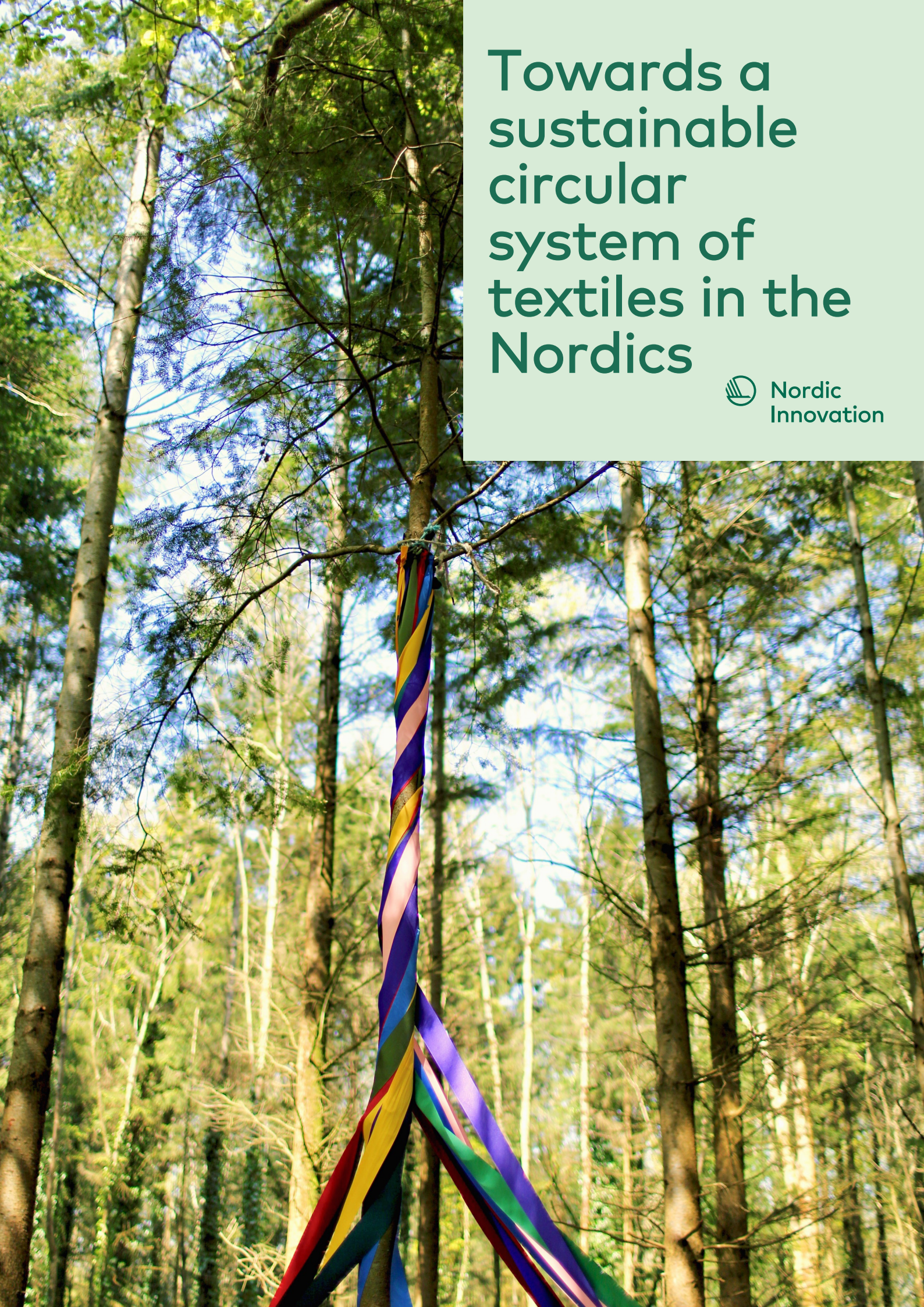
# Towards a sustainable circular system of textiles in the Nordics



Nordic Innovation

# Project End Report

| PROJECT INFORMATION |
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| Project title: Towards a sustainable circular system of textiles in the Nordic region (SATIN) |
| Project number: P-20022 |
| Project period: 26 August 2020-1 December 2022 |

| UPDATED PROJECT ORGANISATION | |
|---|---|
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# Project End Report

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## Summary

The Nordic countries are big consumers of home textiles and clothing, but the textiles do not stay here for a long time. Although some clothes and home textiles are reused among friends, family, sold on marketplaces or donated to non-profit organizations (NGO), most end up in the residual waste and are incinerated. This is leading to huge material and resource lost since over fifty percent of the textiles could have been reused or recycled. Of the textiles that are separately collected, the majority are exported abroad for sorting and reuse whereas a tiny fraction is fiber-to-fiber recycled.

Seeing that the textile industry is one of the most resource consuming industries with a high environmental impact it is important that the Nordic countries increase the collection and recycling rates and reuse more locally. It will not be possible to export EOL textiles in the same way as before. Around 40 countries have stopped importing EOL textiles and the EU is setting requirements for separate collection from 2025. This will mean that volumes of EOL textiles will increase in Europe at the same time as it will be increasingly difficult to find outlets for these volumes. As collection rates increase, so will the proportion of textiles that cannot be reused but hopefully be recycled (recyclables). There is no organized collection for recyclables, but several innovative initiatives are happening within this area, not least in the Nordic countries, where many automated sorting and recycling facilities are emerging.

The SATIN project focuses on increasing circularity of EOL textile in the Nordic region and has a strong focus on supply chain management (SCM). SCM relates to balancing the supply and demand of materials to achieve efficiency in the material flow of EOL textiles and related information, and monetary flows as well as collaboration between actors in the EOL textile value chain. *The purpose of the SATIN project is to develop and test solutions that can address the EOL textile collection and sorting challenges by taking a SCM perspective.*

In the project we have 1) Mapped and identified challenges and opportunities in the current system by interviewing main actors in the value chain of EOL textiles in Norway, Sweden, Denmark, and Finland, 2) Analyzed nine pilot studies of different collection methods. The pilots differ in terms of who organize the collection and sorting, the geographical area in which the collection service is offered, type of collection method, and if collection is carried out in one or two fractions, 3) Estimated volumes of recyclable textiles and their fiber composition and compared this supply with the current and upcoming sorting and recycling capacity (demand) in each country and in the whole Nordic area.

Our results show there are large similarities between the actors in the Nordic countries when it comes to challenges and opportunities in the value chain of EOL textiles. Main challenges can be connected to lack of scale, low profit, no demand, and lack of data whereas opportunities are seen in collaboration, centralization and understanding/finding a market for EOL textiles. Connected to collection methods it was found that it is difficult to compare different methods because there are so many factors at play. However, it became clear that regardless of the collection method, the role of the consumer is very important in scaling up collection. Connected to recyclables our results show that the upcoming automatic sorting and recycling capacity in the Nordic region will be sufficient to deal with the total recyclable fraction, except for some of the synthetic fibers. However, there are imbalances within each country raising a need for collaboration among countries. To make local automatic sorting and recycling possible, it is important to find solutions for pre-sorting within the Nordic region.

## The most important results and key accomplishments

This chapter is divided into two sections: 1) ***The organization and process of the SATIN project*** describing the number and the role of participating companies and organizations, and the key project activities carried out, 2) ***The results connected to the work packages*** **(WP)** describing the most important results of the project and its related outcome and value. For detailed information connected to the results please see Appendix 2 in which all reports such as academic journals, master and bachelor theses, chapter in books developed during the project are listed.

### *The organization and process of the SATIN project*

The SATIN project consists of 24 projects partners: five *researcher institutions/universities* (VTI, CIT, Aalto University, Aalborg University, NTNU), Three *municipalities* (Kungälv kommun, Mölndals stad, Göteborgsregionen), four *waste professional collection companies* (Kretslopp och Vatten, Trondheim Renholdsverk, Vesar, Trasborg), two *waste associations* (Avfall Sverige, Avfall Norge), three *NGOs* (BjörkåFrihet, UFF, Röda Korset) one *denim brand* (Nudie Jeans), one *laundry company* (Kruse Vaskeri), two *upcycling companies* (Better World Fashion, Convert), one *freight forwarder* (DHL), one logistic *consultancy company* (Integrate) and one *real estate company* (Fastighet AB Balder). The project has been carried out though five work packages (WP):

- WP1 focusing on mapping the current collection and recycling system of EOL textiles.
- WP2 focusing on designing solutions linked to collection and sorting.
- WP3 focusing on testing solutions developed in Wp2.
- WP4 focusing on compiling results from the other WPs and thinking though how to take the results further in a next step and who should be involved in this.
- WP5 focusing on project management.

The organisation of the project is presented in Figure 1. The project leader has been responsible for the coordination and financial management among partners, monitoring of other WPs as well as communication and progress reporting to the Nordic Innovation officer. The project leader has worked closely with the WP leaders and together the project leader and WP leaders have formed the "researcher group" that has initiated, organized, and

followed up project activities. The project partners have been actively involved in the activities by participating in interviews, supporting with data collection (statistics and reports), setting up and running pilot tests, validating results, and supporting in dissemination activities. In the beginning of the project the project partners together identified relevant organization/companies and persons that we wanted to involve as an advisory board (see Figure 1). The advisory board has supported in all stages from data collection to dissemination of results by giving input to the process and the results.

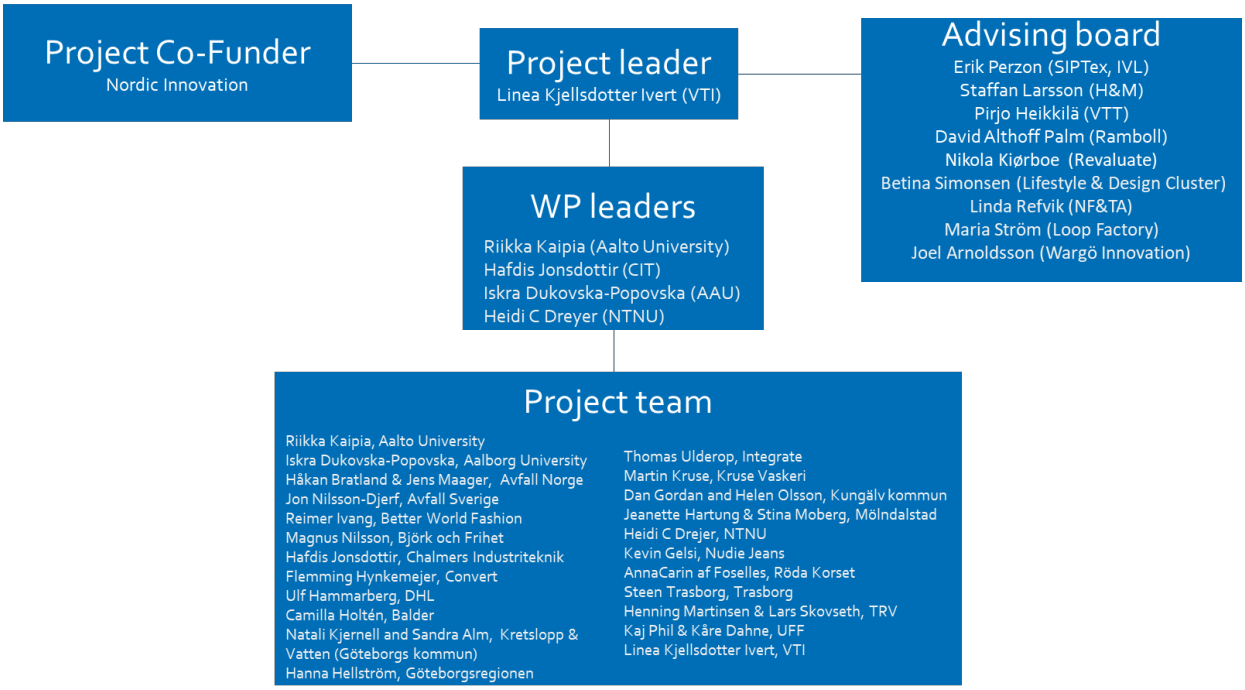


Figure 1: The project organisation

## *Results connected to the work packages*

*WP1 was carried out during the first year of the project and the methods used were literature studies, semi-structured interviews, secondary data analysis of national statistics, and additional documentation (such as different actors' home pages, previous reports, etc.).*

**Main results connected to the current system of EOL textiles**: We have observed that the activity, awareness, and interest about circularity of the textile industry is increasing. Still there are many challenges in the value chain of EOL textiles. The value chain is dependent on the users of textiles, including consumers, organizations, and institutions, and how they hand in their EOL textiles into various recycling and reusing processes, called the first mile problem of reverse material flows (Jäämaa and Kaipia, 2022). Here, the organizers of collection need to balance between collection efficiency and user convenience. Additionally, the volume and quality of textile handed in by users vary across seasons and locations which challenges the operations of the value chain. There are new automatic sorting plants under way and the expectations are high as it will boost fiber-to-fiber recycling. Still, EOL textiles that can be reused need to be separated from what cannot be reused and textiles that can be recycled need to be separated from what cannot be recycled, but for the moment is considered as

waste (until new automatic sorting and recycling technologies has been developed) (McKinsey & Company, 2022). Today there are a lot of uncertainties about where those pre-sorting activities should take place, the actors involved and the feasibility. It was identified that the consumer role in textile sorting deserves attention since it can reduce the need for subsequent pre-sorting. For the transport there is risk for quality drop, a clean collection location and not to full containers minimizes risk for other fractions than textiles to be put in the container. We have also identified that some receivers of textiles want to have the textile delivered in a way that is problematic for the collectors and hinders transport efficiency. The reuse and recycle textile material offer business opportunities but the market development and business models are undeveloped.

The volume of textile flows in Norway, Sweden, Denmark, and Finland are synthetized (Table 1) from previous reports and literature (Watson et al., 2020b; Watson et al, 2018; Dahlbo et al., 2021; SMED 2018, SOU 2020). Obtaining accurate data about the EOL textile volumes is far from easy because the flows are difficult to trace; most of the EOL textiles are exported or incinerated (Watson et al., 2020a). It has become clear that there is a lack of standardization and/or guidelines for how to register and report volumes and quality categories resulting in incomplete statistics. Especially there is a lack of data on volumes that are collected by other actors than the largest NGOs, volumes generated from industries and organizations, and volumes that are reused among consumers (e.g., digital marketplace, flea market).

As can be seen in Table 1 the collection rates are rather low (ranging between 33% in Sweden to 50% in Norway), and a large share of EOL textiles is exported. General problem for all countries (also on EU perspective) is that a large share of EOL textiles end in the residual waste (ranging between 55% in Denmark to 67% in Sweden) and is incinerated. This is leading to material and resource loss as most of the textiles could have been reused or recycled, which decreases the need for virgin material production (McKinsey & Company, 2022). It is also interesting to notice that out of the exported flows, between 16 – 22% get recycled, which is a total of 15340 tons per year (excluding Finland). This is a valuable basis for replacing the use of virgin materials with recycled materials. Most of this material is currently downcycled, for example in furniture paddings. Today less than 1 percent of EOL textiles is recycled into new fibers for textile production in Europe (European Union, 2020; Ellen MacArthur Foundation, 2017).

The project identified several challenges related to the sorting and use of recycled textile materials. In interviews with key actors, many interviewees indicated that the textile industry will not be ready to utilize separately collected post-consumer textile material by 2025. This is due to the heterogeneous nature of textile material and the lack of capabilities to deal with the expected volumes. Even though recycling technologies have improved, there is still a gap to manage textile waste particularly from consumers as it varies in material mix, color and quality making the sorting and recycling processes complex. There is also a need for more reliable sorting, most sorting processes are not efficient enough to meet the needs of recycling companies. Expensive sorting and recycling processes reduce the possibilities of recycled materials to compete with virgin material. Out of the volumes that sorting

companies deal with, only a fraction fits for the need of the recycling companies. Thus, the cost can be lowered if sorting companies can find customers for all types of waste fractions or if sorting can become more efficient.

The study has identified the need for efficient solutions for EOL textile collection, sorting and recycling. To lower the costs connected, the reverse flow needs to apply SCM practices and management methods known from the linear supply chains. In this project the first mile – problem, the multiple sorting phases, and balancing the flow activities to respond to the needs of materials were studied. Other solutions to increase profitability of textile recycling that have been discussed are increased collaboration, to make use of existing knowledge and infrastructure to a larger extent and policy instruments such as ERP, incineration tax, standardization, labeling, recycling targets and taxes that enhance circularly as well as eco-design. A related question to be considered is the paradox between managing the challenges of today and the challenges of tomorrow as they may appear differently. As business models become more circular the recycling technologies of today may not respond to future needs. Therefore, solving the challenges of today is important, but needs to occur in parallel with planning for the future.

Table 1 cloths and textiles flows and EOL volumes in Nordics

| Volumes ton per year | Norway | Finland | Denmark | Sweden | Total |
|---|---|---|---|---|---|
| Imported volumes new textiles | 77 500 | 51 906 | 75 330 | 140 000 | 352 450 |
| Household waste | 31 500 | 40 376 | 42 130 | 75 000 | 191850 |
| Separately collected | 31700 | 22 739 | 36 000 | 38 000 | 122 100 |
| Reused within the country (of separately collected) | 550 | 3 662 | 10 600 | 7 800 | 26 950 |
| Exported to other countries | 30650 | 15 036 | 21 840 | 27 600 | 88470 |
| Of which following is reused | 22068 | N/A | 15 288 | 21300 | 58 656 |
| Of which following is recycled | 6590 | N/A | 4 150 | 4 600 | 15 340 |
| | | | | | |
| | | | | | |
| Percentages | Norway | Finland | Denmark | Sweden | |
| Used textiles/waste | | 63 115 | 75 900 | 113000 | |
| Household waste | | 64% | 55% | 67% | |
| Separately collected | 50% | 36% | 47% | 33% | |
| Reused within the country | 1% | 5.8% | 14% | 20% | |
| Exported to other countries total | 48% | 24% | 29% | 24% | |
| Of which following is reuse | 72% | N/A | 70% | 77% | |
| Of which following is recycled | 22% | N/A | 19% | 16% | |

# Project End Report

*WP2 and WP3 have been carried out in parallel and included the following activities: 1) collecting and analysing pilot studies of collection methods, 2) defining quality and volume performance measures and evaluating the pilots, 3) estimating the supply of recyclables and identifying its balance with the demand of the available and future capacities in automated sorting and recycling in Norway, Sweden, Denmark, and Finland.*

**Main results connected to the collection methods:** Together with the project partners and other collaboration partners we conducted and analyzed nine pilot tests. Three pilot tests took place during 2018 (before the SATIN project started) and we only got access to these data, whereas six were designed or followed and analyzed during the SATIN project. In some pilots' recyclables and reuse textiles were collected in one fraction. Other pilots separated recyclables and reuse textiles in two fractions. The location of some pilots was in outdoor arrangements either at recycling centers, close to home or real estate building, or indoor location such as in real estates or shopping malls. The number of collection points (locations of collection container) varied in the pilots, as well the length of the pilots. Please see Figure 2.

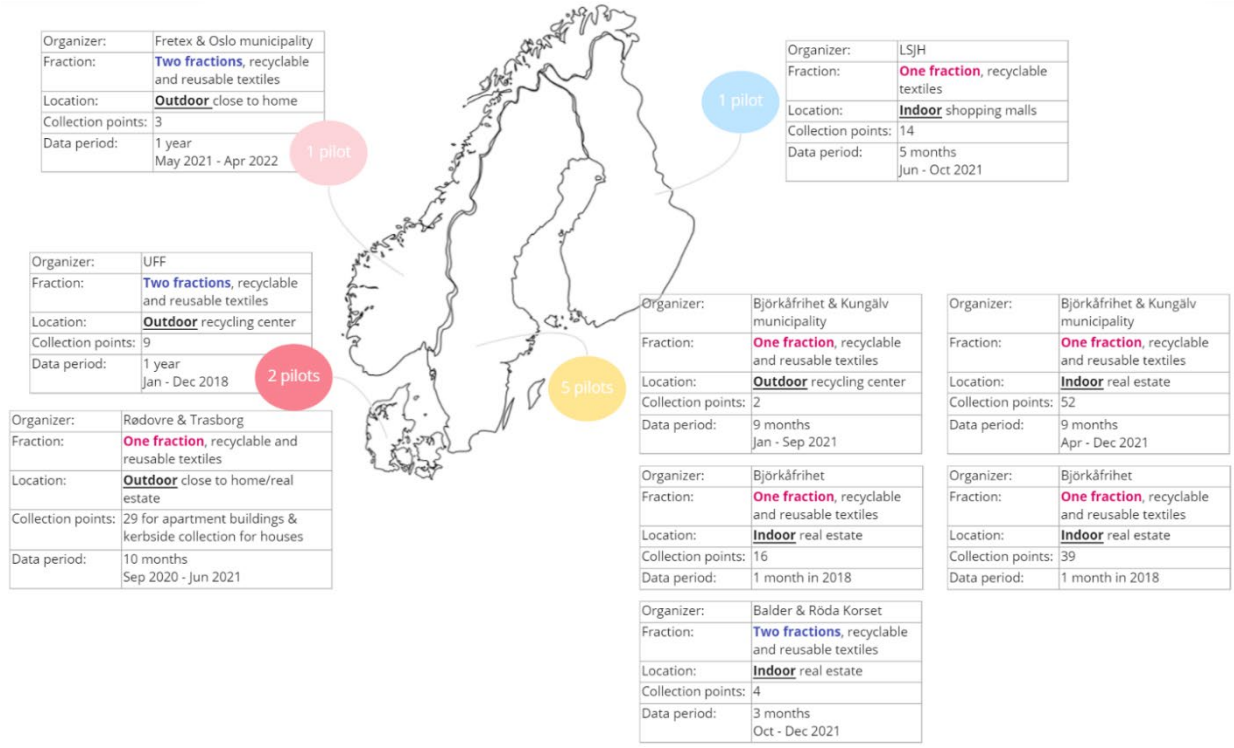


Figure 2 EOL textile collection pilot tests in the Nordic region

The purpose of the pilots was to test and evaluate different collection methods and their impact on subsequent sorting to identify pros and cons of the methods and be able to understand when to use what method. Evaluation criteria were used to evaluate the performance of the pilots. Early in the project, a list of potential evaluation criteria was made. This list consisted of 13 criteria (see the bullet list below) but when analyzing the pilots, only

three of them were used because not all pilots had data about the 13 criteria. Those three were related to volumes and quality seen as bolded in the bullet list below.

To be able to evaluate the volume of collected textile, it was decided to use a criterion that not only looked at the total volume over a certain period, but the volume collected per inhabitants in the area. The number of people having access to the collection points has a big influence on the volumes collected. For evaluating quality, it was decided to look further into the percentage of desired textile fraction collected. As an example, the percentage of desired reusable textile fraction is the percentage of how much reusable textile was found in the collection box when collecting either reusable textile separately or together with recyclable textile. This was an important criterion in the pilot tests as it showed how well the initial sorting had been done by the consumers.

- Volumes
  - Collected volumes per month/week/load during the test period [kg]
  - **Collected volumes per inhabitant per month [kg/inhabitant/month]**
  - Variability of volumes
- Transport
  - Frequency of pick-ups from a single collection point per day/week/month
  - Fill rate in load carrier [kg or volume]
- Quality
  - **Percentage of desired reuse textile fraction**
  - **Percentage of desired recycled textile fraction**
  - Percentage of otherwise useful textile fraction
  - Percentage of not useful fraction
- Cost
  - Operating cost (resources and connected costs for the actors)
  - Initial investment for the collection decision
- Qualitative
  - Attractiveness to consumers
  - Operating companies' experiences

The analysis of the pilots regarding the amount of textile collected in kg per inhabitant per month shows that both the highest and lowest number of textiles were collected in two fraction systems, with the highest amount collected close to the house and at outdoor recycling centers. The highest amount collected in the one fraction system was at outdoor recycling centers. Please see Table 2.

Table 2: Amount of textile collected [kg/month/inhabitant]

| Fractions | Real estate (indoor) | Real estate (outdoor) | Collection close to house (outdoor) | Recycling center (outdoor) | Shopping mall (indoor) |
|---|---|---|---|---|---|
| ***Two fractions:*** Reusable textile | 0,04 | 0,57 - 1,37 | | | |

| | | | | | |
|---|---|---|---|---|---|
| ***Two fractions:*** Recyclable textile | 0,03 | 0,24 – 0,76 | 0,17 – 0,84 | | 0,01 |
| ***One fraction:*** Reusable and recyclable textile | 0,14 – 0,26 | 0,14 | 0,18 | 0,41 | |

The highest quality of textiles collected in terms of the percentage of desired reuse quality fraction came from the two fraction systems, collected indoor in real estate, while the lowest quality came from outdoor collection close to house. For the one fraction collection, the highest reuse quality came from indoor real estate systems, while the lowest quality came from outdoor real estate and close to house collection. Please see Table 3.

The results for the highest textile quality in terms of the percentage of desired recycling fraction came from the collection of recyclables only indoor in shopping malls. The quality from outdoor collection in real estate and close to house scored medium high, while the quality was low in two fraction collection indoor real estate and at outdoor recycling centers. For one fraction collection, the quality of real estate indoor was low. Please see Table 3.

Table 3: Quality of textiles collected in terms of the percentage of desired reuse and recycle fraction

| Fractions | Real estate (indoor) | Real estate (outdoor) | Collection close to house (outdoor) | Recycling center (outdoor) | Shopping mall (indoor) |
|---|---|---|---|---|---|
| ***Two fractions:*** Reusable textile | 97% in reuse bin and 63% in recycling bin | | 76% in reuse bin and 42%-53% in recycling bin | | |
| ***Two fractions:*** Recyclable textile | 16% in recycling bin and 3% in reuse bin | | 40%-49% in recycling bin and 11%-14% in reuse bin | 16% | 82% recyclable and otherwise useful textile |
| ***One fraction:*** Reusable and recyclable textile | 78% reusable<br><br>12% recyclable<br><br>73% reusable | 48% reusable<br><br>28% recyclable | 54% reusable<br><br>29% recyclable | | |

| | | | | | |
|---|---|---|---|---|---|
| | 23% recyclable | | | | |

To conclude, the collection of EOL textiles in two fractions supports the subsequent sorting and location close to house/recycling center seems to be positive. Indoor collection might result in a high share of desired fraction. However, to verify the results there is a need for more pilots to explore the impact on the amount and quality of EOL textiles of different collection and pre-sorting methods and to understand when to use what method.

**Main results connected to the supply and demand of recyclables:** Because of the EU Directive obliging separate textile collection from households in 2025 latest, the volumes of EOL textiles within the EU will increase. The weight share of non-reusable textiles is already quite high (28%) comparing to its value share (4%) and with increased collection volumes the non-reusable share is likely to increase even further (Watson, 2018a). As such it is important to find ways to manage textiles that cannot be reused but potentially be recycled (recyclables). During the last years a lot has happened within the area of automatic sorting and recycling, not least in the Nordic region. With this as a background we found it critical to understand if the Nordic region will have the capacity in automated sorting facilities and recycling facilities to cope with the volumes of recyclables that are generated within the region. Thus, we decided to estimate the volumes of recyclable textiles and their fibre composition (based on created weighting average method) and comparing these estimates with the current and upcoming capacities in each country and the Nordics as a whole.

To estimate the supply, we identified three fractions relevant for the volume of recyclables, see figure 3. We had to estimate the recyclable fraction out of those that are currently incinerated if being separately collected. To this we can add the textile that is currently recycled abroad and finally textile that is already recycled in each of the countries. To estimate the fraction recyclables out of the incinerated we calculated a lower limit of 23% and upper limit of 61% recyclables out of the household EOL textiles based on previous picking analysis (Norup et al., 2018; Watson et al., 2018; Dahlbo et al., 2021). We also calculated out of previous literature (ibid) the expected percentages of different fibers within the recyclable fraction, so that: 49% is estimated to be cotton, 27% mix of oil-based and natural fibers, 9% polyester, 5% viscose fibers, 8% other synthetic fibers, and 2% other (such as leather, etc.).

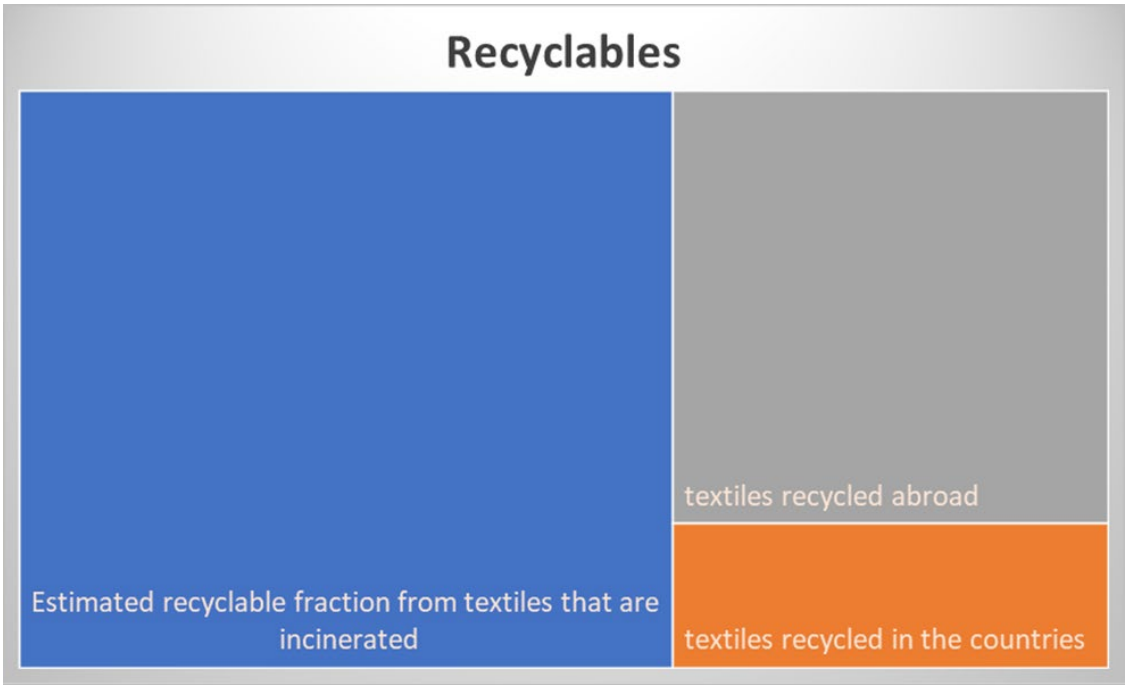


Figure 3: Supply side (estimation of potential recyclable fraction)

To estimate the upcoming capacity in automatic sorting and recycling we identified and interviewed automated sorting and recycling actors active in the Nordic region. Please see Table 4. Some of sorting and recycling actors have reached their planned capacity, while others are still in their development phase, marked with grey in the table. As we can see there are automated sorting facilities planned in each of the four Nordic countries, while the fiber-to-fiber recycling facilities differ by the fiber type they are able to process. "M" in table refers to mechanical recycling. It relates to fiber production manufactured by spinning recycled yarn (Roos et al., 2019). "C" in the table refers to chemical recycling. It means recycle the textile to molecular level (de la Motte et al., 2019).

Table 4: Demand side (capacity in automatic sorting and recycling).

| Actor | Type of actor | Location | Supply requirement | Capacity (ton/year) |
|---|---|---|---|---|
| **SIPTex** | Sorting | Sweden | -Clean; No: hardware, multilayered material, longer than 2m | 24,000 |
| **Wargö Innovation** | Sorting | Sweden | -Clean textiles | 500-1,000 |
| **LSJH** | Sorting | Finland | -Dry and clean, non-reusable, no paddings | 65,000 for sorting |
| **NewRetex** | Sorting | Denmark | - size limitations | 40,000 (2025) |
| **NorSort** | Sorting | Norway | -All textiles | 60,000 (2023/24) |
| **Infinited Fiber Company** | Refining, (M and C) | Finland | -Cellulose-rich waste | 30,000 of Infinna fiber in 2024 |
| **Renewcell** | Recycling (C) | Sweden | -95% cellulose content in each garment<br>-Clean textiles; Hardware removed | Facility1: 5,000 in 2022;<br>Facility2: 60,000 (initial), 120,000 total in 2023/2024 |
| **Södra** | Recycling (C) | Sweden | -50-100% white cotton mixed with polyester; Hardware removed; Clean | 2,000 (2022)<br>25,000 (2025) |
| **Textile Change** | Recycling (M and C) | Denmark | -Clean; Any combination of polyester, plant-based, and/or manmade cellulosic fibers, including up to 15% elastin | 15,000 (2023/2024) |
| **Plastic Nordic** | Recycling (C) | Norway | -Polyester and polycotton textiles | 30,000 (2024) |
| **Rester** | Recycling (M) | Finland | -Clean; from companies, all types of fibers | current capacity 12,000 |

Figure 4 shows the balance of supply and sorting capacities. The first two bars on the left represent the lower and the upper level of supply of recyclables. The two bars on the right represent the automated sorting capacities in each of the countries. Norway, Denmark, and Finland will have more sorting capacity than needed, while Sweden would miss automated sorting capacity, if the volumes estimated in 2018 are to be expected. The sorting capacities in Norway and Denmark are expected to be ready full scale in 2024-2025.

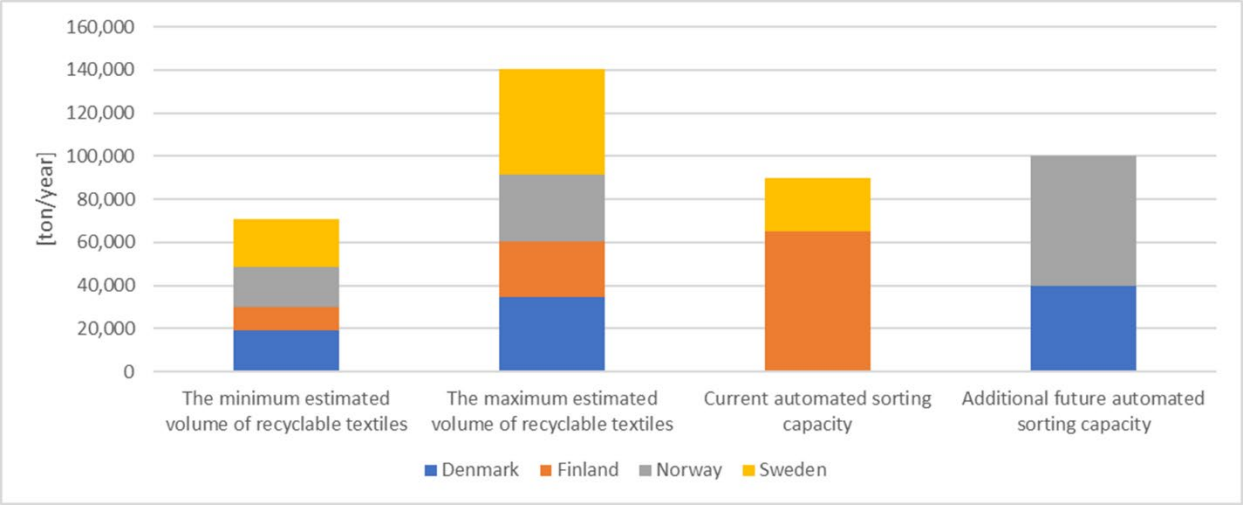


Figure 4: Balance of supply and sorting capacities

Table 5 shows the balance of supply and recycling capacities on a Nordic level. The red part of this table shows the estimated supply volumes of recyclables per country as total and per fiber type. The yellow part presents the demand of the recycling capacities per fiber type per country. The part of the table with green frame shows the balance of supply and demand within each country and on a Nordic level. The yellow fields show that there will be oversupply in the country after they utilize own recycling capacity, while the green fields show available capacity.

Table 5 shows that all countries will have an over-supply (yellow fields) of synthetic fibers other than polyester. Denmark will have an over-supply of some of the fibers (cellulose-rich, polyester, or mixed fibers) since the upcoming recycling facility (Textile change) will have a capacity to process 48% of the maximum estimated supply of those three fiber fractions. Norway will have an over-supply of cellulose-rich fibers and some of the mixed fibers (polyester dominating mixes can be treated in Norway), and Sweden will have over-supply of polyester fibers. Finland and Sweden will have excess capacity to recycle cellulose-rich fibers, while Norway will have excess capacity to recycle polyester and polycotton fibers.

At an aggregated Nordic level (the last line in the table), it is seen that the upcoming facilities for recycling polyester, cellulose-rich fibers, and mixed fibers will be sufficient to process all the estimated incoming fractions (maximum estimate). In fact, it is estimated that about 49% of the capacity for the recycling of cellulose-rich and 42% for the recycling of polyester fibers will require supply from outside the Nordics. There is a lack of capacity in the Nordics to recycle about 11,200 tons of synthetic fibers. Only one facility in Finland accepts polypropylene, but it is not clear what fraction of the synthetics supply this. Seeing that the upcoming automatic sorting and recycling capacity will be sufficient to deal with the total recyclable fraction (except for some of the synthetic fibres) whereas there are imbalances within each country there is a need for collaboration within the Nordic region. To make local automatic sorting and recycling possible, it is also important to find solutions for pre-sorting within the Nordic region.

Table 5: The balance of supply and demand

| | ESTIMATED SUPPLY | | | | | | |
|---|---|---|---|---|---|---|---|
| | Recyclable fraction | >95% Cotton | >95% Viscose | >95% Polyester | Mixed fibers | Synthetic fibers | Other |
| Denmark | 19,257 – 34,419 | 9,436 – 16,865 | 963 – 1,721 | 1,733 – 3,098 | 5,199 – 9,293 | 1,541 – 2,754 | 385 – 688 |
| Finland | 10,751 – 26,094 | 5,268 – 12,786 | 538 – 1,305 | 968 – 2,348 | 2,903 – 7,045 | 860 – 2,088 | 214 – 522 |
| Norway | 18,742 – 30,731 | 9,183 – 15,058 | 937 – 1,537 | 1,687 – 2,766 | 5,060 – 8,297 | 1,499 – 2,458 | 376 – 615 |
| Sweden | 21,862 – 49,222 | 10,712 – 24,119 | 1,093 – 2,461 | 1,968 – 4,430 | 5,903 – 13,290 | 1,749 – 3,938 | 437 – 984 |
| Total | 70,612 – 140,466 | 34,599 – 68,828 | 3,531 – 7,024 | 6,356 – 12,642 | 19,065 – 37,925 | 5,649 – 11,238 | 1,412 – 2,809 |

| | UPCOMING DEMAND | | | |
|---|---|---|---|---|
| | Cellulose-rich | Polyester | Mixed fibers | Synthetic |
| Denmark | 15,000 | | | |
| Finland | 30,000 | | | |
| | 12,000 | | | Polypropylene |
| Norway | | 30,000 | | |
| Sweden | 125,000 | | 25,000 | |
| Total | 155,000+ | 30,000+ | 40,000+ | |

| | SUPPLY – DEMAND BALANCE (within country) | | | |
|---|---|---|---|---|
| Denmark | 2,331 – 15,977 | | | 1,541 – 2,754 |
| Finland | 15,909 | | | |
| | 2,607 | | | <860 – 2,088 |
| Norway | 10,120 – 16,595 | <27,234 | <5,060 – 8,297 | 1,499 – 2,458 |
| Sweden | 98,420 | 1,968 – 4,430 | >11,710 | 1,749 – 3,938 |

| | SUPPLY-DEMAND BALANCE (Nordic level) | | | |
|---|---|---|---|---|
| | 79,148 | 17,358 | 2,075 | <11,238 |

*WP4 was carried out during the last nine months of the project, and we have arranged meetings with the SATIN project partners and potential project partners to discuss how to take results forward. We have also discussed results and ideas with potential funders such as Nordic Innovation to identify relevant calls.*

**Main results connected to how to take the results further in a next step and who should be involved**: It was found that the SCM perspective is very much needed to enhance the circularity of the EOL textile value chain. The SCM perspective is missing in many ongoing projects and initiatives. According to Dervojeda et al. (2014), the established linearity in the current supply chains and economy are the root causes of the difficulties in transitioning to circularity. Economic barriers are a major factor in the inertia of the transition (Levering et al.,2019). However, progressive SCM can promote circular businesses by enabling resource exchange between diverse industries and thereby promote sustainable value generation (Batista et al., 2018). Pal et al. (2019) further elevate how sharing of information and resources can be invigorated through supply chains, which in turn can create favorable conditions for circular activities.

There is a need of effective collection methods that stimulate consumers to hand in their EOL textiles so that more textiles can be reused and recycled instead of incinerated. Due to the upcoming EU requirement, member states are piloting several different collection methods

and are in a process of identifying the most appropriate methods that can lead to increased collection volumes. Comparing and evaluating different waste collection methods has been identified as a challenge in research (Sousa et al., 2019). Several metrics have been proposed in literature (Calabro and Komilis, 2019; Ferreira et al., 2017; Sousa et al., 2019; Dahlén and Lagerkvist, 2010), but no research has focused on systematically comparing and evaluating EOL textile collection. It is important to understand how to successfully implement and upscale collection methods and there is a need to spread best practices and knowledge. It must be easy for consumer to hand in/ get rid of their used textiles. Also, it must be much easier to buy cloths and home textile second-hand.

We have also found that there is a need to make the pre-sorting more effective. Today it is a very expensive process with lack of economic feasibility. Pre-soring is needed in many steps (McKinsey & Company, 2022). Textiles that can be reused need to be separated from what cannot be reused and textiles that can be recycled need to be separated from what cannot be recycled but is considered as waste. Textiles that can be recycled also need to be prepared for automatic sorting. Today there are a lot of uncertainties about pre-sorting activities. Can the consumer separate between what can be reused from what cannot be reused? Is it possible to make use of new technology to simplify and make some pre-sorting activities more efficient? What are the pros and cons of centralized versus decentralized pre-sorting? What are the pros and cons when pre-sorting is done by collectors versus automatic sorting actors/recycling actors? There are also large question marks of what to do with the fraction that today cannot be recycled but is considered as waste.

Finally, it is found that there is a need for collaboration at a Nordic level when it comes to sorting and recycling. Investments in automatic sorting facilities and recycling facilities have increased enormously in the Nordic region. To minimize transportation and $CO_2$ emissions and make those investments meaningful it would be good if pre-sorting also took place within the Nordics. Today the majority of the EOL textiles generated in the Nordics are exported for pre-sorting to Eastern Europe and Baltics due to the low wage costs (Watson, Kant Hvass, et al., 2020). In the SATIN project it was identified that there is enough capacity in the Nordic automatic sorting facilities to handle the EOL textiles generated (Dukovska-Popovska et al., 2022). In other words, if the Nordic countries do not find solutions for pre-sorting one can ask oneself if it is a good idea to first send away EOL textiles for pre-sorting and then transport sorted EOL textiles back to the automatic and recycling facilities in the Nordics. Or if it would be better to use automatic sorting facilities and recycling facilities close to the pre-sorting activities instead. In addition, the domestic textiles production within the Nordic region is almost non existing, but there may be potential alternatives within Europe, which may be preferable compared to sending recycled textiles to production sites in Asia. The pandemic, war, and climate change has increased the awareness of the importance of reliable and sustainable supply chains but there are a lot of uncertainties of how local, reliable, and sustainable supply chain for EOL textiles should be designed.

With those needs as a background, we have identified and submitted an EU application to the LIFE program the 5$^{th}$ of October 2022. Some of the research activities that we aim to perform are:

- ***Consumer collection practices:*** A clear results from the SATIN project was the importance of the consumer in the EOL collection system as consumers are the material suppliers and have a remarkable role and impact on the efficiency of the material flow. Still, there is a need to better understand how consumers can be involved in the collection phase and how consumers perceive different collection methods. In the new project we will conduct surveys and use focus groups with consumers in three different settings, namely: in retail stores, in residential areas and in recycling centers. Based on the current knowledge and the gained knowledge about consumer needs, information material will be developed and used to measure the effects on collection rates when consumers are informed about why to hand in textiles, and how to do it. Measurements of collection rates with be performed prior to, and after this communication effort. The research activity will be conducted by researchers, municipal partners, retailers, and real estate companies.
- ***Online collection:*** The result from SATIN indicates that there is most likely not a "one size fits all", different collection methods are appropriate in different contexts. To increase collection rates, it is important to make it easy for the consumer to hand in their EOL textiles without this being too expensive for the collector (no matter if the collector is a retailer, NGOs, or municipal actors). Most available collection methods require the consumer to travel to a collection point and in the new project we want to explore the possibility of being able to return EOL textiles in the same way as the consumer can receive e-commerce goods (box solutions, home delivery, drop-off points). The research activity will be conducted by researcher, retailer, delivery box company and NGOs.
- ***Developing the role of pre-sorting facilities in the Nordics towards recyclables:*** It is important to better understand pros and cons of different arrangements when it comes to where pre-sorting should take place and by whom. In the new project we will develop and demonstrate solutions for handling recyclables with the aim of improving the effectiveness and efficiency of this flow. Simulation or optimization models will be developed and used to evaluate transport, volumes, $CO_2$ emissions for different pre-sorting set ups. The role and the supply chain network design will be discussed in workshops with project partners to add other aspects such as the need for flexible pre-sorting design depending on different market demands. The research activity is carried out by researchers, NGOs, municipalities, retailers, automatic sorting facilities and recycling facilities.
- ***Establishment of new textile recycling networks*:** An important SATIN project result is the need of collaboration between different actors and countries within the Nordic region. In the new project we want to test new networks in real life, where certain tons are collected, sorted, sent for processing and recycling. The research activity is carried out by researchers, NGOs, municipalities, retailers, automatic sorting facilities and recycling facilities.

The SATIN project partners and the people in the advising bord that are involved in the new applications as project partners are: VTI, Aalborg University, Aalto University, Revaluate, Nudie Jeans, Loop Factory, Avfall Sverige, Norwegian Fashion and Textile Agenda (NF&TA), Kretslopp och Vatten Göteborgsstad, Röda Korset, BjörkåFrihet, UFF, Trasborg. In addition

to those project partners, it was identified that we needed partners in form of automatic sorting facilities, pre-sorting facilities, recycling companies, real estate companies, and delivery box companies but also addition expertise from academia and municipalities. The following partners was identified and are project partners in the new project: Linköping University, Södra, Rester, Re:newcell, Textile Change, Lounais-Sunomen Jätehuolto (LSJH), Sysav, NewRetex A/S, Framtiden, iBoxen, Stockholm Vatten och Avfall, Helsinki Region Environmental Services Authority (HSY).

*WP5 has been carried out throughout the whole project. In the SATIN project we have arranged project meeting, meetings with the advising board and meetings with students' group but also participated at different conferences, seminaries and arranged webinars in which we have presented results from SATIN to organizations outside the project.*

**Main results connected to dissemination:** The following activities connected to dissemination have been carried out during the project. In addition to this the "researcher group" have met at least twice a month and there has been a lot of WP meeting in which researchers have arranged meetings with different project partners:

- **Kickoff 2020-09-30:** The purpose of the kickoff was to get to known each other better, understand the purpose of the project and everyone's role. At the kickoff all project partners participated with *at least one* person. Nordic Innovation represented the program of Nordic Sustainable Business Transportation. At the kickoff we also discussed and agreed upon persons that we would like to involve as advancing board.
- **Webpage and LinkedIn**: We have developed a home page for SATIN (www.vti.se/satin) and a LinkedIn Group for the project partners in SATIN.
- **Press-release**: We have sent out a press-release from VTI, CIT, NTNU, Aalto University and Aalborg University which had a very nice impact. Many relevant actors contacted us such as recycling companies, branch organizations, and collectors.
- **SATIN letters:** We have produced and sent out "SATIN letters" with updates on what was going on in the SATIN project at least once a year. The letter was sent to project partners, advancing board, as well as to other persons that had shown interest in the project or as the project partners identified as relevant. During the project we have sent out three SATIN letters to around 80 persons.
- **Webinar 2020-12-02 arranged by Avfall Norge:** We have presented SATIN at a webinar arranged by Avfall Norge on "Producer responsibility and Nordic co-operation on textiles" the 2nd of December. 40-50 people participated.
- **Webinar arranged by VTT in the beginning of 2021:** We presented SATIN at a webinar arranged by VTT which was part of a webinar series presenting research projects and company development work around circular economy of textile.
- **Project meeting 2021-02-15**: A project meeting was arranged to present and discuss results with the project partners. The results were connected to observation and challenges in the different countries and statistic figures on different flows in the value chain of EOL textiles. All project partners participated in this project meeting.
- **Advising board meeting 2021-04-13**: A meeting with the advising board was arranged in which the researcher team and the people in the advising board met to get to know each other and discuss their role in the project.

- **Student meeting 2021-05-24**: Seven student work was carried out during January-August 2021 in the different countries (one in Norway, two in Sweden, two in Denmark, two in Finland). We arranged a webinar in which the student groups presented their different projects and discussed common challenges and opportunities. At this meeting the students and the research group were participating.
- **Webinar 2021-05-21 arranged by Nordic Innovation**: We presented updates from SATIN at the webinar Nordic circular projects arranged by Nordic Innovation.
- **Webinar 2021-06-24 arranged by Avfall Norge**: We presented SATIN at Avfall Norge's board meeting.
- **Webinars connected to student works during the spring 2021**: We have arranged several webinars connected to the student works that was carried out during the project. At those webinars the student group presented their results and opened for discussions. The project partners, advising board and organizations/companies that was involved in the student works was invited to those webinars.
- **Project meeting 2021-08-24**: A project meeting was arranged by the project group in which findings on collection and sorting solutions and challenges was presented and discussed. During the meeting on-going pilot test was also presented and discussed. For example, Fretex presented results from one pilot test. At the meeting project partners participated and almost all partners were represented.
- **Pilot test meeting 2021-10-11**: A meeting was arranged together with the project partners that was involved in the pilot tests to share experiences and together discuss evaluation criteria.
- **Nordic Circular Summit conference 2021-11-23**. We presented initial results from SATIN at the Pre-session: Circular Fibers - Recycling technologies.
- **Webinar 2021-12-09 arranged by PLAN:** We presented results from SATIN at the webinar arranged by PLAN on circular economy. PLAN is the largest association in Sweden in the field of Supply Chain Management and logistics and has 1800 members from more than 700 organizations.
- **Project meeting 2022-01-25**: A project meeting for the project partners and the advising board was arranged in which results from the pilot test as well as from the supply/demand balance was presented and discussed.
- **Webinar 2022-01-26 arranged by Avfall Norge**. We presented results from SATIN at the webinar "Fiks det!" arranged by Avfall Norge.
- **Conference 2022-02-21 to 2022-02-25 arranged by Production Economics**. We presented a paper at the 22nd International Working Seminar on Production Economics, Innsbruck, Austria.
- **LOOP conference 2022-04-28**. We presented results from SATIN at the LOOP forum for waste and resource management and circular economy, Copenhagen.
- **Conference 2022-05-30 to 2022-06-01 arranged by Avfall Sverige**: At the yearly conference arranged by Avfall Sverige we presented "Collection, sorting and recycling of EOL textile in the Nordic region".
- **Project meeting 2022-09-02**: A project meeting for the project partners and the advising board was arranged in which the main results from the SATIN project was

presented and new project ideas on how to take the results further in a new project was discussed.

- **Seminar 2022-10.** Presentation at RUSKA seminar in Aalto University.
- **Seminar 2022-11.** Presentation at a research seminar organized by LSJ, Finland.
- **SATIN webinar 2022-11-08**: A webinar "The present & future EOL textile system in the Nordics" was arranged with the aim of presenting and discussing results from the SATIN project and related EOL textile initiatives and projects in the Nordics. The target group of the seminar was actors involved in or influencing the value chain of EOL textiles such as recycling companies, automated sorting companies, textile industry, NGOs, researcher, Nordic Innovation, and Ministry of Environment.
- **Academic articles, student reports and book chapter**: Three academic articles, 12 thesis and one book chapter have been written during the project. Please see Appendix 2.

## Nordic added value

The SATIN project has generated new knowledge concerning the role of SCM in the value chain of EOL textiles. The role of the consumer in the collection has been emphasised and different collection methods has been tested and evaluated. Thanks to the project, knowledge has been shared between different collectors in the Nordic region (NGOs, municipality actors and private companies) on how to work to increase the collection rates of EOL textiles. When we started the project, many actors pointed out that the consumer does not have the knowledge to make a first sorting between what can be reused and what cannot be reused. However, we did not drop this issue and sat up pilot tests to understand the effects of allowing consumers to make the first sorting. It became clear in these tests that with the right information and in the right context, the consumer can facilitate for the next steps in the value chain. Knowledge about separate collection of EOL textiles is not only important within the Nordics; it is valuable for all member states in EU. Even though there are uncertainties connected to the responsibility for EOL textiles (producer responsibility vs municipal actors), it is important to stimulate consumers to hand in their EOL textiles.

In the project we have estimated the volumes of recyclables and we have identified automatic sorting facilities and recycling facilities in the Nordic region. This knowledge has been very valuable for actors that are involved in or are affecting the value chain of EOL textiles (collectors, sorters, recycling companies, politicians, authorities, and researchers). Many companies, consultants, and researchers have contacted us and as we are of the opinion that we need to hook arm to take the field forward we have shared the figures we have obtained and explained how we arrived at them. It turned out that several actors did not know each other. The new sorting and recycling facilities that we identified in the project (Table 5) were unknown to many collectors or other sorting and recycling facilities. Thus, the project has facilitated contacts so that new partnerships can emerge. SATIN project has also increased the understanding of how requirements on the feedstock affect the previous steps, knowledge that is valuable for municipalities, retailers, NGO, recycling companies and sorting companies in all Europe.

The result connecting to the exercise where we balanced the upcoming volumes of recyclables with the capacity in automatic sorting and recycling is of great importance for the Nordic region as it indicates that we have enough capacity to handle our own volumes if we collaborate. In other words, if we coordinate our flows there is no need to invest in more automatic and recycling facilities within the Nordic region. Still, it is important that we find solutions for pre-sorting locally (in the region) so that we do not give rise to unnecessary transport and/or flows finding other routes and thus not using the capacity (in automated sorting and recycling) that has been built up within the Nordic region. This knowledge has been disseminated to actors in the Nordic region but also throughout Europe and is important for the development of sustainable textile collection and recycling in Europe.

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# Project End Report

## Annexes

1. A representative example/case/description of the project
2. Detailed information of results

## A description of the project

Most End-of-Life (EOL) textiles in the Nordics end up in residual waste and are incinerated leading to huge material loss. EU's requirements for separate collection in 2025 together with the decision to stop import of used textiles from many countries will result in increased volumes of EOL textiles. The Nordics need to increase collection rates, reuse more locally, and increase fiber-to-fiber recycling (Figure 1) as export possibilities are going to be limited.

The SATIN project has generated new knowledge on collection and sorting of EOL textiles incorporating Supply Chain Management (SCM) perspective. SCM relates to balancing the supply and demand of materials to achieve efficiency in the material-, information and monetary flows. The role of the consumer in the collection has been emphasised and nine pilot studies of different collection methods have been analyzed (Figure 2). It was found that collection in two fractions improves the efficiency of subsequent sorting and collection close to house/recycling center seems to be positive. Indoor collection might result in a high share of desired fraction.

Volumes of recyclables and their fibre composition have been estimated and compared with the current and upcoming sorting and recycling capacities in each country and in the whole Nordic area. It was found that the upcoming automatic sorting and recycling capacities in the Nordics will be sufficient to deal with the total recyclable fraction, except for some of the synthetic fibres. However, there are imbalances within each country raising a need for collaboration among countries. To make local automatic sorting and recycling possible, it is important to find solutions for pre-sorting within the Nordics.

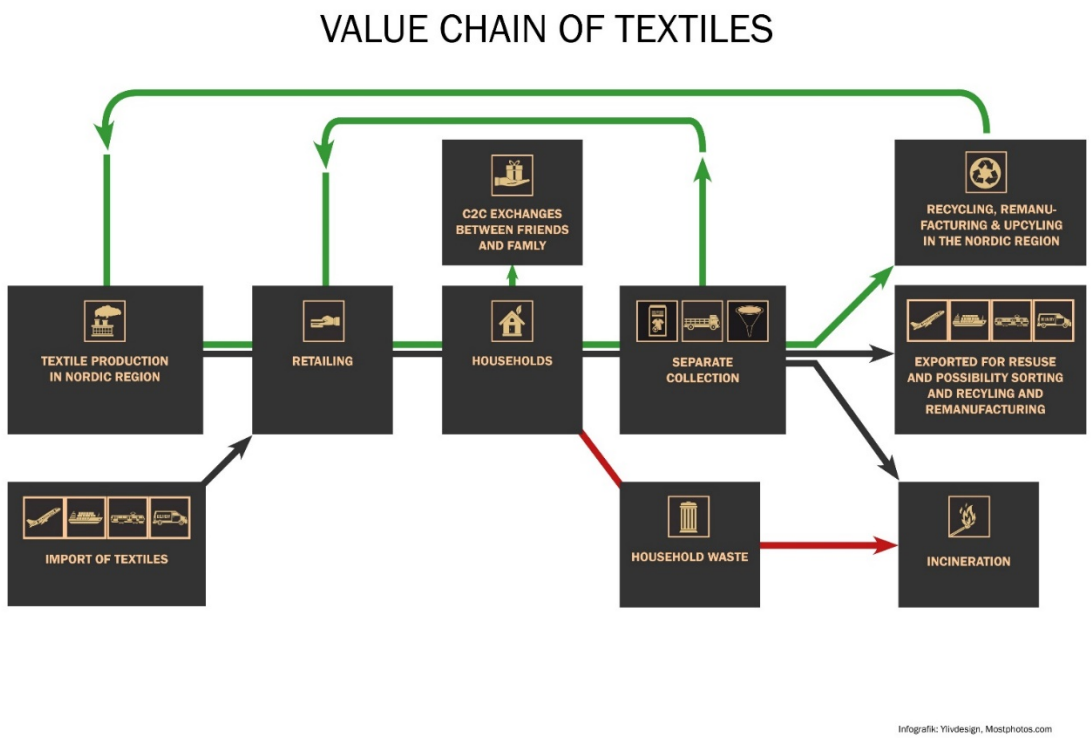


Figure 1: The value chain of textiles in the Nordic region

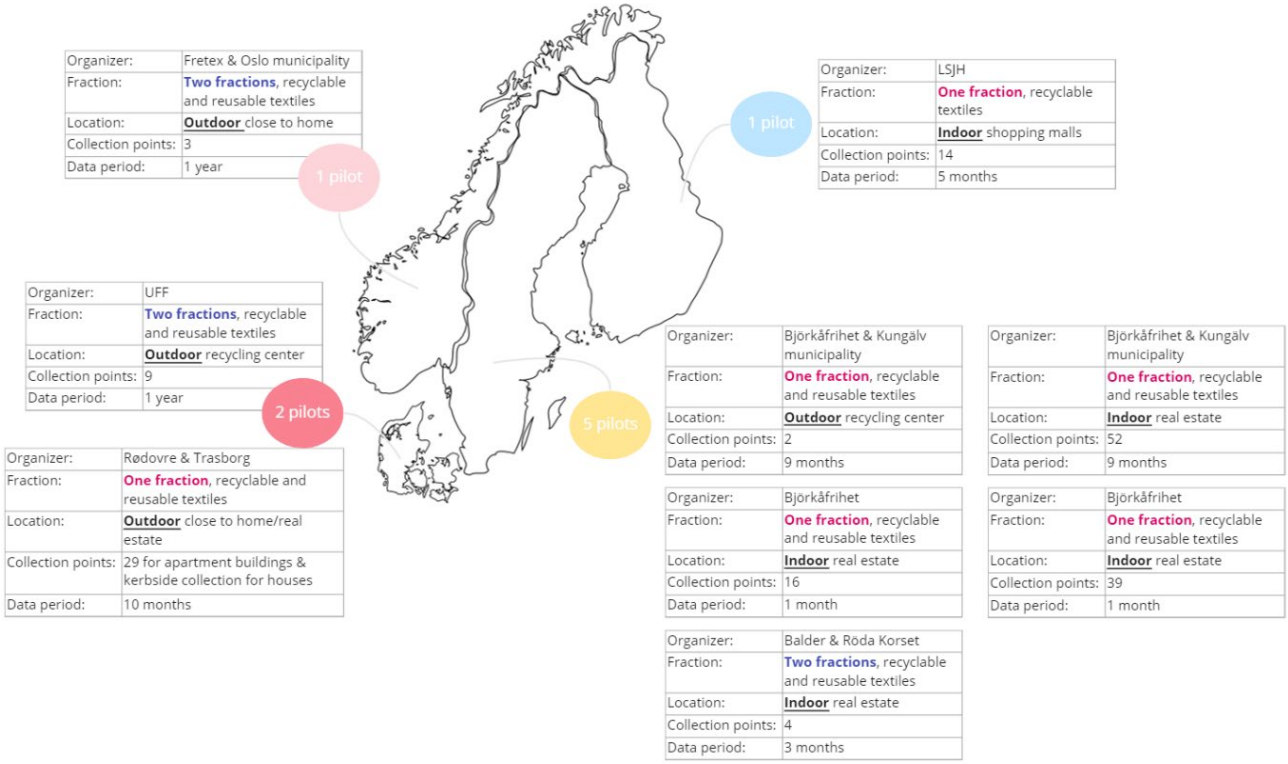


Figure 2 EOL textile collection pilot tests in the Nordics (Norway, Sweden, Denmark, and Finland).

## Detailed information of results

### Journal articles

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