

Bioinnovation Establish Locally Grown Textiles in Sweden

WP6 Recycling

D16. Final report including assessment of value chain efficiency trials

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## Summary

This work package within Establish Locally Grown Textiles in Sweden has been investigating and testing the value cycles for mechanical and chemical fiber-to-fiber textile recycling in Sweden. There is potential for chemical and mechanical fiber-to-fiber recycling of in Sweden based on the findings in WP6 that are summarized in this report. The conclusions are based on several factors, for example that there is market needs for these fibers if they are comparable in properties with conventional man-made cellulosic fibers. Environmental aspects can be promising according to a literature survey, but the method used for the recycling, i.e. chemical or mechanical can show different issues that would need to be tackled in the future. When it comes to the completeness and effectiveness of the value chain there are gaps within the project and the collection and sorting of waste textiles need more development in order to meet the possible market volumes. The project has also been constructed with partners operating on different scales within which the value cycle has been tested. The value chain within project has not been complete since spinning, knitting and weaving is missing. This could also be true when the value cycle is tested in full scale.

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## Introduction

This WP is motivated by a collective strive to meet the coming Swedish milestone's targets for increased textile recycling, now being framed by the Swedish EPA (Naturvårdsverket). As the production chain of textiles is relatively long and segmented, the introduction of recycled textile fibers will require the involvement of many value chain participants. Today, commercial production of recycled mechanical or chemical textile does not exist widely. Even though mechanical recycling exists abroad, there is a demand to increase the control of the Swedish textile waste entering the mechanical recycling, the recycled fiber products and the processes. The mechanical textile recycling chain with Swedish actors on a smaller scale has been tested in this WP.

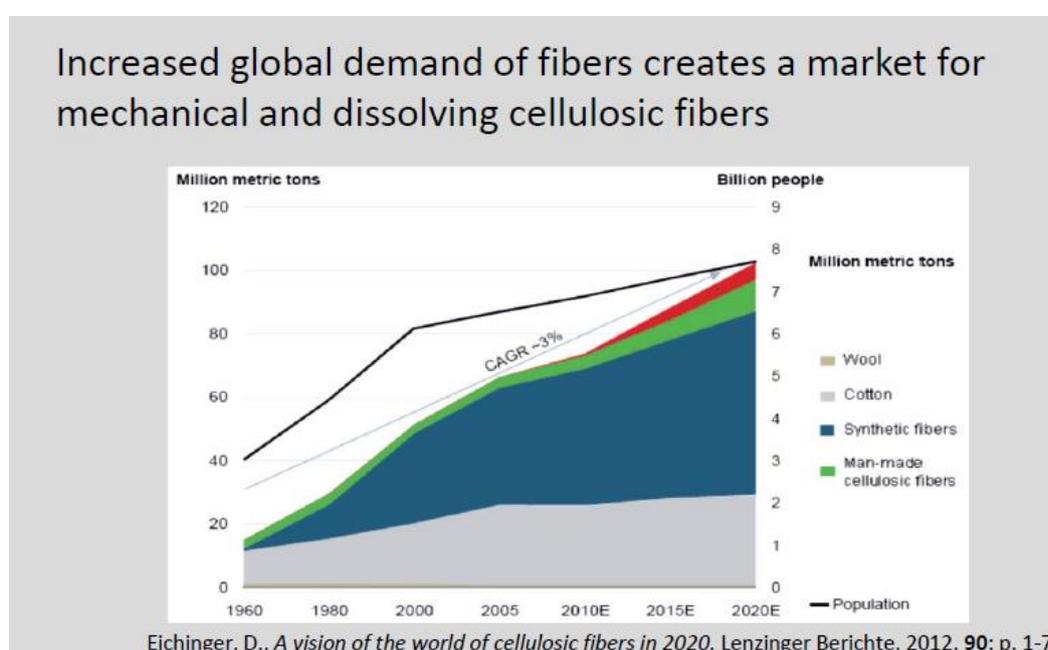


Figure 1 The global demand of fibers and the population growth

## Objectives for WP6

The technical objective of this WP is to test and improve the textile recycling value chain in Sweden. This WP started at TRL 4 using existing textile fiber recycling technology tested on a laboratory scale level. The objective was to adapt the mechanical fiber recycling method based on Swedish actors and Swedish textile waste. The chemical cellulosic fiber recycling process is ready for a semi-industrial scale of production. It has proven itself successful on a lab-scale and needs to prove commercial viability on a semi-industrial scale. The main objective is to make the recycling process fully resource efficient and ensure that there is a demand for recycled Swedish fibers. To do this the collaboration with all actors in the textile recycling was required. As original plan this WP would end at TRL 6-7 for chemical recycling and 5-6 for mechanical recycling, where the effective collaboration will accelerate the launch of a full textile recycling chain in Sweden. This could enable, within the time period of WP6, the possibility for production of chemical recycled fiber prototypes of large volumes, and for mechanical recycled fibers, a start for a Swedish initiative to produce mechanical recycled fibers in Sweden. The large-scale production of recycled fiber prototypes would act as a catalyst for a whole

range of products. The project goal was revised during the course of the project and the final goal is summarized below:

To demonstrate an efficient need-driven textile recycling value chain in Sweden – through proof-of-concept which also identifies gaps in wanted future position – for mechanical and chemical recycling and aiming for large-scale possibilities

### The textile recycling value chain

The value chain has involved actors related to the textile industry that can collaborate to produce resource-efficient prototypes based on chemically and mechanically recycled textile fibers. The actors for a complete value chain would include: collecting organizations, sorting organizations, fiber spinning organizations, textile manufacturers and retailers and consumers. All these steps are needed in order to conceptually fulfill textile recycling, see Figure 2.

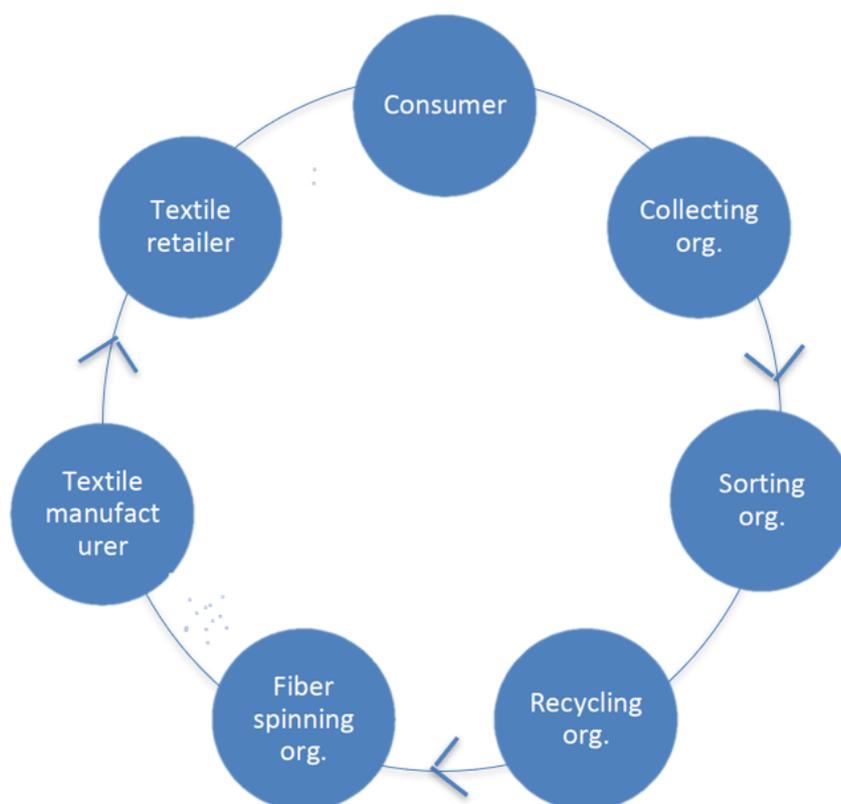


Figure 2 The actors involved in a conceptual textile recycling chain

### Partners in WP6

In order for the chemical and mechanical recycling process to become fully resource efficient and ensure that there is a demand for recycled fibers, collaboration with all actors involved in the textile value chain was required. *Ragn-Sells* and *Stena Recycling* had the role to collect and supply post-consumer and industrial textile waste raw material to the prototypes. *Textilia* provided industrial

waste to the prototypes. *Lunds renhållningsverk (LRV)* and *Vänersborgs kommun* contributed with know-how regarding collecting and sorting textiles with a citizen and municipality perspective. *Myrorna* and *Röda Korset* have know-how regarding collecting and sorting of used textiles, and have also performed manual sorting of the textile waste to the prototypes. The collectors and sorters in WP6 have further develop their part of the value chain. *Re:newcell* is specialised in the cellulosic chemical recycling section. *Wargön Innovation* took a coordinating role in the beginning of the value chain process from consumer, collecting, and sorting to users that will further carry on the recycling process. *Swerea IVF* had an active role in the mechanically recycled fiber prototype, represent the fiber spinning part and support all parts in the value chain. section. They were also deputy WP6 leader. *Wargön Innovation* has taken a coordinating role in the beginning of the value chain process from consumer, collecting, and sorting to users that will further carry on the recycling process. *Swerea IVF* has taken an active role in the mechanically recycled fiber prototype, represent the fiber spinning part and support all parts in the value chain. *Domsjö fabriker* evaluated the supply chain and potential commercialization for regenerated cellulose textiles. *RISE* has been the WP6 leader, provided environmental assessments and supported the first part of the value chain from consumer to spinning. *Haglöfs*, *Lindex* and *Fristads AB Martinson* represented the retailers. They provided retailer knowledge, communicated the consumers' demand and behavior and assessed the quality of the finished prototype. The partners' logos can be found in Figure 3.



Figure 3 The partners in the work package

### Work plan in WP6

The project was created with three tasks that were constructed in order to reach as much progress as possible. The tasks are described in detail in Figure 4.

# Tasks

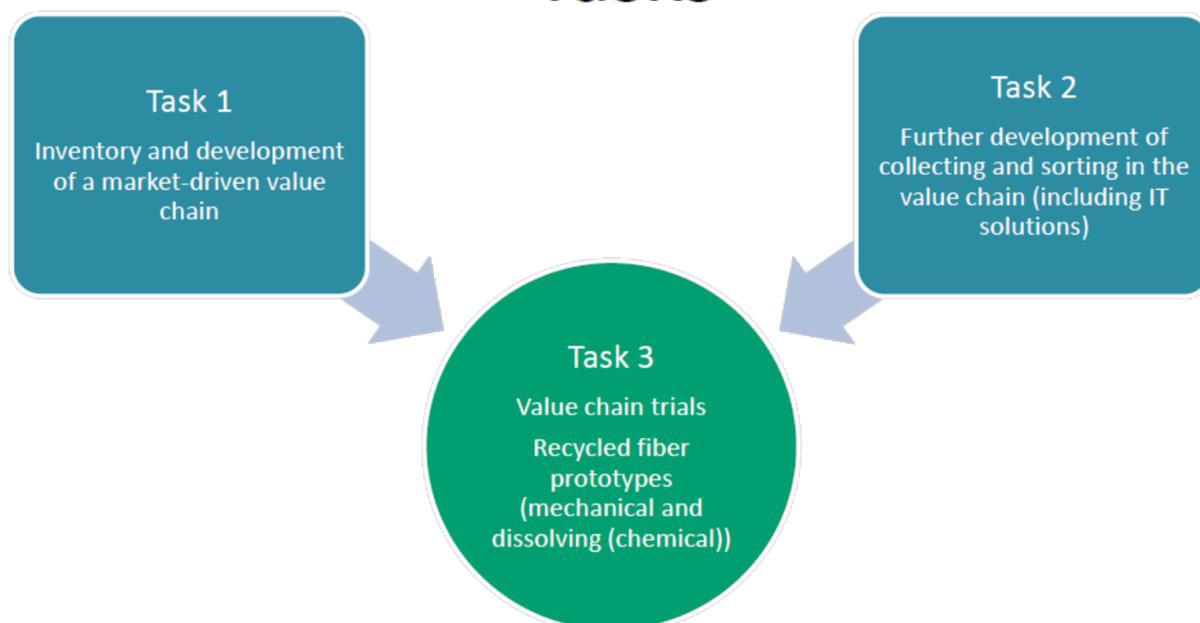


Figure 4 The three tasks involved in the work package

The first task aimed at developing textile recycling chains based on needs from the end-user perspective. The focus was on Swedish textile waste, with the task of promoting Swedish industry. The conclusions were detailed work plans for remaining parts of the project, as well as environmental and market assessments of the recycling chains. The second task was an in-depth analysis of the early part of the value chain, through further development of collection, sorting and mechanical fractionation. Actors with an interest in using textile waste for further upgrading or scaling were included to optimize the use of Swedish textile waste. This resulted in a summary report that included market-driven opportunities for Swedish actors to develop collection and sorting of textile waste and an updated environmental assessment based on the results of task 2. Based on an overall evaluation of the outcome from task 1 and 2, task 3 tested the value chain by conduct trials where the recycling chain was tested for both chemical and mechanical recycling processes. Two prototypes were planned, one with chemical recovery and one with mechanical recovery. The production of these prototypes started in the middle of the project to await the results from task 1 and 2, which was a good time. The chemical prototype was delayed further, but the conditions for starting this recycling chain were organized in the project. The aims and activities of the tasks are described below.

Task 1: Inventory and development of a market driven value chain

**Aim:** Develop textile recycle value chain/s based on end-user perspective

**Milestone:** Structuring a framework for WP6

Activities include:

- Workshop with the complete consortium to assess value chains and challenges
- Specification of partner contribution in the project and beyond
- Market analysis of fibers
- Brief environmental assessment of textile recycling processes

#### *Workshop with consortium to assess value chains, challenges and partner specifications*

During the workshop several important issues of the processes in textile recycling was identified by discussions and participation of the partners in the value chains. Gaps in value chain that would need to be filled were found and discussion about possible volumes and qualities for recycling processes both within and outside the project time. Also, limitations of the recycling processes were discussed and pinpointed. As a result of the discussions during the workshop, specification of what partners can contribute with in Task 3 was clarified. The subtask to assess the environmental aspects of the recycling processes was introduced during the workshop and partners were encouraged to start to identify the processes involved in the recycling chains as input to the environmental assessments carried out in the project.

#### *Market analysis*

The market analysis was also performed during the first task. The general questions that required answers in order to predict the market for the fibers were if there is availability of raw material for recycling and if there is a future demand for existing and new fiber types. These questions were answered positively; there is very good availability of raw materials for textile recycling and there are many sources; however, specific streams that are suitable for the re:newcell process might need to be analysed separately. The future demand for existing and new fiber types is expected to continue to grow at an even pace. The new fiber types need to be, in all aspects, equal to existing fiber types on the market.

#### *Brief environmental assessment*

The brief environmental assessment was presented as a literature review. The findings were:

- That there are potential environmental benefits with future chemical as well as mechanical fiber-to-fiber recycling in Sweden.
- Two factors which have considerable influence on the LCA results are:
  - The assumption about substituted fiber. This in turns depend on the type of product that is produced from the recycled fibers. Also, actual substitution depends on market mechanisms (e.g. price elasticity), and in reality the substitution effect is somewhere between 0 and 100%.
  - The geographical location of recycling and regeneration of fibers, as this influences the opportunities to use environmentally preferable suppliers of energy and chemicals.
- The following appear to contribute the most to the environmental impact of the recycling processes:
  - For mechanical recycling: the transportation and the pulling of the textile waste (*rivning*, in Swedish).

- For chemical recycling: the pretreatment (including de-dyeing), the dissolution and the spinning (transportation and pulling appear to be rather negligible).

## Task 2: Further development of collecting and sorting in the value chain

**Aim:** In depth analysis of first part of value chain

**Milestone:** Deliver feedstock to mech/chem recycling according to end-user needs

Activities include:

- WS with consortium to set common goals
- Recommendation for collecting and sorting
- Brief environmental assessment

### *Workshop with consortium to set common goals*

This workshop was also set up with all partners of the consortium in order to set the specification of future prototypes. Raw materials for the prototypes were set and further specifications or what partners can contribute with in task 3 was also defined.

All agreed on to:

- Find large-scale solutions that are economically, logistically and environmentally feasible.
- That there is a clear need for knowledge transfer and coordination
- That we need to understand the needs and limitations of suppliers and customers
- That we need increased understanding of required quality of material for recycling and reuse to enable efficient collection and sorting processes.

### *Recommendations for collecting and sorting*

The early part of the value chain, collecting and sorting, of Swedish actors was analyzed when it comes to the capacity and future potential to handle the future collection and sorting assignment in textile recycling. The findings in the report is summarized in the points below:

- Existing collection, sorting and recycling systems are not enough and need to be complemented
- To create new collecting and sorting facilities is important for establishing a circular economy
- Collection solutions must be efficient, environmentally sound and have depositions for the collected materials, i.e. the destination of the sorted goods needs to be known already during the sorting in order to make it efficient
- Current collection actors have good potential for this

### *Brief environmental assessment*

A brief environmental assessment was done with regard to re:newcell's process. The screening LCA indicates a potential for the re:newcell process to be part of an environmentally competitive fiber-to-fiber recycling system. Due to confidentiality of the process, all results of the full report are not cited

here. It should be stressed that this was a screening LCA which provided a preliminary estimate of the environmental impact of the studied system, but that a full LCA is warranted to be able to say more. Such a study should, among others, consider further environmental impact categories, include further life cycle processes, and include a thorough sensitivity analysis of the results.

### Task 3: Value chain trial (mechanical/chem)

**Aim:** Test recycling loop for mech/chem recycling of Swedish textile waste

**Milestone:** Production of mech/chem prototype and evaluation

Activities include:

- Production of mechanical prototype (lab scale)
- Production of chemical prototype (pilot scale)
- Evaluation of results

#### *Production and evaluation of mechanical prototype*

The production of the mechanically recycled prototype was performed in lab scale, using the textile shredding machine newly installed at Swerea IVF. The first material tested was from Fristads AB Martinson and from Textilia. This material was not working in the mechanical shredding machine right now, but there is potential to be able to work with this material in the future, after some more optimizations have been done. The material may have become hornified (förhornat, Swedish) due to that it has been subjected to industrial washing, which makes the material brittle and harder to shred. Instead a thin yarn, white and dark, has been spun (40 Nm) from used textiles with origin from outside the project (from Emmaus Björkå). A mix (50%/50%) of virgin and postconsumer cotton/viscose was used in the construction which is a very high level of postconsumer textile waste. A small test piece has been produced and evaluated visually by a partner in the project, Lindex. The evaluation said there is a potential market for mechanically recovered textiles in Lindex's future products. In follow-up projects, several mechanically recycled textiles have already been manufactured that have even better quality and marketability. Due to limitations in the project set-up, knitting and weaving capability not present in project and only a very small piece could be fabricated.

#### *Production and evaluation of chemical prototype*

Regarding the chemical recycling, we have evaluated the possibility of using Swedish used textile in the re:newcell pilot plant, which is now being built in Kristinehamn. This part of the project has been after schedule since the test running of the pilot-scale facility has taken longer time than expected. However, textile material has been sent to the plant during the latter part of the project for intended evaluation in the process. Material from Textilia - white, cotton text without printing and finishing – could not be run in the pilot plant at the moment but an evaluation of the materials said that it is probably possible to be used in the future when the plant is in operation and the processes have been optimized. A comparison with previously treated material at re:newcell showed that the material sent during the project is very similar to that previously successfully regenerated at re:newcell in smaller scale, which also indicates that it should work in the pilot plant soon (see Figure 5). During the course of the project, a dialogue has continuously been held with re:newcell and other project partners about opportunities, properties and market needs in the field of chemical recovery, and in particular re:newcell's process. This has developed both re:newcell and other partners in the project in the field of chemical recycling technology.



*Figure 5: Re:newcell pulp*

Task 4: Management, meetings, dissemination and demonstration

Management, meetings, dissemination and demonstration has been performed according to plan.

## Conclusions

There is very good potential for fiber-to-fiber chemical and mechanical recycling of waste textiles in Sweden as a general conclusion. The market needs exist for recycled fibers. Environmental aspects can be promising for the processes and different issues are visible for different recycling technologies, such as mechanical and chemical. The value chain is not complete and needs to be developed further. Especially collection and sorting of waste textiles need more development. The value chain within the project is not complete either since operations such as spinning, knitting and weaving were missing.

### Suggested future work

Since the most development is needed for the collecting and sorting of waste textiles, most efforts should be directed there. More digital options could also be tested in these processes in order to achieve higher efficiency. This is also being tested in other research initiatives that started after this project.

It is also important to secure raw material quality so that the right quality of the waste textiles reach the recycling facilities in order to ensure an even production quality. This is also related to the collection and sorting development that needs to be done, that was mentioned in the first paragraph.

In the long run it would be beneficial if more textiles were designed in order to be recycled, i.e. design for recycling, which could imply textiles consisting of monomaterials or buttons in the same plastic material as the fiber type. This would also facilitate a future recycling of textiles.