Re:Mix – materialåtervinning av textila blandmaterial med nylon och elastan

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Summary of Re:Mix II

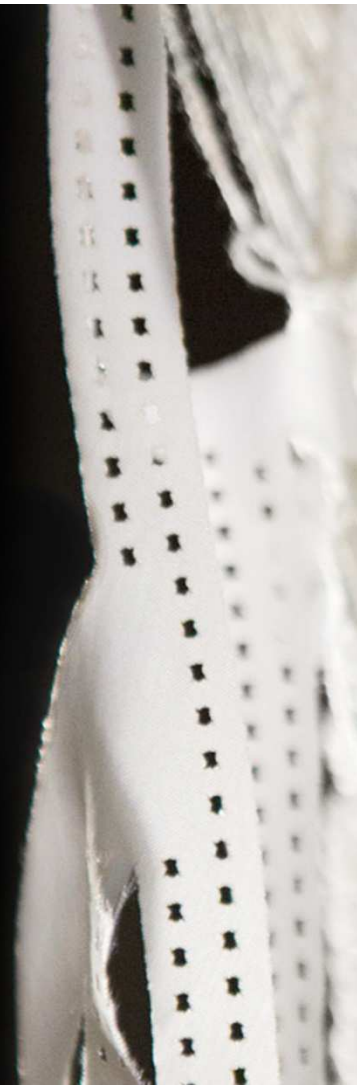
The overarching goal with the project is to enable recycling technology for separation of fiber blends containing nylon and elastane.

To contribute to:

- Products and services designed for increased resource efficiency and / or circular economy
- Increased use of secondary raw materials
- Biological processes that provide attractive raw material and / or energy products from waste.

subgoals

- To develop sustainable recycling processes for textile fibre resource efficiency in industrial production with optimized energy and cost demands
- To develop enzymes specifically designed for selective depolymerization and recycling of pure elastane and nylon
- To further develop enzymes targeting elastane and/or nylon in blends with other fibres (i.e PES and cotton)
- To investigate thermo-mechanical recycling of elastane-nylon blends with melt filtration
- To investigate thermo-mechanical separation of blends with elastane and/or nylon and other fibres (ie PES and cotton)
- To serve as a platform for further technology development



Re:Mix – project organization

- Project leader Sara Olsson, RISE
- Communications manager Malin Wennberg

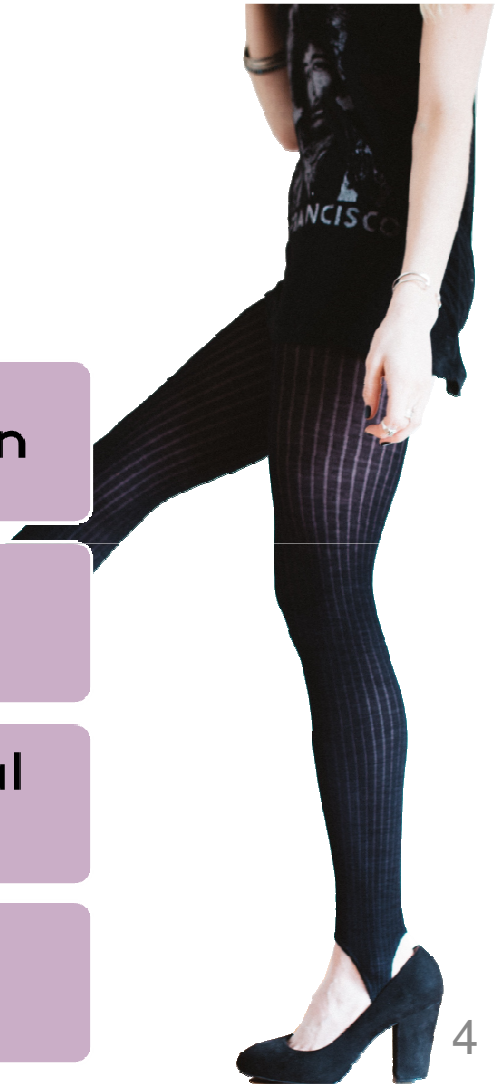
WP1) Management & Communication

WP2) LCA & Cost Assessment

WP3) Enzymatic Design

WP4) Mechanical Separation

WP5) Case studies with focus on industrial challenges



mistra future fashion

vision: enabling a **systemic change** of fashion industry & society

11,5 million EUR
2011-(2019)
14 research partners
50+ industry partners

funded by

MISTRA
The Swedish Foundation for Strategic Environmental Research

hosted by

RISE


material
processing
design textiles
to apparel
manufacturing
retail/
wholesale
use / reuse
disposal

4 recycling

We develop knowledge and new processes in recycling methods and the impact of post-consumer textiles in order to provide guidance on necessary steps to enable sustainable textile recycling.

1 design

We explore and evaluate the environmental potential of the design and user potential of short-life vs long-life garments, and the full spectrum in between, to find the most suitable choices for a circular textile economy for different types of garments and uses. Expected outputs will be recommendations, guidelines and tools for how to design for resource circularity.

3 user

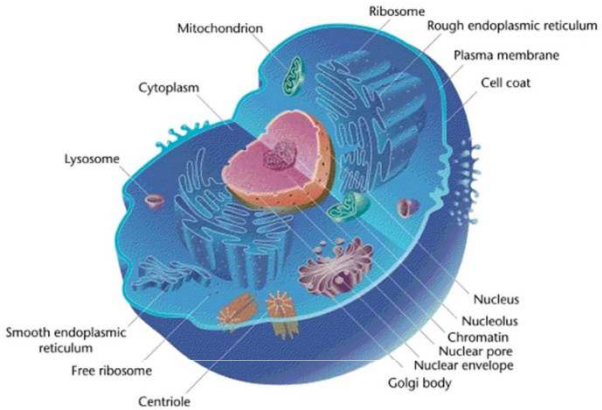
We make recommendations on how to encourage sustainable consumer behavior and to increase user engagement in sustainable consumption. Specifically, we develop recommendations for increasing services for extending the life of garments, reuse, and second-hand consumption.

2 supply

We identify the necessary actions in textile and garment supply chains to enable circular economy guidelines for governance on how to transition to and sustain a circular textile supply chain.

The role of enzymes

WP3) Enzymatic Design

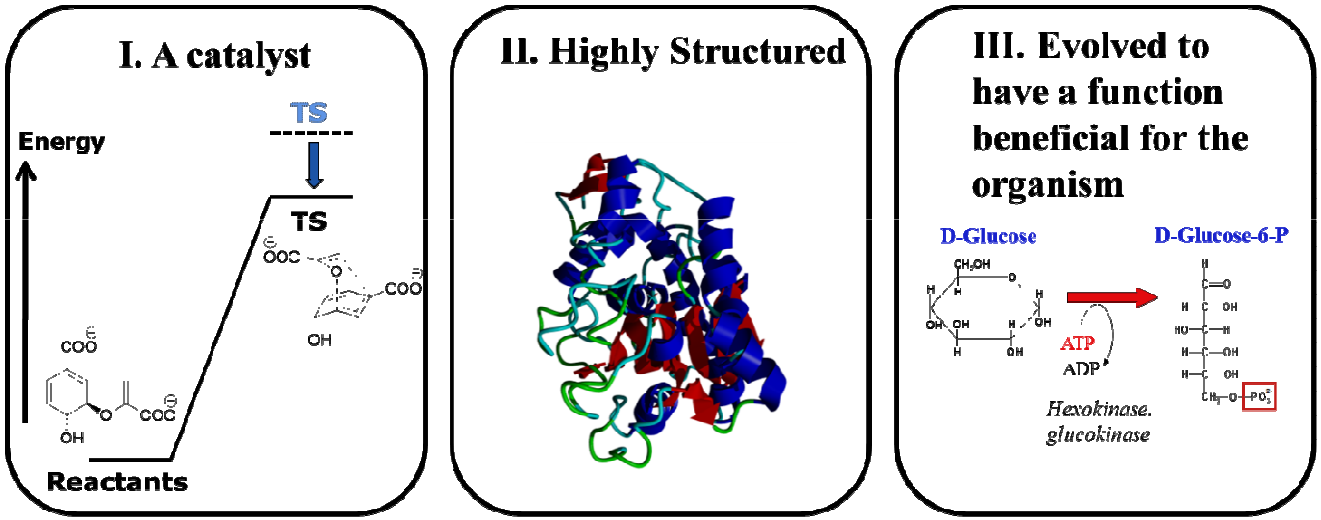


Workhorses in all cells

Industrial applications

Production of interesting compounds

What is an enzyme?

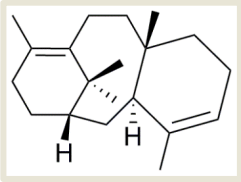


Enzymes are important

Reaction	Half-life of uncatalyzed reaction [years]	Relevance in the cell
Decarboxylation	2.3×10^9	Pyridine biosynthesis
Hydrolysis of phosphate diesters	3.1×10^7	DNA
Hydrolysis of sugars	1×10^6	Energy metabolism
Hydrolysis of amide bonds	500	Energy, Signaling, Nociception, Inflammation, Cancer

Data from *Annu. Rev. Biochem.* **2011**. 80:645–67

Enzymes are key to modern industry



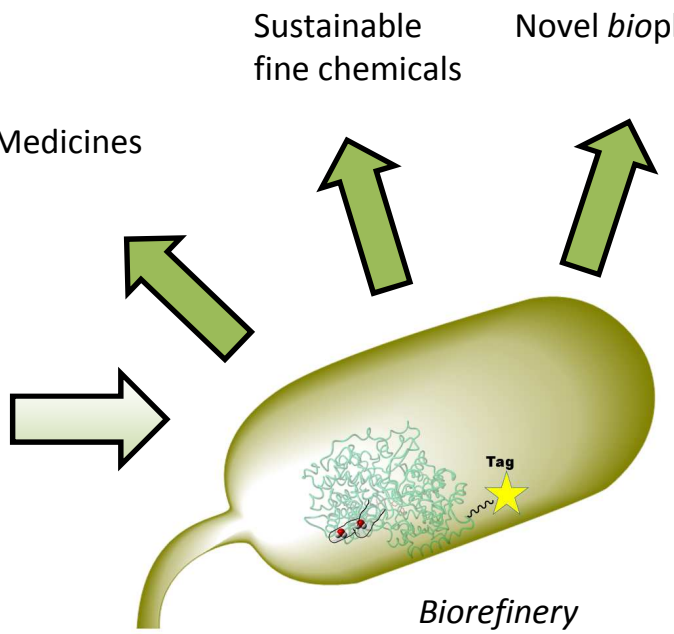
Taxadien (anticancer)

Nat.Prod.Rep., 2012, 29, 683–696

Enzyme technologies at KTH

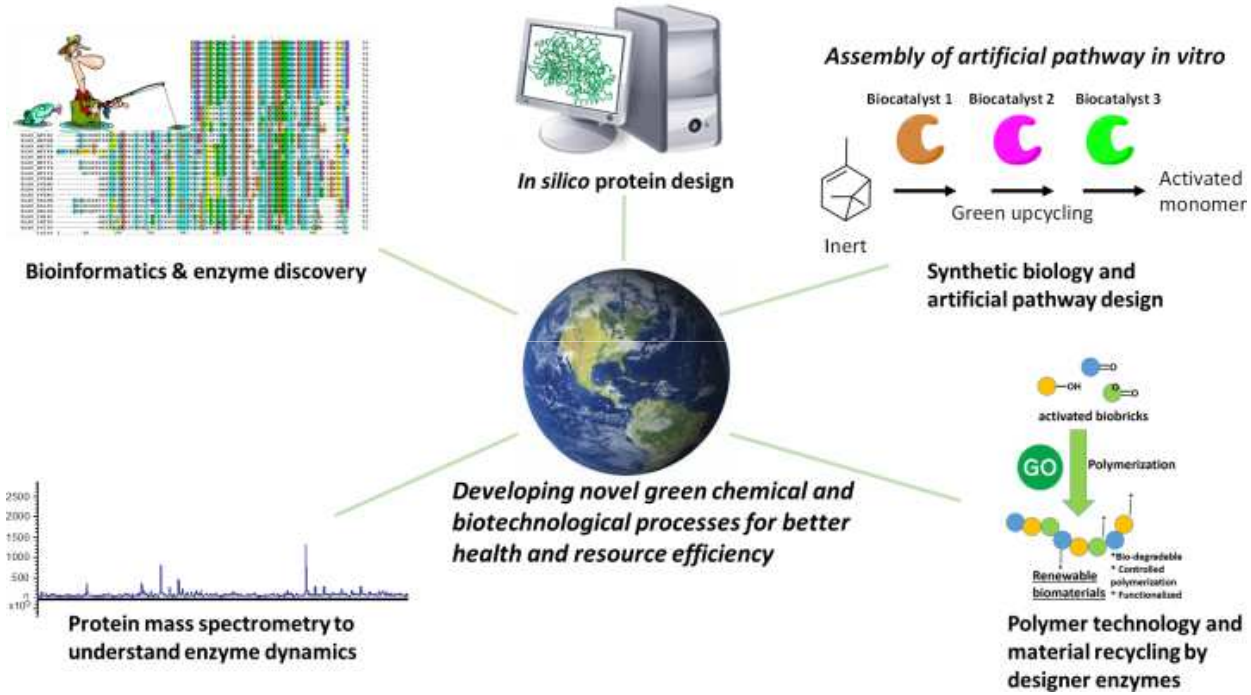
WP3) Enzymatic Design

"Developing novel green chemical and biotechnological processes for a better health and environment."



Technologies

WP3) Enzymatic Design



The challenge:
Currently only 1-2% of all man-made polymers are recycled

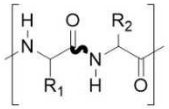
43 % of the plastic used worldwide is disposed of in landfills where it may take up to 1,000 years to decompose

Polyesters (e.g. PET)

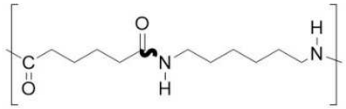
Polyamides (e.g. Nylon)

Production > 10 Mega tons/year

Natural polyamides in proteins

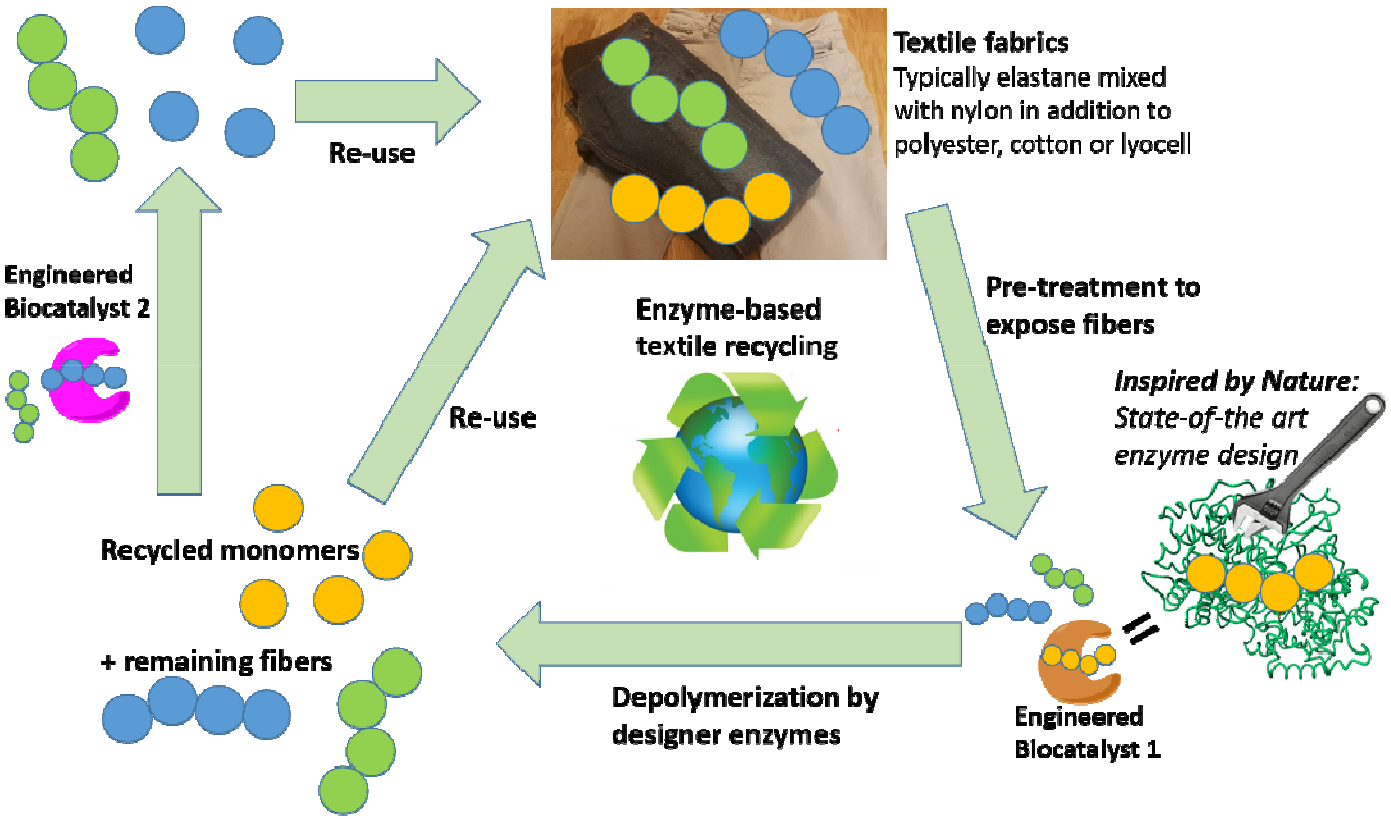


Man-made synthetic polyamide plastics



Vision

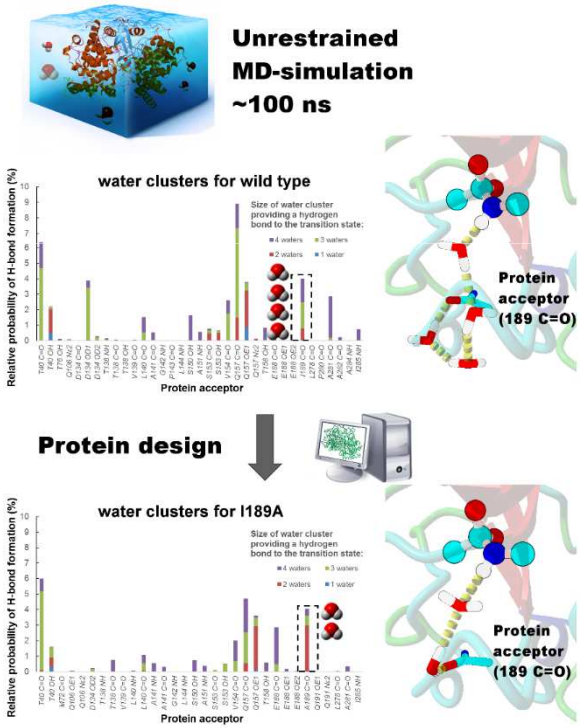
WP3) Enzymatic Design



Results: Software development at KTH within the scope of Re:Mix

WP3) Enzymatic Design

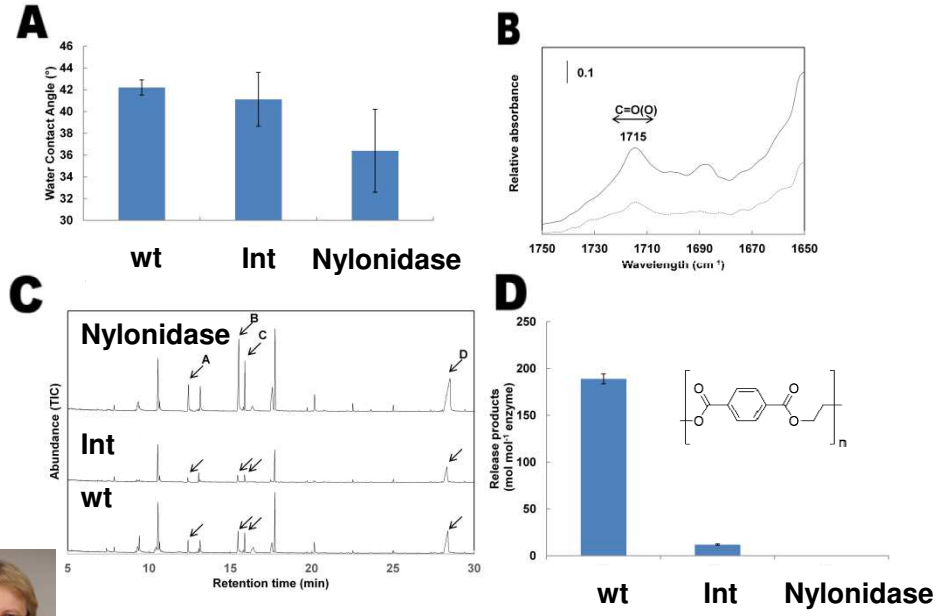
"In house" software



Generation of designer enzymes for depolymerization of man-made materials by computation based on transition state

Generation of a "Nylonidase" as part of the pre-study

WP3) Enzymatic Design



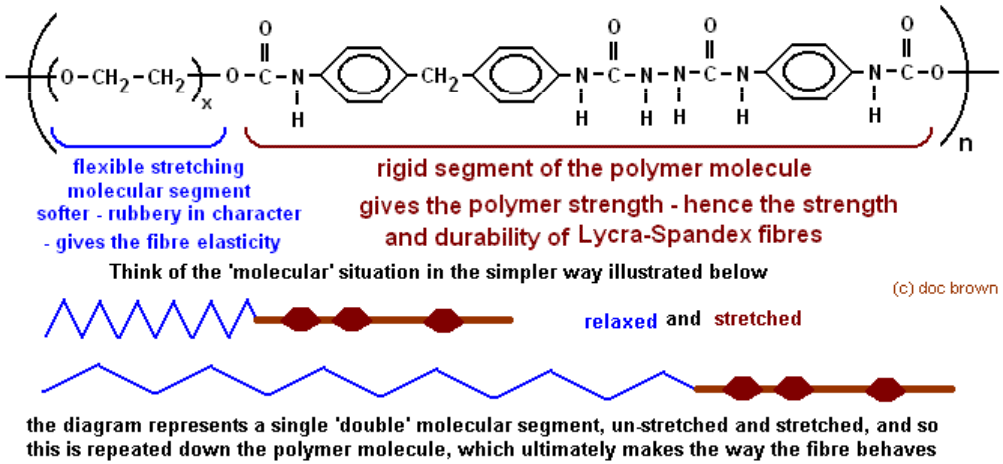


Antonino Biundo Georg Gübitz Doris Ribitsch

Polyurethane degrading enzymes

Selection of enzymes with potential for Elastane hydrolysis

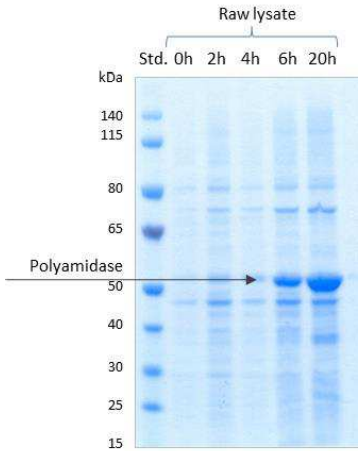
Several enzymes have been selected for degradation of polyamides and polyurethane.



Polyurethane degrading enzymes

Polyamidase of *Nocardia farcinica*

Polyamidase NfPolyA is overexpressed in *E.coli* and purified by affinity chromatography. The enzyme showed activity on **Polyamide 6 tricot fabrics** and was engineered for activity on **PU 1080** and **PU 1050 pellets**.



SDS PAGE recombinant expression in *E.coli*

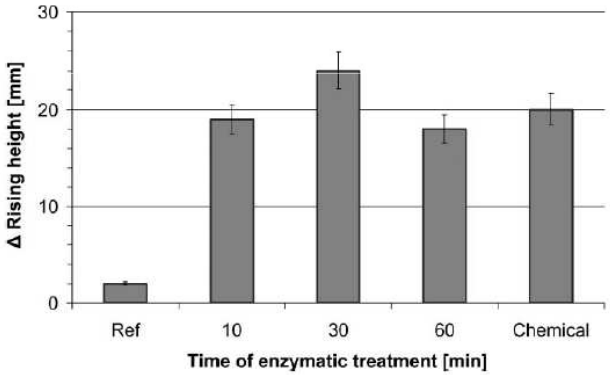
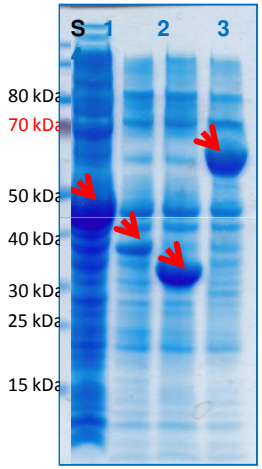


Figure 4. Increase of rising height of polyamide 6 fabrics after treatment with a polyamidase from *N. farcinica* compared to controls containing enzyme inhibitor and compared to the effect of silicone based finisher ("chemical"). Data represent the average of three measurements.

Polyurethane degrading enzymes

Other enzymes with potential for elastane activity

- Imidase from *Pseudomonas putida*
- Amidase from *Rhodococcus globerulus*
- Serinehydrolase (also chloroperoxidase) from *Streptomyces*
- Malonamidase from *Bradyrhizodium japonicum* (MAE2)



SDS-PAGE of cleard raw lysates
1: Malonamidase, 45.8kDa
2: Imidase, 37.4kDa
3: Serinehydrolase 32.6kDa
4: Amidase 58.3kDa

Results from Re:Mix I

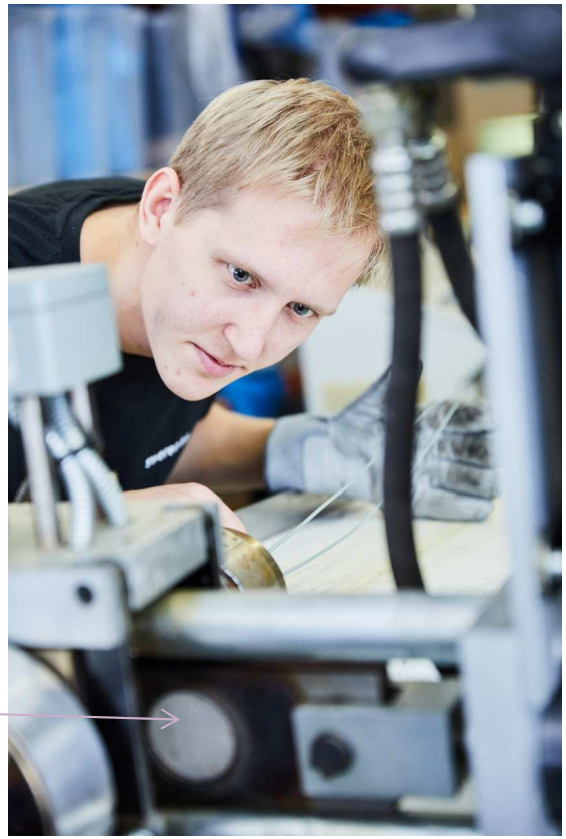
WP4) Mechanical Separation

- It was not possible to make new fibres of PA6.6 containing EL
- It was not possible to make new fibres of PA6 containing > 10% EL (< 10% is not tested)
- It was possible to injection mould PA6.6 with 5% EL
- It was possible to injection mould PA6 with up to 22% EL
- Recycling of a textile with PA6 and EL gave a plastic with impact resistant properties
- Drying the material is very important before processing!

Mechanical separation of elastane from nylon via melt filtration

- The technique is used today for separation of contaminations from thermo plastic materials
- Non melting particles and plastic with lower melting temperatures stops in the filter. A cleaner fraction is received

Melt filter



Initial trials in Re:Mix II

WP4) Mechanical Separation

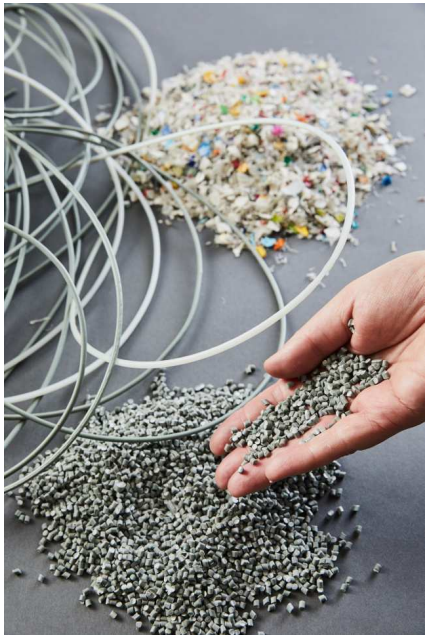
- Investigate process parameters for melt filtration such as temperatures, screw speeds and filter size by using specified material containing PA6 and 0%, 5%, 10% and 15% elastane

Planned work

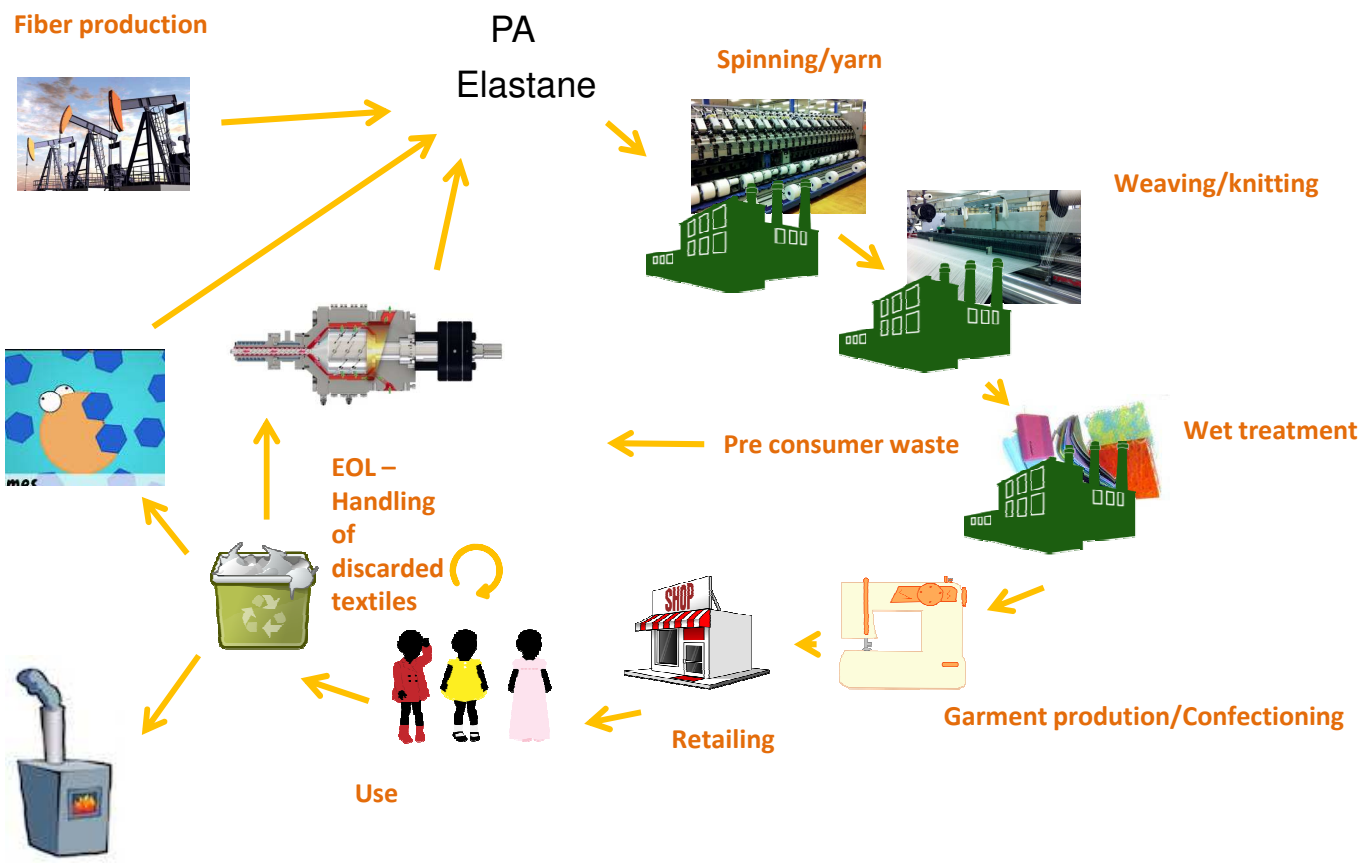
- Melt filtration of post-industrial materials
- Trials with PA6.6 with 0, 5, 15% EL
- Case study Pantyhose – melt filtration of pantyhose with 5-12% EL
- Case study Hoody – melt filtration with focus on finishing, process aid etc.
- Trials for development of demonstrator/s from fibres, injection moulding or 3D printing

Results so far

- EL melts and the screw knead the fibres to particles 0-100 um
- 60 um filter does not separate the EL particles from PA6
- 20 um filter separate EL from PA6 at certain temperature, speed and pressure
- Monitoring the pressure is important
- Optimization of compounder temperatures in different zones important to be able to handle the material
- Method for evaluation of elastane content in a separated mix of elastane/polyamide is developed



Life cycle perspective in Re:Mix



Thank you for your attention!

RE:
SOURCE