TECHNISCHE UNIVERSITÄT WIEN

ICEBE IMAGINEERING NATURE

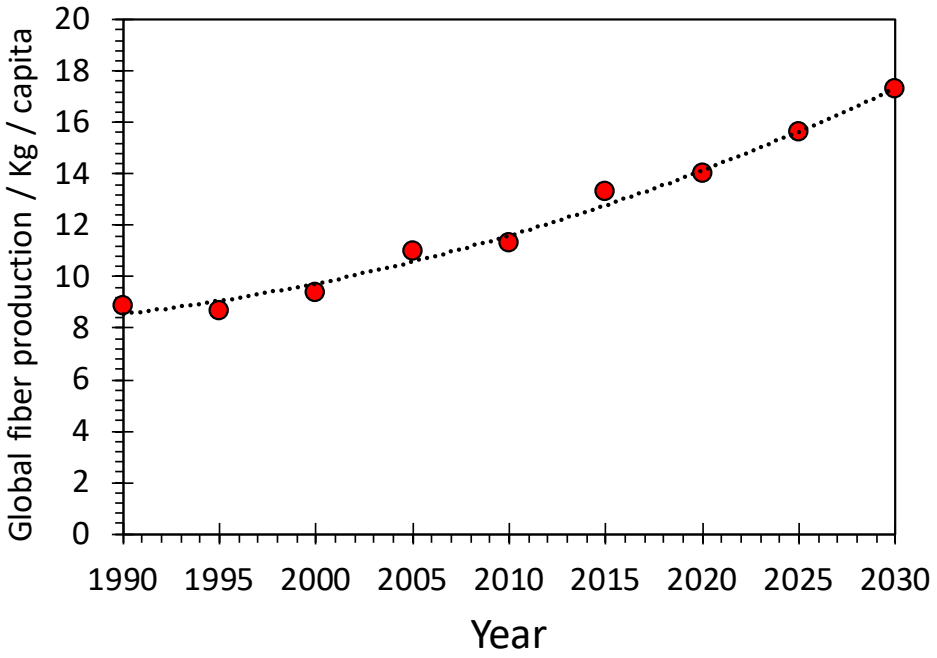
Recy & DepoTech 2024

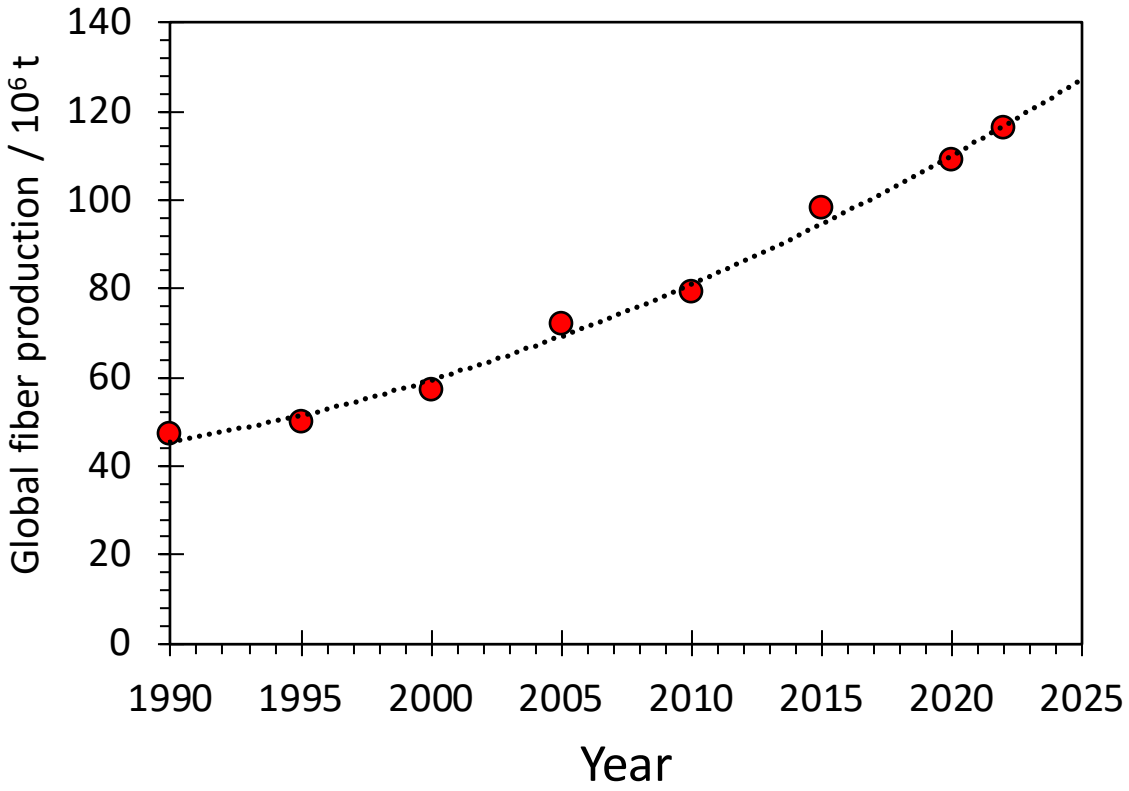
Textilrecycling: unerlässlich, aber nicht genug!

Andreas Bartl, Wolfgang Ipsmiller & Sebastian Rosenbusch

How big is the problem?

- Large volume of textile fibers
  - 116 Million t total (2022)
  - Growth of world population
  - Growth of per capita consumption

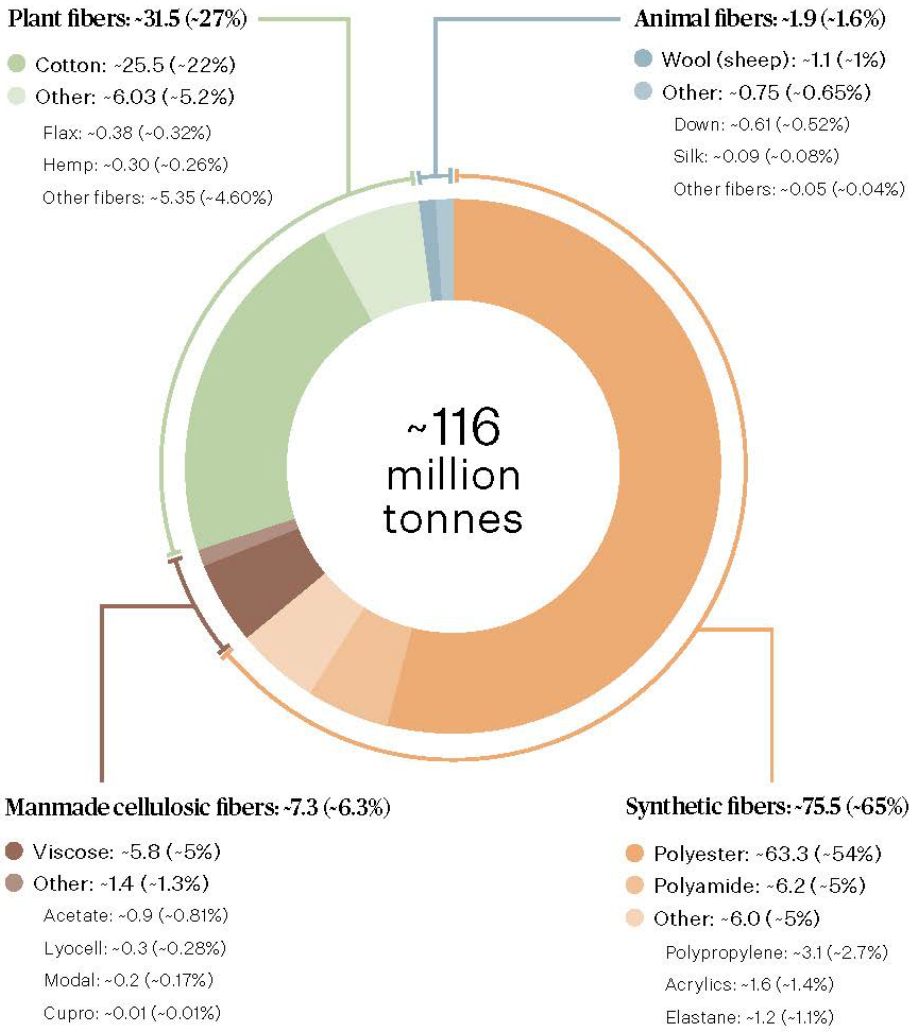




Source: Statista, 2022; Textile Exchange 2023

How big is the problem?

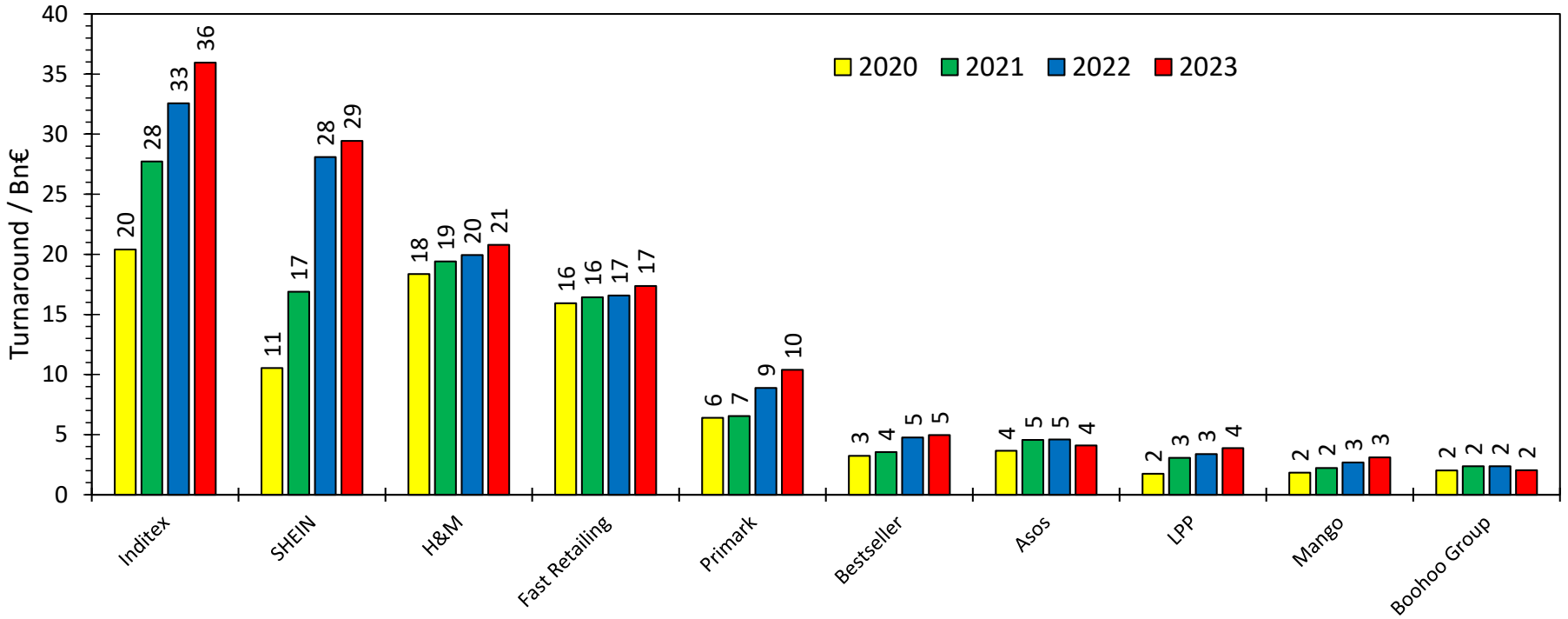
- Growth takes place
  - Synthetic fibers
  - Man-made cellulosic Fibers
- Stagnating production
  - Cotton
  - Other crop fibers
  - Wool



Source: Textile Exchange, 2023

How big is the problem?

- Fast fashion is accelerating into ultra-fast fashion
- Production cycles have shortened even further, with new styles appearing weekly or daily
- Ultra-fast fashion increases pressure on workers and resources

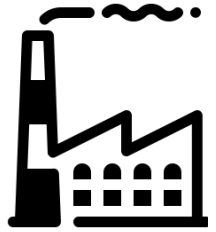


Source: Statista

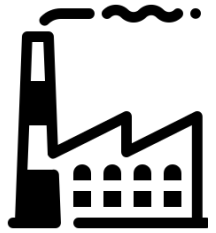
Why is textile recycling difficult?

- Packaging: high recycling rates
  - Separate collection: **Yes**
  - Material complexity: **Low** (or at least recycling techniques are better equipped)
  - Production chain: **Short**

PET



Paper

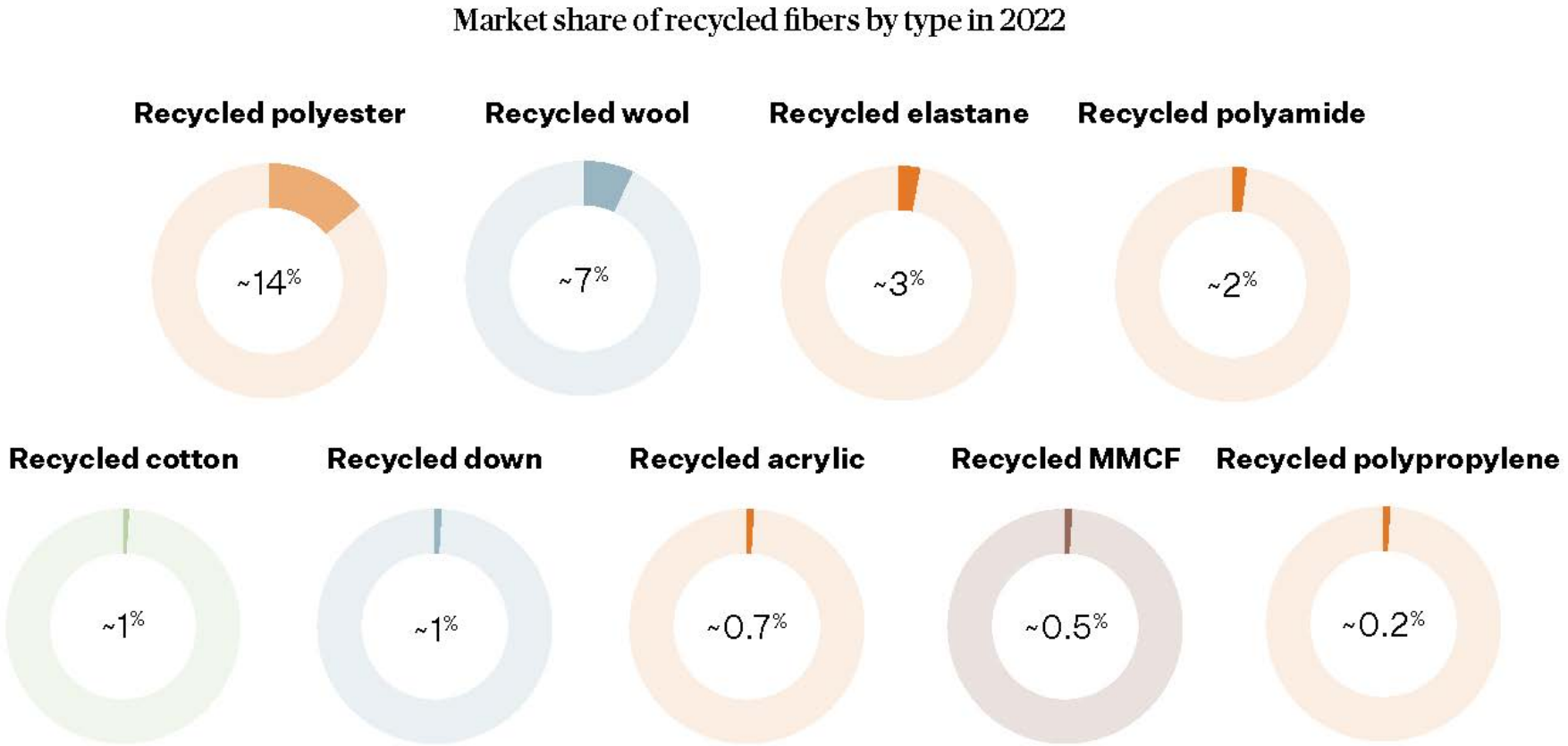


- Textiles: low recycling rates
  - Separate collection: **Partly**
  - Material complexity: **High**
  - Production chain: **Long**

44% Polypropylene
33% Polyamide
22% Polyester
1% Elastane

Fiber Recycling?

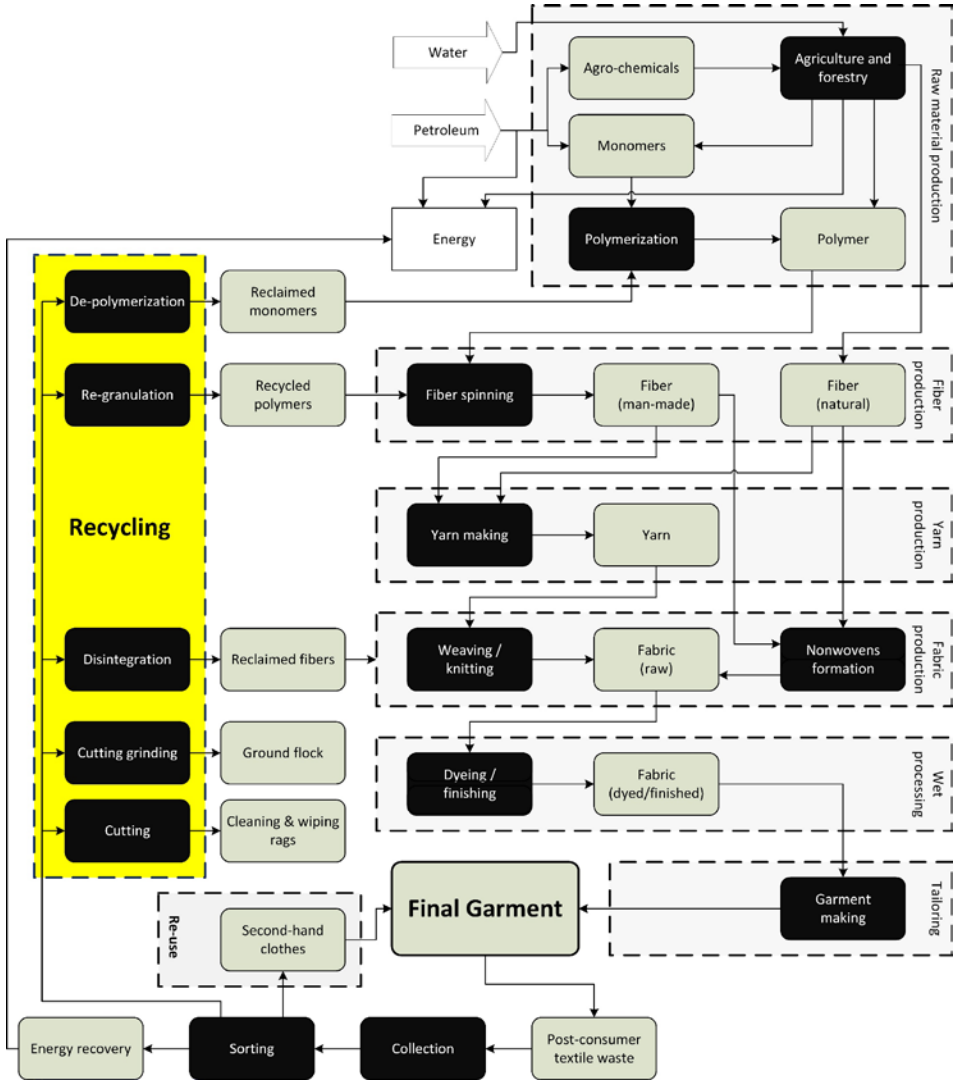
- Fibers derived from recycled material



Source: Textile Exchange, 2022

Textile recycling routes?

- Possible cycles
  - (Re-use)
  - On fabric level
  - **On fiber level**
  - **On polymer level**
  - **On monomer level**
  - (Thermal recovery)



Recycling on Fiber Level

- Principle

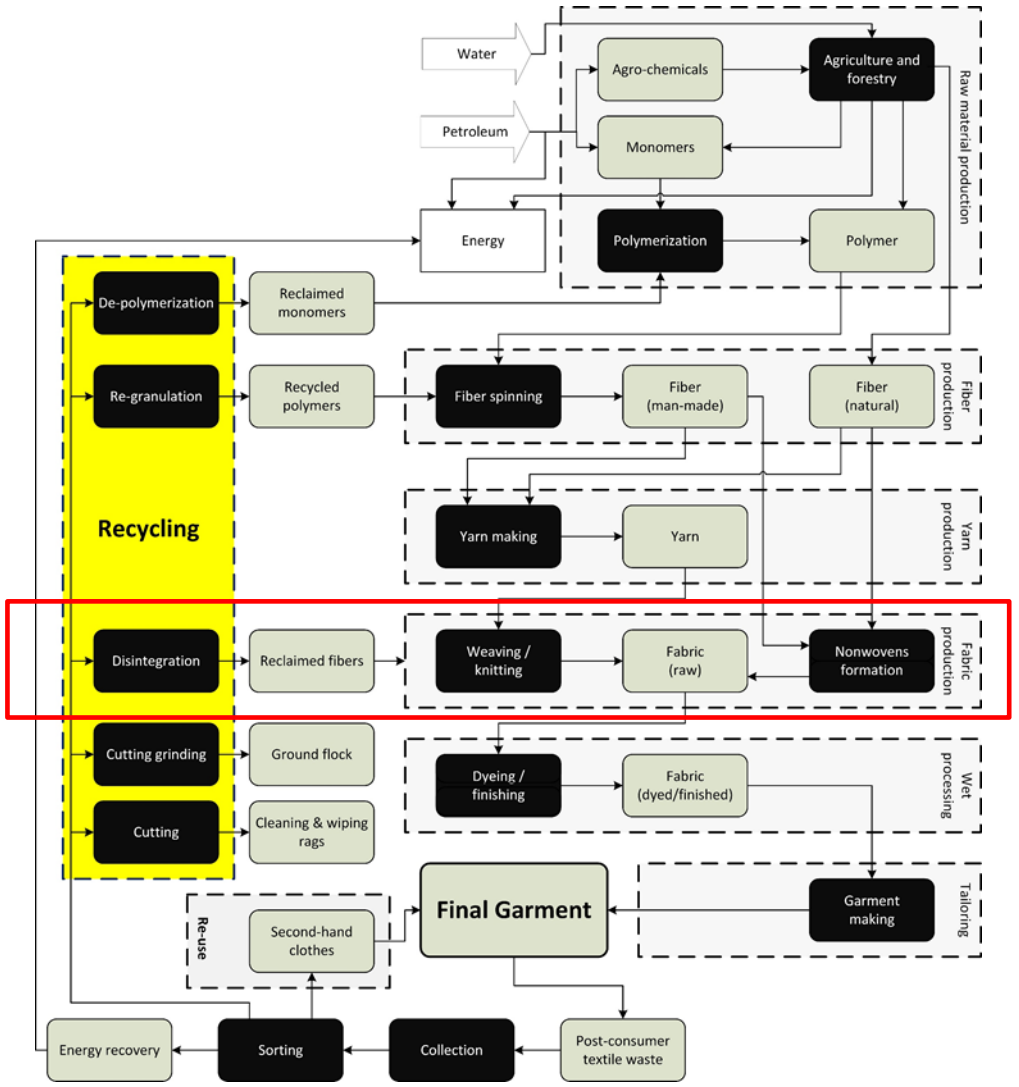
https://www.euwid-recycling.de/news/wirtschaft/ico-baut-ruecknahme-von-altkleidern-im-handel-aus-310123/

https://www.andritz.com/nonwoven-textile-en/locations/andritz-laroche

https://www.tha.de/Forschungsschwerpunkte/KI-Produktionsnetzwerk/Sortierung.html

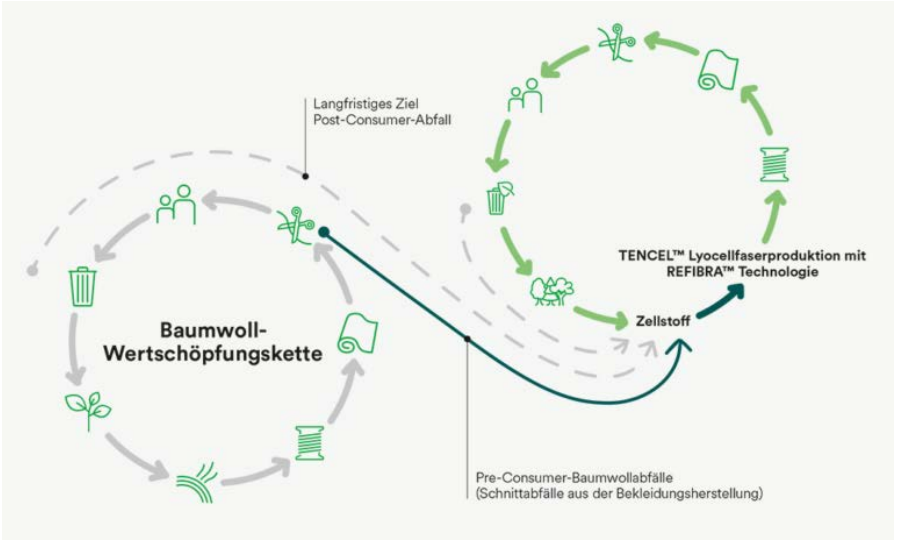
Recycling on Fiber Level

- Principle
  - High savings potential
  - “Rubbish in – rubbish out”
  - “Mechanical Recycling”



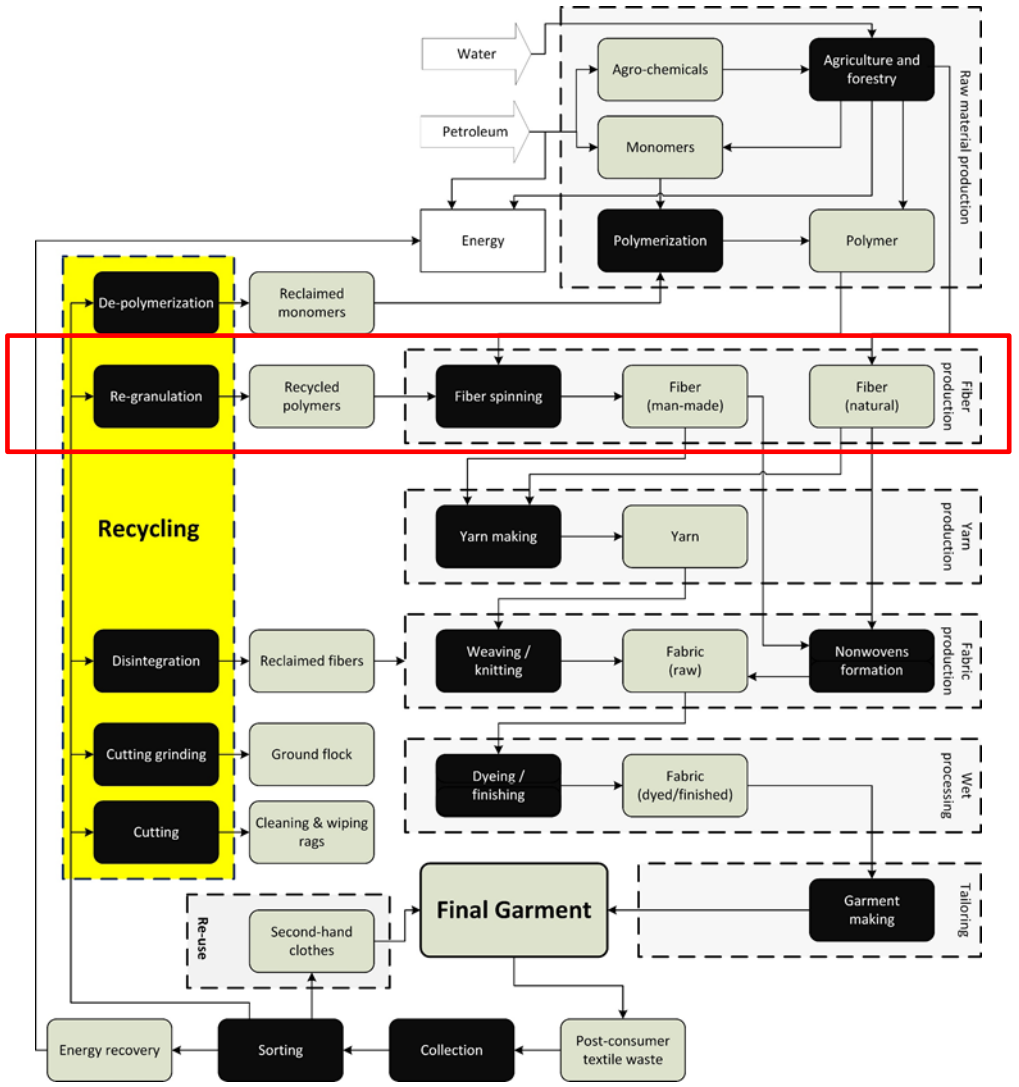
Recycling on Polymer Level

- Principle
  - Recycled material (polymer) instead of virgin
  - “Mechanical Recycling” or “thermo-mechanical recycling”
  - Cellulosic fibers
    - solvent spinning
    - REFIBRA®
    - SÖDRA, RENEWCELL,…
  - Thermoplastic fibers
    - Melt spinning
    - Bottle to fiber
    - TEX2MAT



Recycling on Polymer Level

- Principle
  - Medium savings potential
  - Problem: textile mixtures

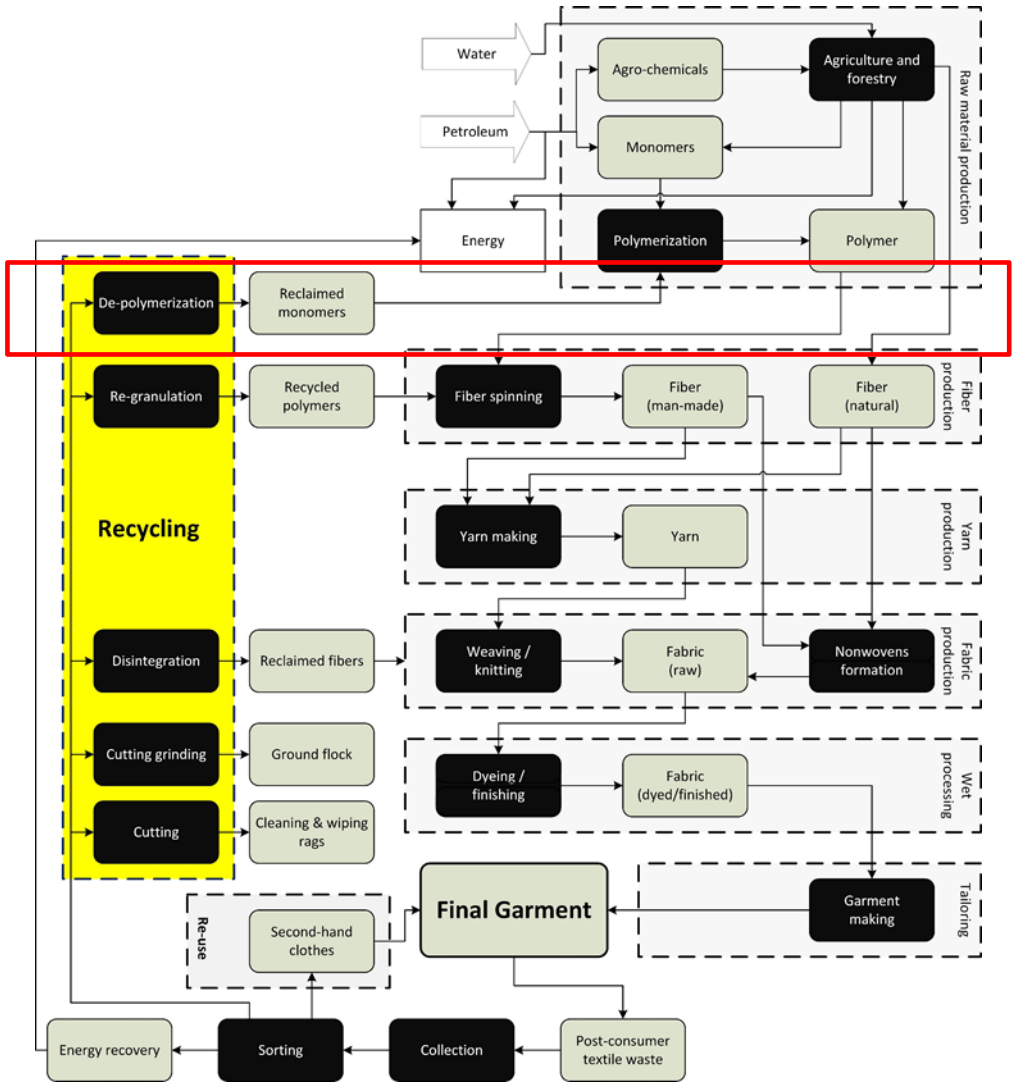


Recycling on Monomer Level

- Principle
  - Break down polymers into the constituent monomers
  - “Chemical Recycling”
  - Polyethylene Terephthalate (PET): Glycolysis, methanolysis, aminolysis, hydrolysis (enzymatic or non-enzymatic)
    - Ethylene glycol and terephthalic acid
    - Recyclable PET without loss of quality
    - Can also process complex and contaminated plastics as well as textiles
  - Polyamide 6 (PA6) and Polyamide 66 (PA66)
    - Alkaline hydrolysis, hydrothermal reaction, acid hydrolysis, ammonolysis, alcoholysis, microwave-assisted hydrolysis
    - Caprolactam (PA6), hexamethylenediamine and adipic acid (PA66)

Recycling on Monomer Level

- Principle
  - Low savings potential
  - Textile mixtures processable

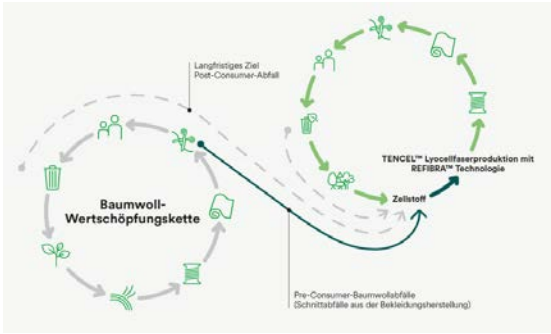


Textile Recycling Procedure

- Closing the loop

https://www.fibre2fashion.com/industry-article/9595/secondhand-clothing-a-new-trend

https://www.wieland.nl/en/innovation-fibersort/



(bio)chemical treatment

“Preparation for Recycling”

- Principle
  - Separation of specific polymers through dissolution or depolymerization to obtain a recyclable textile
- Examples
  - Enzymatic hydrolysis of Cotton to obtain pure PET (→ recycling on polymer level)
  - (Enzymatic) hydrolysis of PET to obtain pure Cotton (→ recycling on fiber or polymer level)
  - Dissolution of EL from PA or PET based textiles to obtain pure PA or PET (→ recycling on polymer level)
  - Dissolution of EL from Cotton to obtain pure Cotton (→ recycling on fiber level)
  - Enzymatic hydrolysis of wool and dissolution of EL to obtain pure PET (→ recycling on polymer level)
  - …
- Increase share of recyclable textiles

Problems

- Interfaces between sorting – processing – recycling are missing
- For paper
  - EN 643
  - 5 groups
  - subgroups in each case

DEUTSCHE NORM November 2014

DIN EN 643

DIN

ICS 85.060

Ersatz für
DIN EN 643:2014-05

Papier, Karton und Pappe –
Europäische Liste der Altpapier-Standardsorten;
Deutsche Fassung EN 643:2014

Paper and board –
European list of standard grades of paper and board for recycling;
German version EN 643:2014

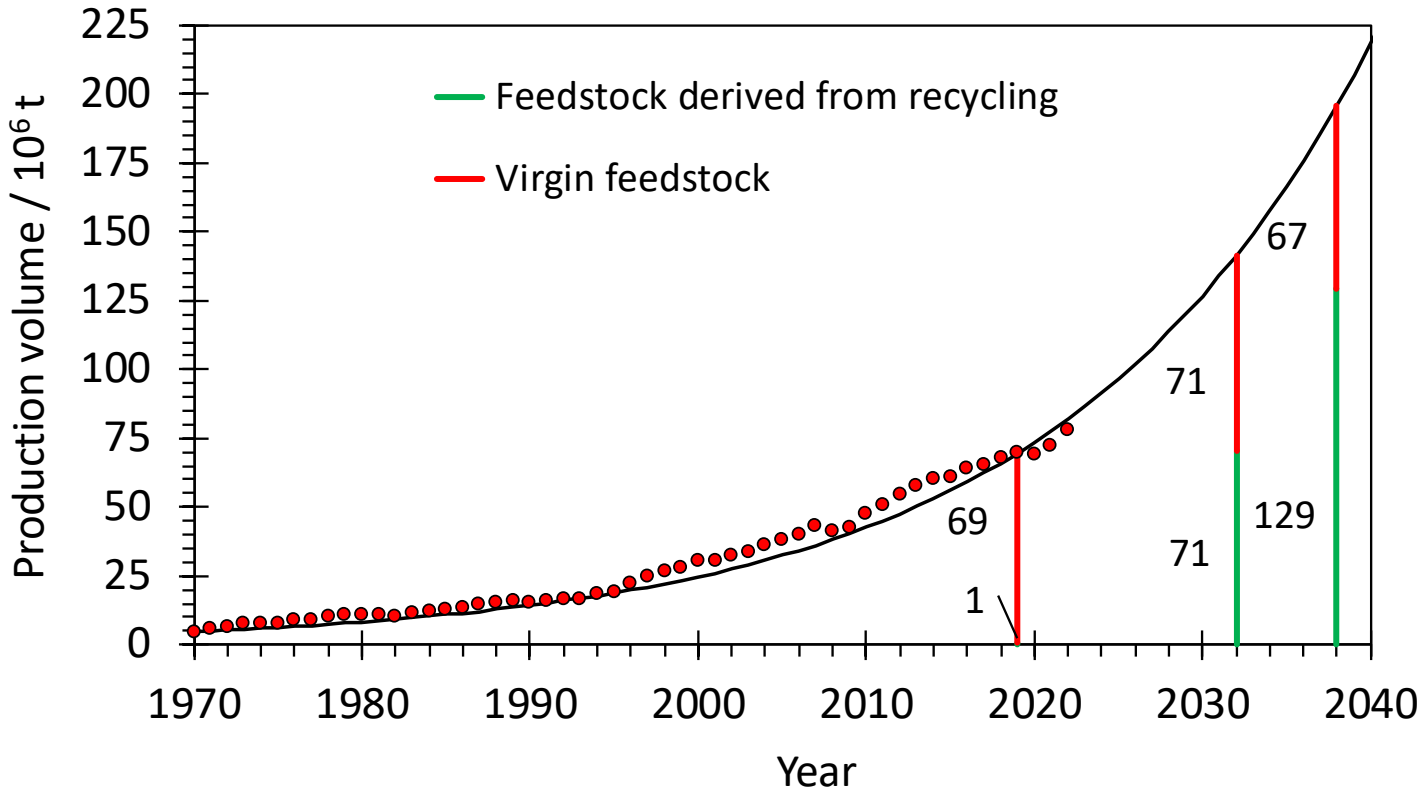
Tabelle 1 — Gruppe 1, untere Sorte *(1 von 2)*

Gruppe	Bezeichnung	Beschreibung	papier-fremde Bestand-teile, in % max.	uner-wünschte Mate-rialien, in % max.
1.01.00	einfaches gemischtes Altpapier	Mischung verschiedener Papier-, Karton- und Pappesorten	1,5	3
1.02.00	gemischtes Altpapier	Mischung verschiedener Papier-, Karton- und Pappequalitäten, die maximal 40 % an Zeitungen und Illustrierten enthält	1,5	2,5
1.03.00	Graukarton	bedruckter und unbedruckter, weiß gedeckter und ungedeckter grauer Karton oder eine Mischung beider, frei von Wellpappe	1	2
1.04.00	Verpackungen aus Papier und Karton	gebrauchte Papier- und Kartonverpackungen, die mindestens 70 % Wellpappe enthalten, der Rest sind Verpackungen aus Papier, Karton und Pappe	1,5	3
1.04.01	Wellpappe 70	gebrauchte Papier- und Kartonverpackungen, die mindestens 70 % Wellpappe enthalten, der Rest ist eine Mischung aus Papier, Karton und Pappeprodukten	1,5	3
1.04.02	Wellpappe 80	gebrauchte Papier- und Kartonverpackungen, die mindestens 80 % Wellpappe enthalten, der Rest ist eine Mischung aus Papier, Karton und Pappeprodukten	1,5	3
1.05.00	Wellpappe 90	gebrauchte Schachteln und Bogen aus Wellpappe unterschiedlichster Qualitäten, dürfen 10 % andere Verpackungspapiere, Kartons und Pappe enthalten	1,5	2,5
1.05.01	Wellpappe 95	gebrauchte Schachteln und Bogen aus Wellpappe unterschiedlichster Qualitäten, dürfen 5 % andere Verpackungspapiere, Kartons und Pappe enthalten	1,5	2,5
1.06.00	Illustrierte	Illustrierte, mit oder ohne Kleber	0,5	1
1.06.01	Illustrierte ohne Kleber	Illustrierte ohne Kleber	0,5	1

- For end-of-life textiles
  - No defined qualities
  - Various polymers
  - Reuse / recycling

Is recycling enough?

- Recycling is not enough



Source: CIRFS 2021

Conclusion

- Recycling of textiles can take place on
  - Fiber level
  - Polymer level
  - Monomer level
- Savings potential
  - The savings potential increases the less we have to revert in the textile chain and the fewer stages need to be repeated
- Optimization
  - There is no “best” recycling option
  - Finding the optimal combination of various recycling (as well as re-use, “preparation for recycling”, and thermal recovery) procedures
- Essential
  - Recycling only tackles the symptoms, not the root causes

Institute of Chemical, Environmental & Bioscience Engineering

1060 Vienna, Austria

Andreas Bartl
andreas.bartl@tuwien.ac.at