVAL

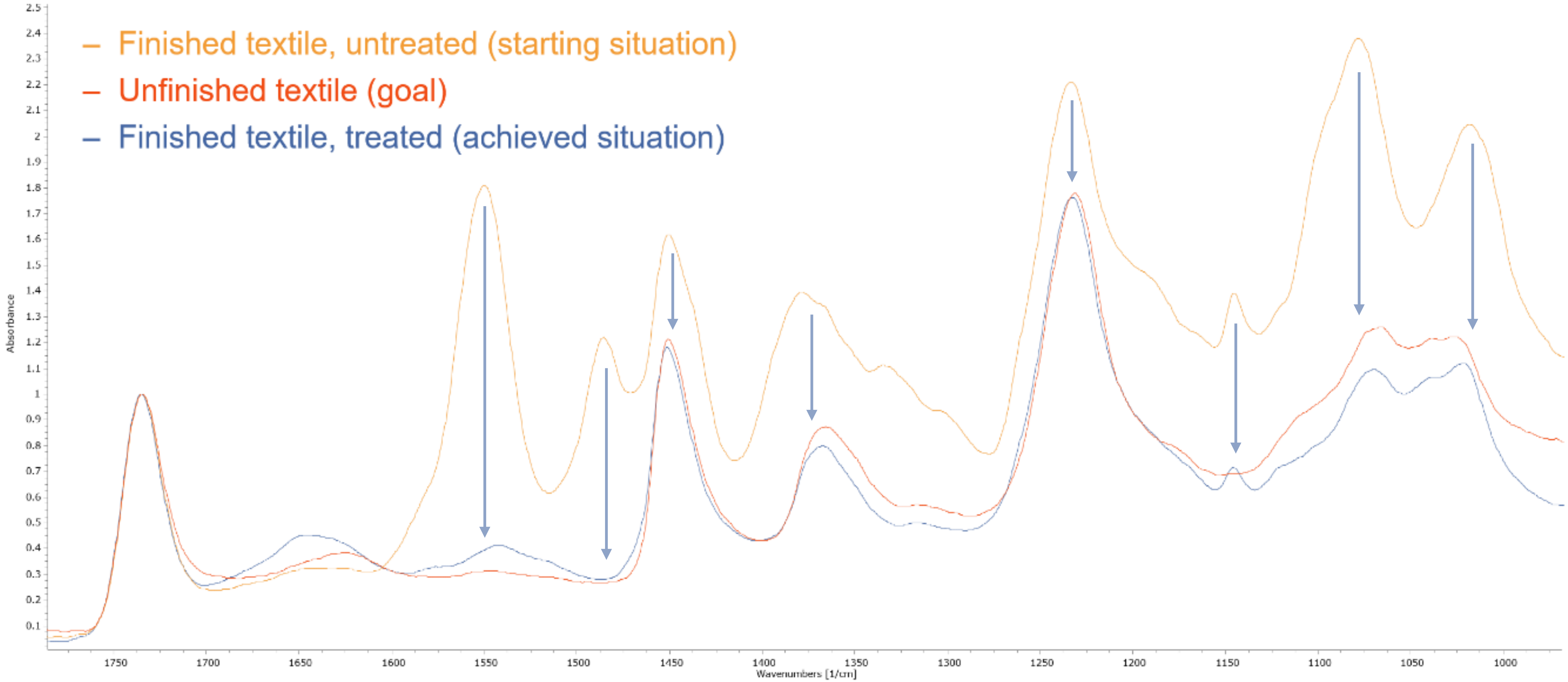


FTIR-ATR LETS US IDENTIFY A CHEMICAL SIGNATURE

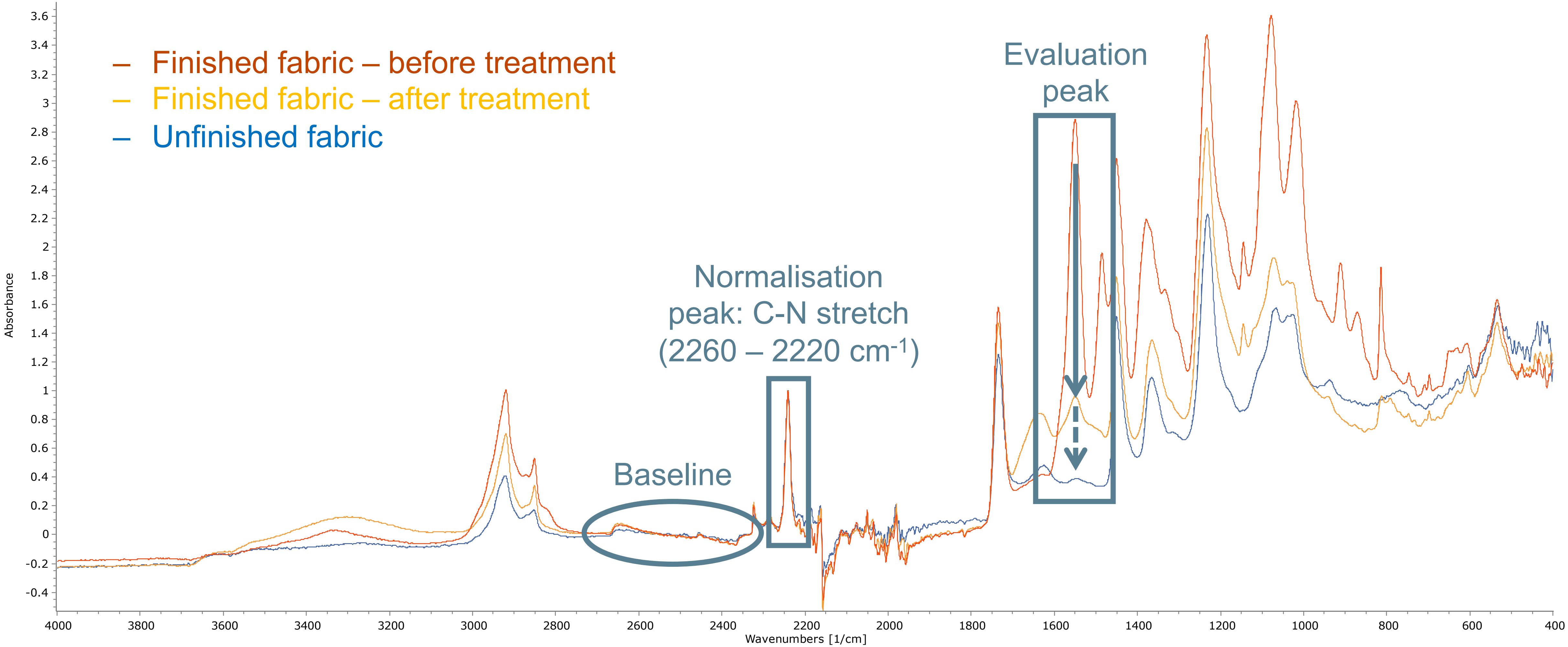
- Uncoloured, unfinished acrylic fabric



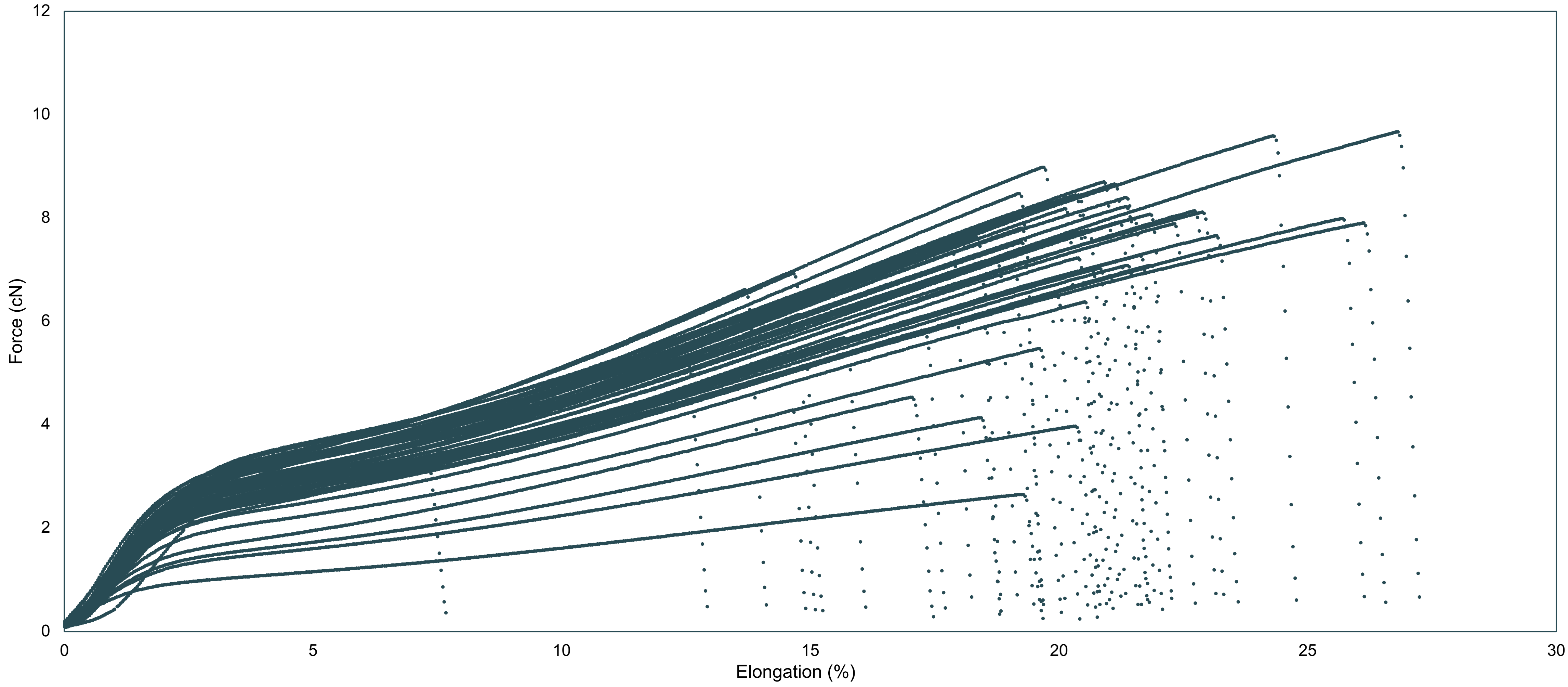
PEAK CHANGE SHOWS FINISH REMOVAL EFFECTIVENESS



PEAK CHANGE EVALUATION REQUIRES NORMALISATION



TENSILE TESTS LET US EVALUATE FIBRE DAMAGE



DOE METHODOLOGY

EXPERIMENTAL METHODOLOGY

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1. Preliminary tests
   - Determine parameter ranges for screening design
2. Definitive screening design
   - Determine which parameters are important to the process
   - Investigate possible mechanical damage to the fibres
3. Model creation
   - Used to optimise the parameters of the process
4. Optimised tests

DEFINITIVE SCREENING DESIGN

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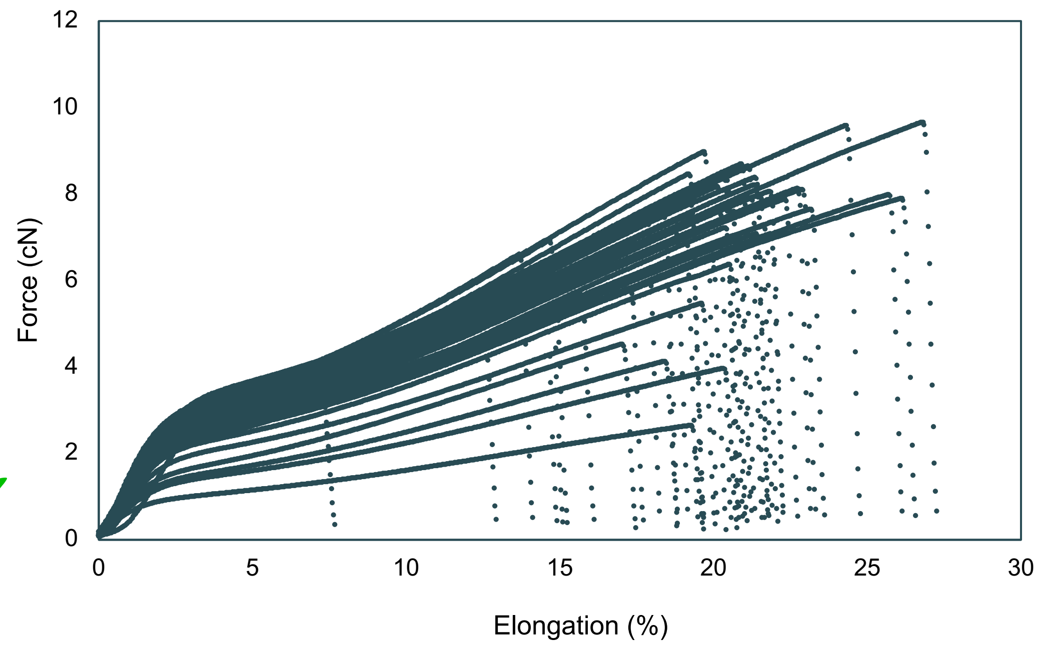
Run	X1	X2	X3	X4	X5	X6	Thermosetting resin removal [%]	Fluorocarbon removal [%]
1	-1	-1	1	1	0	L1		
2	1	-1	1	-1	-1	L2		
3	1	1	1	-1	1	L1		
4	1	0	1	1	-1	L2		
5	-1	-1	-1	1	-1	L2		
6	0	0	0	0	0	L1		
7	-1	1	-1	1	1	L1		
8	1	-1	-1	0	1	L2		
9	0	0	0	0	0	L2		
10	-1	1	0	-1	-1	L2		
11	1	1	-1	1	-1	L1		
12	0	1	1	1	1	L2		
13	0	-1	-1	-1	-1	L1		
14	1	-1	0	1	1	L1		
15	-1	-1	1	-1	1	L2		
16	-1	1	1	0	-1	L1		
17	1	1	-1	-1	0	L2		
18	-1	0	-1	-1	1	L1		

- Complete removal
- Partial removal
- No removal

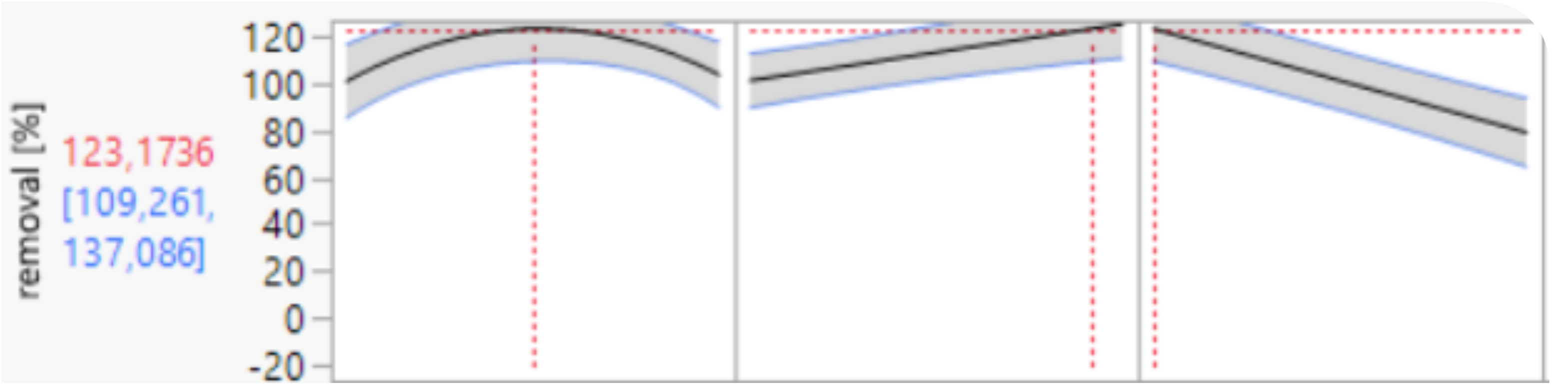
EVALUATION OF MECHANICAL PROPERTIES

- Linear density (dtex) ✓
- Maximum force (cN) ✓
- Tenacity (cN/dtex) ✓
- Elongation at break (%) ✓
- Modulus [0..1% elongation](GPa) ✓



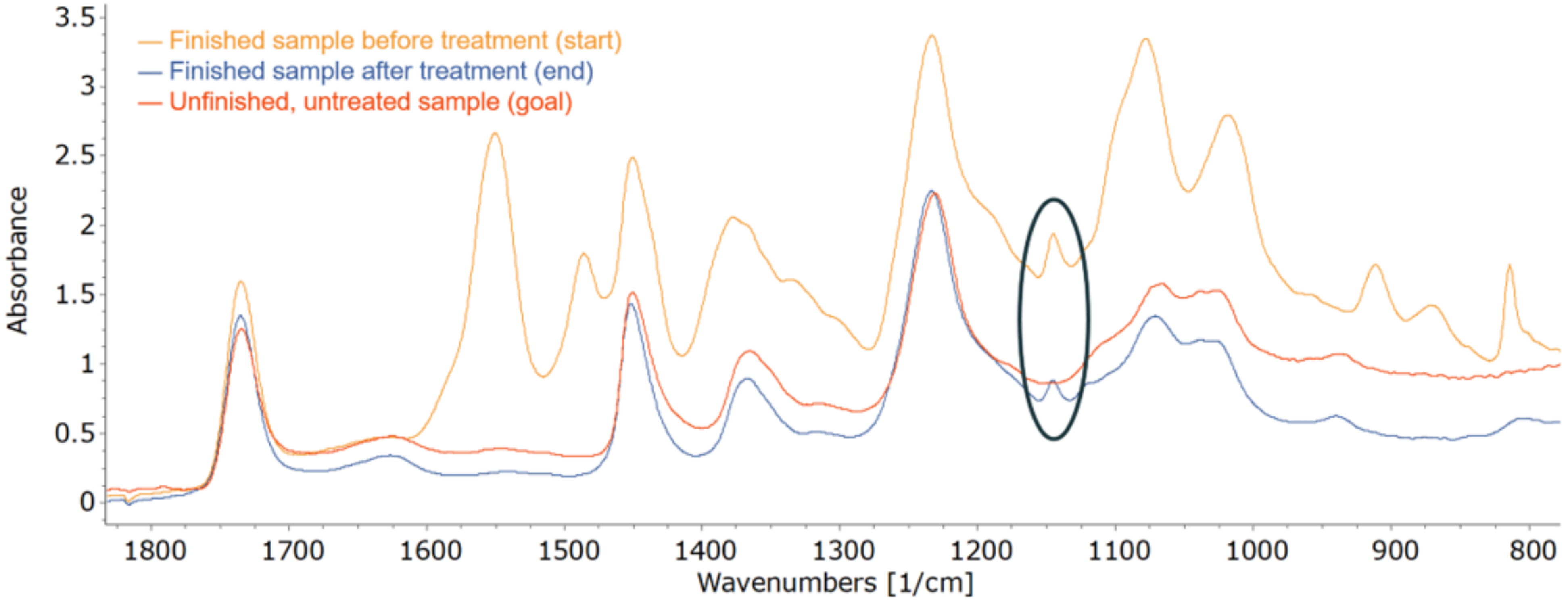
STATISTICAL MODEL TO OPTIMIZE EXPERIMENTS

- DoE approach allows to define model composed of statistically significant (95% confidence) parameters
- Different sets of optimized parameters can be defined from definitive screening design
  - “Maximum removal”
  - “Industrial removal”

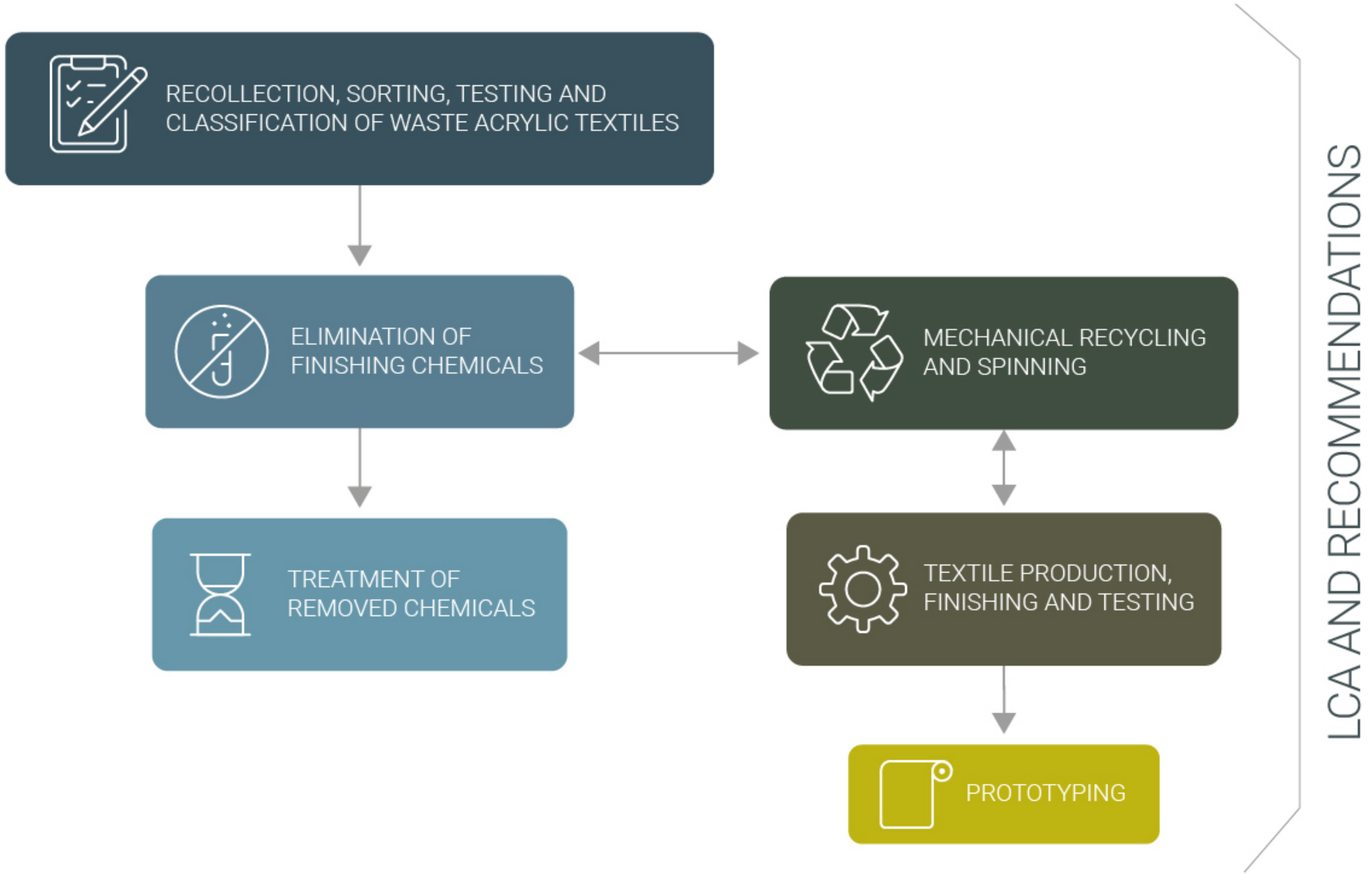


FINISH REMOVAL BY OPTIMIZED PARAMETERS

- Thermosetting resin: complete removal
- Fluorocarbon: partial removal



CONCLUSION


RECOLLECTION, SORTING, TESTING AND CLASSIFICATION OF WASTE ACRYLIC TEXTILES
ELIMINATION OF FINISHING CHEMICALS
MECHANICAL RECYCLING AND SPINNING
TREATMENT OF REMOVED CHEMICALS
TEXTILE PRODUCTION, FINISHING AND TESTING
PROTOTYPING
LCA AND RECOMMENDATIONS

THANK YOU FOR YOUR ATTENTION

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