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Mapping of textile flows in Denmark

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Sources must be acknowledged.

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Summary

Background and goal

Clothing and textiles is the most impacting European consumption area after mobility, food and housing. Exploiting the value of textile products and the material resources that they contain through increased reuse and recycling, is a key means for reducing these impacts. Recent proposals for changing Article 11 of the Waste Framework Directive will require Member States to adopt separate collection systems for used textiles by 1st January 2025.

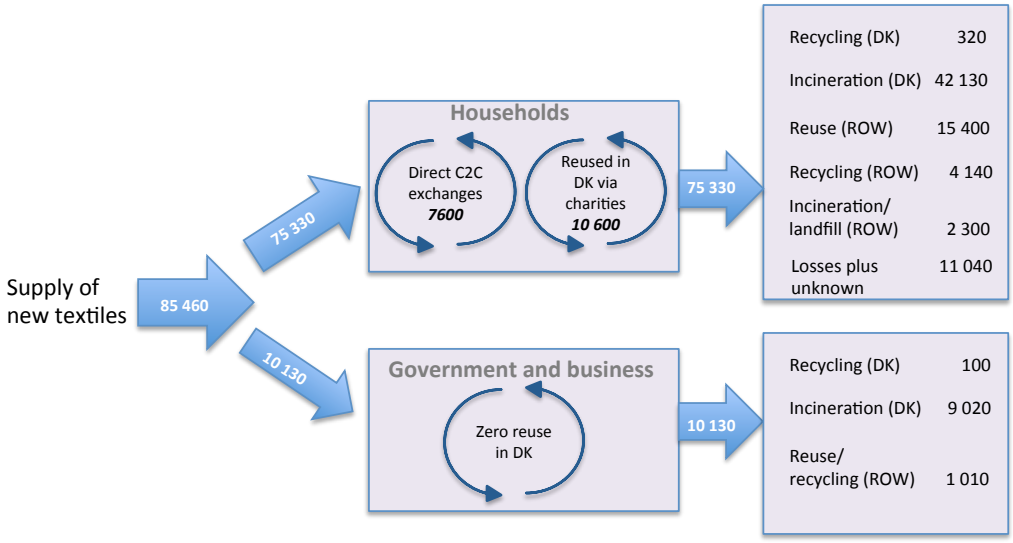
The goal of this project was to gain an updated and detailed overview of the flows of new and used textiles in Denmark as the basis for a possible review of current systems and regulations with the aim of increasing collection, reuse and recycling rates. The study encompassed clothing and home textiles (bed linen, towels, tablecloths, dishcloths, curtains etc.) purchased by households and similar textiles used by businesses and government.

Methodology

We used import, export and domestic production to calculate the total supply of new clothing and home textiles to Denmark in 2016 in tonnes. This supply was split between households and government and business sectors using Physical Supply and Use Tables (PSUT). In PSUT's the monetary purchases of different textile products given by national accounts are used to estimate the quantities of textiles consumed by each sector in tonnes.

Flows and final fate of used textiles discarded by households and by government and business sectors were estimated using a mixture of waste statistics, other statistics held by Statistics Denmark, existing studies supplemented by primary data gathered through surveys of a range of relevant actors. Surveyed groups included charities and other collectors of used textiles, municipal and private waste companies, the five Danish regions and the hospitals that they run, textile leasing companies, consumer-to-consumer (C2C) exchange platforms, hotel and restaurant chains, cleaning service companies and municipal departments responsible for nursing homes, day care and other children's institutions.

Simplified overview of flows of new and used textile in Denmark



Finally, we carried out detailed sorting and quality evaluation of 235 kg of textiles found in residual mixed waste collected from households in seven municipalities across four of

Denmark's regions. This allowed us to estimate the lost economic value of textiles discarded in mixed household waste streams

The supply of new textiles
Consumption of textiles by Denmark as a whole has remained stable since at least 2010. Overall consumption in 2016 was 85 000 tonnes; 75 000 tonnes to households, 5 000 to private businesses and 5 000 to government/municipal run organisations. Household consumption of textiles amounts to an average of 13.2 kg/person. Total consumption of textiles by all sectors comprises 15 kg/capita.

83% of textiles supplied to households comprise clothing with the remaining 17% being home textiles. 58% of business/government consumption comprises work wear with the remaining 42% comprising bed linen, towels, curtains and other non-apparel textiles.

Reuse and recycling of textiles from private households
Collection, reuse and recycling systems for the 75.330 tonnes of textiles purchased by households are relatively well-functioning. Between a fifth and a quarter of clothing and home textiles that are no longer wished for by the original owner, are re-circulated back to new users within Denmark. An estimated 7 600 tonnes of textiles are exchanged consumer-to-consumer (C2C) either between family and friends or with strangers via exchange platforms. A further 10 600 tonnes is collected from households by charities and other collectors and recirculated back to Danes via second-hand shops for reuse. The 10 600 tonnes are part of an estimated 36 000 tonnes of used textiles collected from households in 2016. Collection remains dominated by the traditional collectors of used textiles. Municipal waste companies have begun to enter the arena in recent years.

Of these 36 000 tonnes of separately collected textiles, 21 800 tonnes are exported for reuse and recycling elsewhere. Approximately 70% (15 400 tonnes) of the exports are reused and 19% (4 140 tonnes) are recycled somewhere in the world. The remainder is landfilled or incinerated in the sorting country.

The lost value of incinerated textiles
Despite relatively high collection rates compared to other Nordic countries, an estimated 54% (39 900 tonnes) of textiles supplied to households end in mixed waste streams and are, for the most part, incinerated. An additional 2 230 tonnes of waste textiles are judged to have no value and are sent for incineration by textile collectors. This gives a total of 42 130 tonnes of textiles incinerated each year.

An analysis of textiles separated from mixed household waste collected in seven municipalities estimated that 23% would have been reusable and 26% recyclable under existing markets prior to being discarded in mixed waste, with a further 37% being potentially recyclable under future markets. The reusable share is lower than found by other studies. The total lost value of clothing and household textiles incinerated each year in Denmark is estimated to be at least 12-15 million Euro a year at current market prices.

The quality, and thus the value, of textiles discarded in residual household waste (mean value of 36 Eurocent/kg) is much lower than the quality and value of separate collected textiles (mean value of 180 Eurocent/kg). Thus householders are making fairly reasonable decisions in terms of what they think has a value and should be donated/sold for reuse, and what they consider to be waste. Nevertheless, this loss of value and resources should be avoided.

Challenges in increasing separate collection from households
Gaining this lost value by diverting textiles from incineration towards reuse and recycling can either be achieved through increasing separation at source i.e. in households or by separating

textiles from mixed waste during processing. For the 20 000 tonnes of textiles in mixed residual household waste, the latter approach is not viable since textiles are contaminated by kitchen and other wet waste. For these textiles the focus must be on increasing the separate collection of textiles.

New collection and communication methods may be needed to increase separate collection rates. Door-to-door collection of textiles is being piloted by a handful of municipal waste companies. This increases convenience for citizens but has a higher cost than collection via containers on streets and in recycling centres. This, and the low value of non-reusable textiles challenge the economics of significantly increasing collection rates of household textiles.

Prices for recyclable textiles are currently at rock-bottom and prices for lower quality reusable textiles are also falling as global markets become saturated. Textile-to-textile recycling may be most important future opportunity for non-reusable textiles, both economically and environmentally, but this is some way off from being mainstreamed due to technical and product design challenges.

Until then, economic support may be needed to divert low quality textiles from mixed waste streams. In France, Flanders and the Netherland producers, regions and/or municipalities support is provided through wage supplements for disadvantaged groups in the collection, sorting and resale of textiles.

Separating textiles from bulky waste
Bulky waste, on the other hand, may present an opportunity for diverting a significant share of textiles from incineration during the waste processing stage. Several thousand tonnes of textiles are estimated to be discarded in bulky waste each year, and the majority is incinerated. However, approximately two thirds of textiles in bulky waste have been discarded in clear plastic bags. This protects them from contamination and allows easy identification and separation. Where bulky waste is sorted in a municipal recycling centre or another sorting centre prior to waste treatment, this presents an opportunity to separate textiles and place these in textile containers. A few municipal waste companies already do this but more could implement such a practice relatively easily. There are economic interests in this since the per kg value of textiles discarded in bulky waste is likely to be of higher quality than that in residual household waste. We recommend a study of the quality of textiles in bulky waste.

Low reuse and recycling rates in non-household sectors
In sharp contrast to households only an estimated 10% of the approximately 10 000 textiles purchased each year by business and the public sector is reused or recycled following discarding by the first user. There are a number of potential explanations.

Firstly, textiles discarded by business and public organisations have lower potential for reuse. There is a higher share of linen, towels and other non-clothing textiles (42% compared to 17% for households) for which there tends to be lower demand on global markets. Moreover, clothing often comprises work wear and uniforms for which there again is limited demand. Secondly, not all organisations wish for their textiles to be reused, even if a reuse market could be found due to perceived risks of misuse of a logo. The military and police have a strong policy of destruction of their discarded uniforms for this reason.

Thirdly, while many large organisations have centralised procurement for textiles, individual departments and branches are responsible for discarding their own textiles. Central administrations tend not to have policy nor issue guidance on what should be done with used textiles. Finally private waste companies report that they do not separately collect textile waste from their clients.

How to increase collection in the private/public sector
Reducing the quantity of work wear, bed linen and other textiles disposed of in mixed waste by the business and the public sector can be assisted if central administrations develop policy/guidelines on how to discard textiles more sustainably and develop logistics systems to gather textiles from departments around the country. Textile service companies/laundries presents an opportunity for increased reuse and recycling of textiles from a range of sectors due to the built in central logistics that they provide. Especially larger organisations in each sector lease rather than own their textiles.

The two largest textile service companies had limited information and no central policy on how their local departments deal with discarded textiles. However, the Industry Association for Laundries and Textile Leasing (BVT) is encouraging increased collection and recycling in the branch. Regions and municipalities can further encourage the sector by using clauses in service contracts with textile service companies to require that they collect, reuse or recycle textiles provided under the contracts.

We also found examples of regions and municipalities that are actively engaged in reuse/recycling of their own textiles. An organisation within Region Central Denmark, for example, is responsible for finding a second life for much of the region's discarded equipment including healthcare textiles.

Improving data availability
There is a gap of 10 150 tonnes in our mapping of textiles (1.8 kg per capita). Part of this may be represented by increased storage of textiles in households. However, most of the gap is likely to result from uncertainties in our data. If Denmark wishes to monitor the status of circular economy for textiles in the future then there is a need to improve data availability.

Data availability could be improved through:

- ***Requirement of codes of conduct for textile collectors*** including weighing and reporting on all flows of textiles. It would be a bureaucratic burden for them to weigh and report quantities delivered and resold in shops, but would fill a significant data gap and increase the transparency of the sector.
- ***Regular surveys of citizen behaviour*** similar to UK WRAP's 2016 survey of 1000 Danes under the European Clothing Action Plan. This would provide improved information on C2C exchanges and attitudes and hindrances to delivery of used textiles and purchase of second hand textiles
- ***Systemised picking analyses*** of bulky waste, small combustibles and mixed household waste to ensure compatible, reliable and regular data availability on quantities, and possibly also quality, of textiles in mixed waste. If evaluation of the quality of textiles in these waste streams was included in regular picking analyses this would require significantly greater allocation of resources.
- ***More systematic registration of bulky waste collection*** by municipalities and municipal waste companies in the national waste registration system (ADS). Current registration is variable in terms of at what point in the system the waste is weighed and registered, and where it is recorded in ADS.
- ***Requirements for registration of separate textile collection*** by municipal and private waste companies

1 Background

The consumption of textiles has been shown by various studies to be the most impacting European consumption area after mobility, food and housing (EEA, 2013; JRC, 2014; Tukker et al 2006 etc.). Over the past 5 years, reducing the environmental impacts of textile production and consumption has risen up the agenda both for government and the textile industry itself.

There is a wide range of measures for reducing these environmental impacts. One area of focus has been in exploiting the value of textile products and the material resources that they contain as far as possible. This can be achieved through extending active lifetimes of textile products (in part via reuse), and through material recycling once the product is no longer fit for use.

The Nordic Council of Ministers has put particular focus on this first under the Green Growth Initiative and subsequently under the Nordic action plan *Well-Dressed in a Clean Environment.* The latter has been implemented under the direction of the Danish EPA.

Increasing reuse and recycling of textiles can be viewed in the larger political context of the circular economy. The EU's Circular Economy Package called for amendments to the EU's waste legislation to increase circularity in a number of streams including. Accordingly, proposals for changes to Article 11 of the Waste Framework Directive, among other things require Member States to adopt separate collection systems for used textiles by 1st January 2025.

It is, therefore, relevant to gain an updated overview of the flows of new and used textiles in Denmark under current conditions. This will provide a basis for designing the implementation of this new requirement.

Danish flows of new and used clothing and home textiles in Denmark have been mapped out before. Tojo et al (2012) carried out a mapping using a methodology adapted from Carlsson et al (2011). The data year was 2010. Watson et al. (2014) updated this mapping with recalibrated import and export data from Statistics Denmark and updated information from stakeholders including charities, for the same data year.

More recently, Watson et al (2016) carried out a detailed mapping of the exports of used textiles from Denmark by processing UN import/export data for Denmark and receiving countries for the period 2000-2014. This was supplemented by interviews with the largest Danish exporters and their buyers.

Finally, Schmidt *et al* (2016)[1] gathered and processed Danish import, export and production data from years 2013 and 2014 for 438 different product categories (as classified under the 8-digit Combined Nomenclature codes[2]) of clothing and home textiles, as part of a Life Cycle Assessment of the treatment of used textiles in Denmark. Using this data, calculations were made of the supply of each of these products to Denmark in tonnes.

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[1] See Appendix A in Schmidt et al (2016)

[2] The Combined Nomenclature (CN) is a tool for classifying goods set up to meet the requirements both of the Common Customs Tariff and of the EU's external trade statistics. See https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/what-is-common-customs-tariff/combined-nomenclature_en At the detailed 8-digit CN product disaggregation level, it was possible to differentiate each product by fibre type i.e. cotton, synthetics, wool etc. which was important for the LCA calculations.

The studies found that approximately 89 000 tonnes of textiles were supplied to Denmark (in 2010). Approximately 39 000 tonnes of post-consumer textiles[3] were collected by charities and some private operators. At least 31 000 tonnes were estimated to be discarded in mixed household waste streams bound for incineration with energy recovery (Tojo et al 2012).

Approximately 55% of textiles separately collected from households by charities and private collectors are exported (Watson et al 2014). Across the Nordic countries as a whole, approximately 75% of exported textiles are entirely unsorted (so-called 'original'). Most of the remaining 25% of exports comprises partially sorted textiles where premium quality garments have been removed for sale in Denmark. Unsorted and partially-sorted textiles exports are sent for detailed sorting in facilities in the Baltic countries and Eastern Europe (Watson et al 2016) prior to being sold on global markets.

These mapping studies did not differentiate between different consumers of textiles. Flows of new textiles were calculated for Denmark as a whole irrespective of whether the purchaser was a private household, public organisation or business. Moreover, most focus with respect to mapping the fate of post-consumer textiles was placed on households as the dominant consumer. Since the collection of waste from the public sector and larger businesses is carried out separately to household waste collection, it is worth gathering information on these flows as a precursor to a review of these systems.

Moreover, the earlier mapping exercises experienced large gaps in knowledge on the fate of used textiles that *aren't* collected separately by charities and other operators. Estimates of used textiles discarded in mixed waste had to be made using very limited household waste picking studies available at the time. Mass-balance calculations based on these estimates left approximately 20 000 tonnes a year, or 23% of the total, unaccounted for. It wasn't possible to determine whether the 'missing' textiles were found in growing household storage, or whether amounts of textiles in mixed household waste streams were significantly underestimated.

A national scale picking analysis of mixed household waste was initiated in the summer of 2017 with textiles as one of fractions being sorted out and weighed. This offers opportunities for an up-to-date and more accurate mapping of flows of textiles in Denmark. It also offers the opportunity to analyse the degree to which the textiles in mixed waste for incineration would otherwise have been suitable for reuse or recycling, and the potential economic value of these textiles. This has also been a knowledge gap in Danish used textiles.

[3] this figure includes shoes and bags

2 Project objectives and outputs

The objective of this project is to increase knowledge about the flows of new and used textiles in Denmark in preparation for a possible review of current systems and regulations. It will also provide the basis for the development of policy for increasing collection, reuse and recycling rates of textiles in Denmark.

This report is the key output of the project in which we provide:

- An overview of the yearly supply of new textiles (in tonnes) to households, the public sector and private business (for own use)
- Estimates of yearly flows of textiles from households, the public sector and private businesses via various collection routes and estimates of the percentages that are 1) reused 2) recycled 3) incinerated/landfilled in Denmark or elsewhere
- Estimates of the quantities of used textiles in mixed waste streams destined for incineration that could otherwise have been reused or recycled and the economic value lost annually
- Policy-relevant interpretation of the results

3 Method for data collection and analysis

The methodology has taken its starting point in Tojo et al (2012) as adapted from Carlsson et al (2011). We have adapted it further to take account of splitting of textiles between households, public and private sectors.

3.1 General principles

3.1.1 Scope – product types and categories

In line with Tojo et al (2012) and Carlsson et al (2011) and following discussions with the Danish EPA, we focus on clothing, home textiles and similar textiles for use in the public and business sector. We exclude carpets, upholstery on furniture, duvets and pillows, shoes and other textiles whose weight represents a minority of the product's weight.

More specifically, for new textiles we will consider all products that have Common Nomenclature[4] CN 2-digit codes 61 and 62 and a selection of the products that have CN 2-digit code 63. This comprises a total of 438 different product categories under the CN 8-digit categorisation and 39 different product types at the more aggregated level CN 4-digit level.

For accurate calculations of the consumption of new textiles we have used the 8-digit CN product groups (for import, export and production data) or 4-digit CN product groups (for PSUT calculations). For *presentation* purposes, however, we use a more simplified aggregation of 18 groups of products. For an overview of these groups and their relationship to CN codes, see Appendix A.

It should be noted that our scope for textiles covered in this mapping does not necessarily reflect the scope used in other contexts. For example, picking analyses of mixed waste streams use a range of fairly loosely defined groupings. Some only include clothing but this also includes non-textile clothing such as leather jackets. Others include clothes and shoes, and still others also cover household textiles which often also include duvets and pillows. Moreover, used textile collectors almost always include shoes, bags and non-textile clothing such as leather jackets in reported weights of collected and exported textiles. We have taken care in this report to remove these from the overall figures (see under relevant methodology sections).

3.1.2 General approach to data collection

Similarly to Tojo et al (2012) and the subsequent studies, we have used a combination of data sources for the various elements of the flows. Where statistical data is available from Statistics Denmark (DST) we have made use of this. DST's inclusion as subcontractor in this project has ensured that we have the best access to additional data. This has facilitated an update and improvement of the so-called Physical Supply and Use tables from DST that include detailed information on the use of textiles in Denmark (see more under 3.3.1).

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[4] For a description see https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/what-is-common-customs-tariff/combined-nomenclature_en and for a full list of 2-digit, 4-digit and 8-digit CN codes see http://www.cnwebb.scb.se/?languageId=GB

Where DST does not have data we have made use of other data from Danish studies or, if not available, from countries with similar conditions.

We have supplemented, verified or updated data found in these studies via primary data gathering exercises. This has mostly comprised questionnaires supplemented by interviews with sample organisations and, where available, branch organisations. All questionnaires and interviews were carried out in Danish.

A general principle of our approach is that most effort has been made in data collection and mapping of flows where expected magnitude of flows are greatest.

3.1.3 Data Year

One of the key data sources will be data gathered from a national coverage picking study of mixed household waste available for a single year (2017). Since we have a single point for this data our map of flows is presented as a snapshot rather than attempting to present trends from year to year. For each data flow we have used the latest available year. This is 2016 for textiles imports, exports and production data. Interviews with collectors and businesses and other organisations have (mostly) provided 2016 data. Supply and Use data, which allow splitting of consumption by industry (see under 3.2), had latest data availability for 2009 but has been updated to 2016 using national accounts and new import, export and production data.

3.1.4 Units

All flows have been primarily presented in physical units (weight in tonnes) rather than economic value. Where physical data is not available (e.g. Danish textile production data is only available in DKK and in pieces or square metres but not tonnes) this has been converted to tonnes using appropriate methodologies.

3.2 Stage 1: Calculations of total supply of textiles to Denmark

Here we describe our calculations of the total consumption of textiles in Denmark each year. This will then feed into calculations of how this total consumption is divided between sectors.

The consumption of clothing and home textiles can be assumed to be equivalent to supply, and supply is guided by the simple equation:

Supply = Domestic production + Import – Export *(1)*

See Figure 3.1 for a visual representation of the supply of textiles.

Annual supply can be calculated for any product for which there is compatible import, export and production data. Import and export data[5] is provided by DST in both kg and kroner. Domestic production data[6] is available for the same product type but is not available in kg. Rather it is found in physical units such as pieces or square metres along with economic value in Danish kroner.

To convert production quantities into kg we have multiplied the value of production by a *kg per kroner* conversion factor that we have derived from the export data. We calculated these conversion factors at the CN 8-digit level to which is the most disaggregated data available to

[5] Dataset KN8Y found in Statistics Denmark's statistics bank: https://www.statistikbanken.dk/KN8Y

[6] Dataset VARER1 Statistics Denmark's statistics bank: https://www.statistikbanken.dk/VARER1

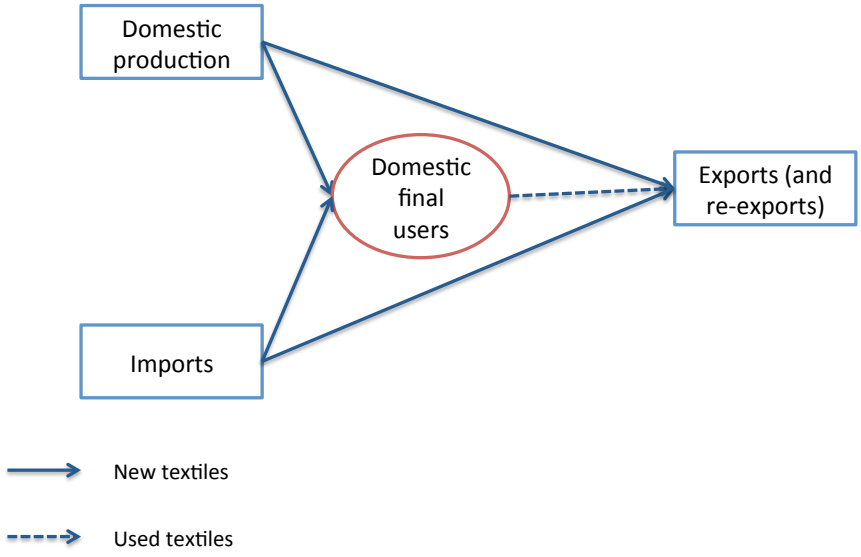
reduce uncertainty as far as possible. At this disaggregation level there are 438 different final product categories of garments and home textiles, split by product type and fibre type.

The kg/kroner conversion factors were subsequently quality controlled and adjusted by Statistics Denmark as appropriate. Adjustment was carried out in particular where exports exceeded imports plus production.

Finally, adjustments were also made to import volumes for certain products following the PSUT quality control under Stage 2 (see below).

In addition to making the calculations for new textiles, we also calculate net imports of used textiles and rags using data that are included for import/export tables for Denmark under CN codes *6309* and *6310.* There is a net export of used clothing from Denmark.

Figure 3.1: Textiles supply to Denmark (all final users)



We present the following results later in this report for the year 2016:

- Total consumption (supply) of new textiles in Denmark by all sectors and breakdown by product type
- Per capita consumption of new textiles by all sectors
- Per capita consumption of new textiles by households

3.3 Stage 2: Calculations of Overall Split in Consumption by Sector

This describes the use of Supply and Use tables to split the total consumption of textiles as calculated above, between individual sectors and identify the key sectors to focus on in further data gathering.

3.3.1 Use of Physical Supply and Use Tables

Supply of textiles to individual sectors/industries cannot be gained directly from import, export and domestic production data. This data breaks down import and export and production by product at a very detailed level, but not by the purchaser. Calculations can be made of the supply of work wear to the Danish economy as distinguished from ordinary clothing for private use using products with SIC code 1412 in European PRODCOM database as was carried out by Bartlett et al (2012) for WRAP in the UK. However, the same ‘work’ versus ‘home’

distinctions are not made for textiles such as bed linen, towels, curtains etc. which we are also interested in in this project. Moreover, Bartlett et al (2012)'s method does not allow the consumption of individual economic sectors to be calculated.

Estimates of the split between various sectors, i.e. industries, households, etc., is made, however, in the so-called Physical Supply and Use Tables (PSUT). See Box 1 for a description.

The environmental accounts department of Statistics Denmark (DST) has earlier developed PSUTs for Denmark with a breakdown of approximately 2 000 products and 117 industries plus categories of private and public consumption etc. With respect to our interest area, these give the supply and use of 39 different categories of clothing and home textiles by 117 different industries plus households.

The 117 industries correspond to the classification used in the national accounts and include a mix of private businesses and public administration grouped by function. Sectors of interest in terms of consumption of textiles include; *laundries, hospitals, nursing homes/ home help, children's institutions, hotels and restaurants.*

The latest PSUT developed by DST included data for the reference year 2009. As part of this project DST updated this with the economic flows from the latest national accounts and with physical flows consistent with the latest import, export and production data from 2016 for the 39 textile products.

Box 1: Physical Supply and Use Tables

PSUTs are comprehensive and consolidated tables that describe, on one side, the domestic production and imports of products, and on the other side, the use of the same products by industries and house-holds. They also include inventory changes and ex-ports. All information is provided by weight.

The physical supply and use tables are based on the same information on imports, exports and domestic production as described under the methodology for Stage 1, but build also on specific quantitative infor-mation from industries and on a conversion of mone-tary flows in national accounts to physical flows of various kinds to, and from, sectors.

Although the PSUTs reflect uncertainties and missing information in the underlying data, the PSUT ap-proach ensures that all data included is consistent.

Complete and comprehensive PSUTS include flows of all types of products whether they are based on fossil energy, biomass, or metallic or non-metallic minerals. minerals, biomass, etc.

For more information see section 6.5 in Statistics Denmark (2017)

3.3.2 Cleaning up errors

Statistics Denmark and PlanMiljø subsequently checked and cleaned the 2016 PSUT for textiles for apparent errors in the split of total consumption of clothing and home textiles between private households, the public sector and private businesses.

One 'clean-up' process was to remove *intermediate use* flows that were disguised as *final use*. An example would be a Danish company that purchases t-shirts for printing and then subsequently sell to final users. Because the t-shirts are a finished product this purchase might

appear as final use in the PSUT even though it is in fact intermediate use and the final users would be households or the re-export market.

It is often difficult to determine when a purchase is for intermediate use and not final use. What sprang out clearly, however, was the textile and clothing industries' apparent own final use of textile and clothing products was far too high (just under 1300 tonnes) to be explained by purchase of uniforms for staff. The product types they were purchasing also didn't fit with final use; for example it seemed unlikely that the clothing industry would purchase 54 tons of baby clothing for own use.

We decided to assume that all 1 300 tonnes of use by these two industries was intermediate use and not final use and removed them from the PSUT. This also meant removing the same flows from the total supply of textiles to Denmark calculated under 3.2 above since these must in fact be represent imports and/or production of intermediate products and not final use products.

A second apparent error was identified in the final use of textiles by the cleaning service company sector (SIC code 810000). According to the PSUT estimates this sector used 7 400 tonnes of textiles in 2016, whereas reports from interviewed larger companies working in this sector indicated a yearly consumption by the whole sector of between 200 and 400 tonnes. No immediate cause of this discrepancy could be identified in the PSUT calculations. We decided to redistribute the large majority of this sector's final use at the 39-product group disaggregation level to households and other sectors, in proportion to their prior estimated use of these products.

It should be noted that the PSUT are derived by using non-exhaustive data in combination with a number of assumptions and are therefore associated with some uncertainty.

The full methodology for the PSUT work is included in Appendix B.

3.4 Stage 3: Mapping flows of used textiles from households

Here we describe the methodology for mapping out the various flows of used textiles from households, and estimate the share that is reused, recycled and incinerated/landfilled. The flows are checked for internal consistency and inconsistencies interpreted with respect to uncertainties and assumptions.

This task takes its starting point in the data-gathering methods used by Tojo et al (2012) to map out flows of used textiles from households in Denmark, using secondary data where available and gathering primary data where necessary.

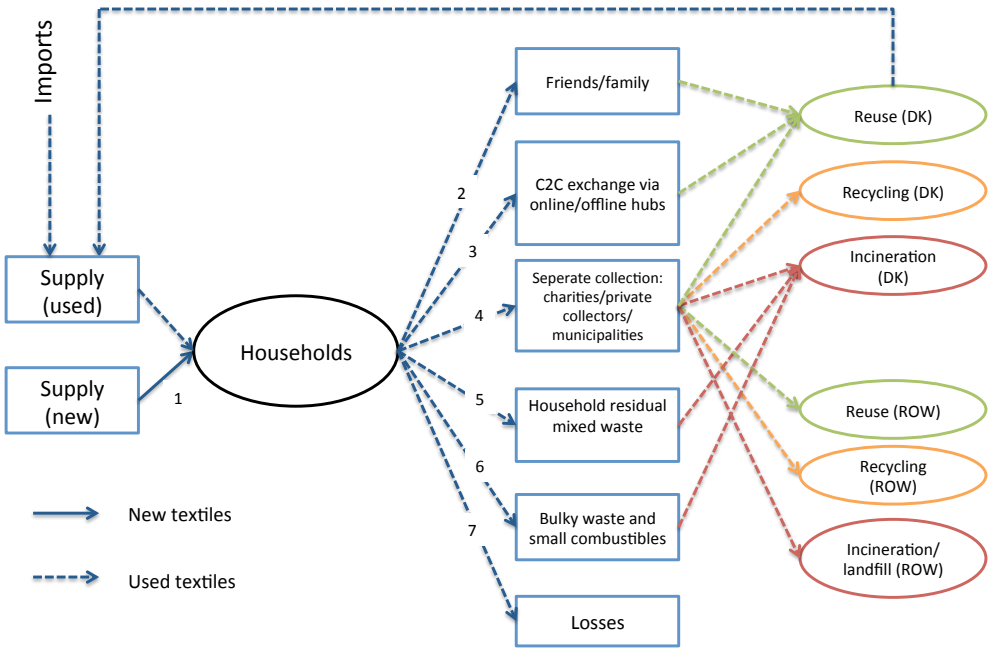
Figure 3.2 gives an overview of flows of textiles to and from private households. The task is essentially to populate this with estimates for the quantities of each flow. A further sub-task will be to check the estimated flows for internal consistency using a mass balance approach[7].

The consumption of new textiles (Flow 1) is calculated under the previous two stages of the methodology. Methods for estimating flows of used textiles 2-7 and the fate of these with

[7] One important thing to note in this context is that while recycling and incineration/landfill are endpoints since they represent a transformation of textile products to something else, reuse is not. Reuse is effectively a continuation of the product in its original form and function. Some of these reuse exchanges can be visible and others invisible without affecting the maps internal consistency provided that the reuse stays within Denmark.

respect to reuse, recycling and incineration are described here. This is split into a number of stages below.

Figure 3.2: Overview of flows of textiles to and from private households



Note: ROW means Rest of World

3.4.1 Stage 3A: Estimating C2C exchanges

In this stage we map Flows 2 and 3 in Figure 3.2.

These flows represent exchanges of used textiles between consumers, both non-economic direct exchanges between friends and family, and exchanges taking place via online and offline platforms such as social media, business exchange platforms, flea-markets and swap markets.

Flow 2 textiles passed on to friends and family. This represents an informal flow of used textiles for which there is no means for recording data directly since there are no formal transactions. The only means for estimating this is via interviews with households. A study of 1000 Danes carried out under the European Clothing Action Plan provided some information on the prevalence of exchanges. We also made use of studies from the UK[8] from which we could tentatively make assumptions for Denmark.

The results are considered uncertain due to the lack of concrete data.

Flow 3 C2C exchanges of textiles via online and offline hubs. This can be via physical flea markets and swap markets and sales via online sites such as Den Blå Avis, Trendsales, Tradono, ReShopper etc.. This represents a more formal flow of textiles than Flow 2, involving money transactions and/or hubs and can be effectively influenced by policy such as measures to encourage online sharing hubs, swap markets etc.

Only rough estimates can be made for these exchanges. There is no data available for flea markets and little possibility of gathering any due to the fact that these are unregulated.

[8] Bartlett et al (2013)

Exchanges of used goods tend to be weighed and recorded at swap markets and we obtain this data via contact with the NGO *Byttemarked.dk*.

We also contacted a number of exchange sites to identify numbers of transactions a year concerning clothing and household textiles, and made an estimate based on this on the quantities of textiles that had been exchanged via these sites using an average factor quoted in Watson et al (2014) of 400g per transaction (and 70g for baby/children's clothing for exchanges on baby focused sites).

Finally, we looked at trends of C2C exchanges from Sweden and the UK where studies have been carried out.

3.4.1 Stage 3B: Mapping flows of separately collected textiles

In this stage we map Flow 4 in Figure 3.2. This is the most important flows of used textiles from private households and needs to be mapped in detail.

Charities and private collectors collect via containers and over the counter in their own shops for those that have them. Containers can be placed in recycling centres or on publically owned land (in both cases under agreement with the municipality) or on privately owned land/buildings e.g. owned by supermarkets or other retailers.

Not so long ago almost all containers in recycling centres were owned and run by one of the traditional collectors. In recent years, however, waste companies/municipalities have been setting up their own textile containers and selling some of the best quality textiles in their own shops, before selling/donating the remainder to the traditional collectors or selling on global markets (Watson et al, 2018). This additional flow of sales by waste companies needs to be estimated.

Separate collection from households by charities and private collectors
For mapping collection by these actors we took as a starting point the flows reported in Tojo et al (2012) updated by Watson et al (2014), and the data gathered by Watson et al (2016) via interviews with the largest collectors. We then carried out a survey of the most important (in volume terms) organisations collecting via containers and/or shops.

The key organisations were identified in Watson et al (2014) as; *Trasborg, Røde Kors, Frelsens Hær, UFF, Kirkens Korshær, Folkekirkens Nødhjælp*. To this we added *Dan Mission, Blå Kors, Mission Afrika* og *Den Permanente Tøjindsamling*. Together these organisations are estimated to represent 85 % of all second-hand shops where clothing may be delivered, and over 90 % of containers. We also gained data from *H&M* on their collection in shops in partnership with the international used textile collector and processor I:Collect.

The surveys were carried out via a questionnaire, followed up by telephone or email questions as necessary. The survey included questions on the quantities they collect annually from households, private companies and public organisations including municipally-owned waste companies. They were also asked to estimate the share of these volumes that aren't products included in our scope (see under 3.1.1) but are delivered to them via their containers e.g. toys, shoes, bags, duvets, pillows etc. We needed these estimates to remove these volumes from the totals.

Finally, there were asked questions on the subsequent flows of the textiles they collect: the share sold for reuse and recycling in Denmark, the share exported either sorted or as original (unsorted) and finally the share sent for incineration.

We have used Watson et al (2016)'s mapping of exports of used textiles from Nordic countries to estimate the shares of Danish exports that are reused, recycling and undergone other waste treatment (incineration and landfill) in other countries.

We estimated the flows of textiles collected by the remaining smaller organisations and individual shops using the same method as used by Watson et al (2014).

Separate collection from households by municipally-owned waste companies
Unlike in some other European countries, textiles delivered to recycling centres aren't registered in the national waste registration system (ADS). We carried out a survey of municipal waste companies to gain a picture of the volumes of textiles that they separately collect in recycling centres and via door-to-door collections. In the survey we also asked questions concerning textiles in household mixed waste flows (Flows 5 and 6 - see below).

In partnership with Dansk Affaldsforening (DAF) we sent out a questionnaire to 32 municipal-owned waste companies. We asked the following questions concerning separate collection:

1. Do you have your own (i.e. not owned or run by a charity or another collector) separate textile collection via containers or door-to-door?
2. (If so) what quantities of textiles did you collect in 2016?
3. How much of this did you sell in your own shops?
4. What did you do with the remainder?

The amounts sold onwards to the traditional collectors had already been established via interviews with collectors. We took care not to double count these.

We extrapolated the results to Denmark as a whole using a simple population-scaling method.

3.4.1 Stage 3C: Mapping textile flows in bulky waste, small combustibles and household mixed waste

In this stage we map out Flow 5 and 6 in 3.2.

Textiles discarded by households and not separately collected by organisations and municipal waste companies can find their way into various mixed waste streams. These can be kerbside collected residual waste (Flow 5), kerbside bulky waste collection organised by municipalities or small combustible waste delivered directly to municipal recycling centres (combined as Flow 6).

Flow 5: textiles in household residual mixed waste

A number of datasets were available to assist in estimates of the quantities of textiles found in residual household waste:

A. The results of 8 picking tests of residual waste carried out in selected municipalities over the past 3-4 years. This was provided to us by municipal waste companies as part of the survey described under Stage 3A
B. Our own analysis of textiles separated from mixed residual waste by the consultancy Econet in seven municipalities across Denmark during the second half of 2017. See Section 3.6 for a description of this dataset and analysis
C. 17 picking tests and analyses of residual household waste in 11 municipalities in 5 regions carried out by DTU Environment and UFF-Humana in cooperation with Econet (Nørup et al, 2018a)

In total, we obtained results from picking analyses of residual waste from 8 758 households (5 479 single-family houses with gardens and 3 279 apartments in multi-family housing) and just under 20 000 inhabitants across all five Danish regions..

The picking tests presented results in the form of '*share of residual mixed waste represented by textiles',* or *'kg of textiles per household found in residual mixed waste'*. We used additional data provided in the picking analysis to translate the findings into '*kg/person of textiles in mixed waste per year'* split according to housing type.

Where data on the number of people living in the apartments/houses covered by each analysis was not made available in the picking analysis report, we used average household sizes for the municipality as a whole. Where necessary, the textiles found per person in the picking analysis were then multiplied by the number of residual waste collections per year to give us a yearly quantity. Often this scaling up had already been carried out in the original analysis.

We then averaged the results to give us average values for kg textiles per person per year for single-family houses with gardens, and for apartments in multi-family housing. Since the scope of picking analyses ranged from 100 to 2 800 households we used weighted averages. These averages were then multiplied by total numbers of each of the two broad housing types across Denmark to gain estimates for total quantities of textiles found in mixed residual household waste.

We feel that this method is more accurate and reliable than using *shares* of textiles in residual waste that are given by picking tests and multiplying by total residual waste quantities across the country as a whole. *Shares* of textiles in residual waste are highly dependent on what separate systems are in place for collecting recyclables such as metal, plastic paper, glass, kitchen waste etc. *Kg/person* of textiles in residual household waste, on the other hand, should be independent of what else is found in that waste stream.

We assume that all textiles found in residual household waste end in incineration with energy recovery. Waste companies do not sort textiles from residual mixed household waste for reuse or recycling due to contamination by kitchen waste and other wet waste.

Flow 6a: textiles in bulky waste

Municipalities and/or municipal waste companies often collect so-called bulky waste directly from households. This often comprises waste that is too large to be disposed of in ordinary mixed waste containers e.g. furniture. However, it can also include clothing and household textiles. This occurs, for example, when households are disposing of large quantities of unwanted items when moving house.

Our original plan was to estimate quantities of textiles disposed of in bulky waste using existing picking analyses, combined with registrations of bulky waste in the Danish EPA's waste database (ADS) and information on bulky waste provided by our survey of waste companies.

Ideally, the data given in ADS would provide us with total quantities of bulky waste collected from households. However, according to the Danish EPA (2017)[9] there are large differences in what happens to bulky waste once it is collected, and in how and where it is recorded in the ADS system (see Box 2). This made it impossible to assess the total quantities of bulky waste collected across Denmark through data from ADS. We were forced to use other methods.

Based on information obtained from waste companies and on Danish EPA (2017), we determined that the majority of textiles in bulky waste follow one of three routes:

1. Sorted from bulky waste in municipal recycling centres where they for the most part (see below) end in small combustibles

[9] Miljøstyrelsen, 2017, "Idekatalog om storskraldsindsamling fra husholdninger"

2. Sorted from bulky waste in other sorting facilities where they mostly end in small combustibles
3. Transported directly to incinerators for energy recovery

Some waste companies reported that if textiles found in bulky waste that were sorted at municipal recycling centres had been deposited in bags, these were subsequently placed in textile containers (either run by charities/established collectors or by the municipality). These textiles are already captured by the surveys described under Stage 3B earlier.

The determination of the quantities of textiles discarded in small combustibles in recycling centres is covered under the next section, and is independent of the route by which the textiles came into the containers. Therefore, here we only need to consider textiles in Routes 2 and 3 above.

We asked the municipal waste companies to estimate quantities of bulky waste collected in their regions that followed these two routes in 2016. We used this data to upscale to Denmark as a whole, using a simple population-scaling method. This made the assumption that the municipalities were representative in terms of approaches to bulky waste processing.

We then used data from five bulky waste picking analyses that we had access to, to determine the share of textiles in bulky waste collected from households. The final result should be treated with caution due to the small number of picking analyses.

Flow 6b: textiles in small combustibles

As described above one of the waste fractions collected at municipal recycling centres is known as *småt brændbart* or small combustibles. This fraction is primarily for combustible non-hazardous items that are not suitable for delivery to containers for recyclable fractions. It can include expanded polystyrene, bicycle tyres, small carpets, cushions and pillows, dirty paper and cardboard, rotten wood and textiles not suitable for reuse. Small combustibles are sent for incineration.

Households, but also small businesses, can deliver small combustibles under agreement with the recycling centre. In addition, as described above, in some municipalities bulky waste is driven to the recycling centres for sorting into fractions. Under these circumstances textiles would be one of the fractions that may end in small combustibles.

To estimate the quantities of textiles in small combustibles we used data provided by municipalities on total quantities of small combustibles, combined with results from 28 picking analyses on the share of textiles in small combustibles[10].

[10] We would rather have calculated *textiles per person per year* for each picking study since we would expect this to vary much less than the *share* of textiles found in small combustibles; the latter is dependent on many factors such as collection opportunities for the other waste fractions. This was not possible, however, since the picking analyses did not specify the population served by each small combustibles container or what period the sample had been collected over. The results are therefore more uncertain than the result for textiles in residual mixed waste. Fortunately, we had a wide range of picking analysis to make use of.

Box 2: Problems with bulky waste and ADS

Bulky waste can, and is, reported in many different categories in the ADS system. Categories such as, "large-scale", "flammable", etc. can be used for bulky waste. The category "Combustible waste" (code: H 27) in ADS also covers containers from recycling sites such as large and small combustibles, mixed construction waste, etc. as well as bulky waste collected directly from households.

The experience is that few collectors use "Bulky waste" (code: 03) when they report on bulky waste. Both the "Combustible waste" category and "Bulky waste" have the same EAK code: 200307, which are designated "Bulky waste". Both categories are used even if the fraction is a mixed fraction. Other fractions such as electronics are reported under separate code. This makes ADS unusable with respect to isolating bulky waste from other waste streams.

Moreover, bulky waste is not only combined with other waste streams in the ADS system, it is also in some cases physically combined with other streams. While some municipalities transport bulky waste directly to incineration, others transport it to recycling centres where it is sorted into various fractions and placed in the appropriate container. Here it is mixed with large and small combustible waste and other fractions that have been delivered directly by households. We assume that clothing and home textiles are mainly sorted into the small combustibles container.

A few municipalities send bulky waste to other types of sorting centres for the same process.

Where bulky waste is sent to recycling centres or other centres for sorting it is typically first registered after the sorting has happened i.e. as large or small combustibles and the other waste fractions it has been sorted into.

3.4.1 Stage 3D: Losses to the system

In this stage we map out Flow 7 in Figure 3.2.

Losses of textiles and textiles weight from the mass balance system described by Figure 3.2, can follow a number of different pathways: fly tipping (dumping of waste in unofficial sites); theft of donated textiles from containers and loss in weight of clothing due to lint loss in wear and laundry processes.

Fly tipping is assumed to be low in Denmark, but theft from containers can be significant. We added a question to the survey of charities and private collectors to gain their estimates on losses due to theft.

We carried out a review of the limited literature there is on lint loss, and asked the large laundry companies in Denmark whether they have figures for lint loss in their processes as this could potentially be used to estimate lint loss in households.

Finally, a further flow that can be considered as a loss from the system are textiles (dominantly clothing) that are either returned by consumers to retailers due to damage or are unsold by retailers and subsequently disposed of. Some of these are donated to charities and other collectors and were picked up by the collectors and reported on under Flow 4. However, some is incinerated or exported for recycling elsewhere. This is considered as a loss to the system. Data on this was available from two of the largest brands selling clothing in Denmark and was extrapolated to Denmark as a whole, via knowledge on the two brands' market share..

3.4.1 Stage 3D: Mass-balance consistency check and interpretation

We carried out mass-balance calculations on all estimated flows to check for internal consistency. The mass balance equation is as follows:

> Supply of new + imports of used (INPUTS) = recycling (DK) + incineration (DK) + exports of used textiles + losses (OUTPUTS)

Note that textiles collected and then reused in Denmark do not leave the system and are therefore not included in the mass-balance equation. This is an important error in other studies.

The balance between left and right in the equation will only be met if our estimates of flows are accurate AND the following assumptions hold:

1) **Consumption of new textiles remains constant** year for year. If this isn't the case then the mass balance equation for a single year won't hold since the textiles that are discarded in year 1 may have been purchased in year 1 or in year 10 or anywhere in between.
2) **Amount of textiles stored in households remains constant** year for year. If instead textiles begin to be accumulated at increasing rates this will reduce the weight of the right hand side of the balance equation

We tested the equation to see the degree to which the two sides differ from one another and interpreted this with respect to uncertainties in the individual flow calculations and in the likelihood of the assumptions being correct.

3.5 Stage 4: Mapping flows of used textiles from business and government or-ganisations

Here we describe the methodology for mapping flows of used textiles from business and government sectors, and estimate the share that is reused, recycled and incinerated/landfilled.

Figure 3.3 gives a schematic representation of flows of textiles to and from individual public and private sectors. The largest consumers are identified through analysis of the Physical Supply and Use Tables (PSUT) by Statistics Denmark (DST) described under Stage 2. Rough estimates of the magnitude of consumption of new textiles by each sector were also provided by the methodology under Stage 2.

Under Stage 4 we gathered data from selected organisations within these sectors with the aim of 1) providing additional data to support or counter estimates made for purchases of textiles by the sector as a whole and 2) to estimate the shares of used textiles from each sector that end in reuse, recycling and incineration in Denmark and elsewhere.

We set 500 tons of textile consumption per year as the cut-off threshold for sectors that we would investigate further. This gave six sectors. A specific questionnaire was developed for each sector and these sent to representative organisations, followed up in several rounds by mails and phone calls both to encourage participation and to ask further clarifying questions on received information. The approach for each sector is described in Table 3.1.

In addition we contacted organisations that receive used textiles from these sectors. This included the ***collectors of textiles*** already described under 3.4.1, two ***recycling companies*** that collect used textiles from hospitals and laundries, the four large ***private waste companies*** that are included in the branch organisation for private waste companies (ARI) and some private companies that collect textiles for recycling: Dantextil and REALLY.

Table 3.1: Organisations contacted under each sector

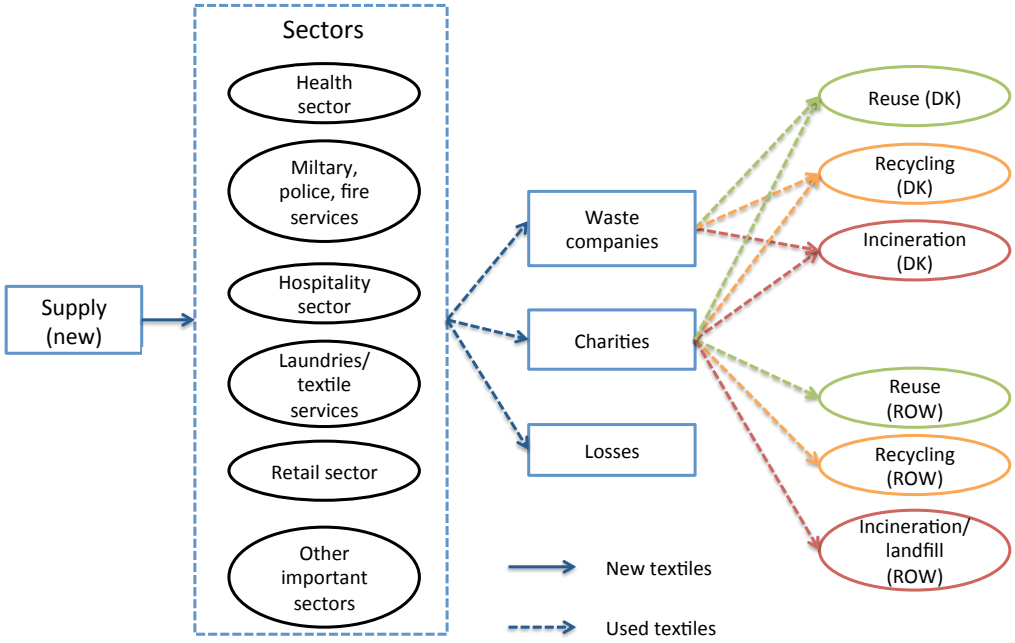
Sector	Approach
Hospitals	Denmark's five Regions are responsible for all publically-owned hospitals. Procurement of textiles and textile services are mostly carried out centrally, but disposal of used textiles is more locally determined. Surveys were sent to procurement departments in all five regions with instructions to pass on questions on disposal to other departments. Private hospitals represent less than 5% and were not contacted.
Laundries/leasing companies	Two companies run over 80% of the private textile leasing/laundry services in Denmark. Surveys were sent to these and one of the smaller companies. Publically owned laundries were also contacted via the regions as described above. A meeting was held with the laundry branch organisation BVT.
Hotels and restaurants	These are privately run. Canteens in the public sector i.e. hospitals, schools etc. are covered by other sectors. Surveys were sent to procurers/operational managers in nine hotel chains and eight chains of restaurants.
Nursing homes, home help and children's institutions	84% of children's institutions and 98% of nursing homes are operated/financed by municipalities in Denmark. Surveys were sent to the relevant departments in over 90 of Denmark's 98 municipalities. Some municipalities have collective procurement agreements.
Cleaning services	88% of cleaning services are privately owned. Surveys were sent to five private companies that represent over half of the sector.
Military, police, fire services	The national administrations of police and military were contacted directly. Fire services are administered at regional level. Three of Denmark's five Regions were contacted.

The questionnaires included the following types of questions, though these differed from sector to sector:

1. What types and quantities of textiles do you purchase for the companies own use (i.e. not for processing and selling on) each year? Do you lease textiles instead/as well?
2. Do you have estimates for annual losses of your own textiles from the organisation via theft by employees/clients (i.e. patients in hospitals)?
3. What best describes your organisation's approach to worn out/unwanted textiles?
    a. We have a collection/return system in place for these
    b. Textiles are generally discarded ad hoc in ordinary mixed waste
    c. Our workers are responsible themselves for disposing of their worn-out work wear
4. What is the organisation's strategy for collected textiles?
    a. They are donated to collectors/charities
    b. They are sold for shredding/recycling
    c. They are sent for incineration

Care was taken not to double-count textiles that have been donated to charities/other collectors if these had been included by collectors in collection *Flow 4* from households.

Figure 3.3: Overview of flows of textiles to and from private and public sectors



Note: ROW means Rest of World

3.6 Stage 5: The value of textiles in mixed waste

Here we describe the methodology for evaluating the 'pre-discard' quality and lost economic value of clothing and home textiles discarded in household mixed waste.

Hultén et al (2016) carried out an evaluation of textiles in mixed household waste in Sweden and found that 59% would otherwise have been fit for reuse. This share is likely to be lower in Denmark since separate collection rates are approximately twice as high. The share left in mixed waste is therefore likely to be of lower quality. In the UK, the share in 2008 was 43%, having steadily fallen from 59% in 2000 due to increasing separate collection rates (Morley et al, 2008).

In addition to calculating shares that are reusable and recyclable on global markets as Hulten et al and Morley et al carried out, we also estimate the lost economic value of textiles discarded in mixed waste.

We had at our disposal 235 kg of textiles that were separated from household mixed waste bins in picking studies carried out by Econet under a separate project. The waste was collected from seven municipalities, from four out of the five regions of Denmark during October 2017 to January 2018 (see Table 3.2).

Following receipt of the textiles from Econet we washed them three times to remove contamination from kitchen and other wet waste as far as possible and dried them. Textiles from multi-family housing (MFH) and from single-family housing with gardens (SFH) were gathered into two groups. Products that do not fit with clothing and household textiles included in the scope of this project were weighed and then discarded.

Table 3.2: overview of textiles made available from picking studies

Date	Municipality	Housing type	No. house-holds	No. of pe-ople	Emptying period (weeks)	Dry weight of textiles (kg)
3 Oct + 16 Jan	Horsens	MFH	210	327	1	27.0
6 Okt	Kertemind e	MFH	212	368	1	34.0
16 + 17 + 20 Nov	Guldborgs und	MFH	294	664	1	54.1
1 Nov	Rødovre	SFH	185	549	1	36.4
3 Nov	Aabenraa	SFH	199	565	2	34.0
9 Nov	Viborg	SFH	197	464	1,17	16.4
22 + 28 Nov	Odsherred	SFH	179	390	2	32.7
Total			**1476**	**3327**		**235**

The remaining textiles were then sorted by professional sorters from Danish second hand clothing collector and processor Trasborg, into various grades of textile as follows:

- Reusable
  - Shop quality (prime quality for sale in Denmark and rest of Europe)
  - Grade A (better quality for sale in Europe)
  - Grade B (lower quality for sale in Africa, Middle east, Asia)
- Recyclable
  - Industry wipes (Grade A & B cotton)
  - Wool/acrylic for unravelling (India & Pakistan)
  - Other primarily cotton textiles (for mechanical recycling)
  - Poly-cotton blends (for chemical recycling)
  - Nylon, viscose
- Waste (for incineration)

See Figure 3.4 for an overview of the sorting and weighing process.

Care was taken when sorting to make an evaluation for each item based on its assumed quality, *prior* to it being discarded in household mixed waste. The three laundry cycles carried out assisted in this, but attention was also given to other indications of soiling from mixed waste such as food stains, oil and paint stains etc. That said, it is difficult to distinguish between stains that have occurred prior to and after disposal in mixed waste.

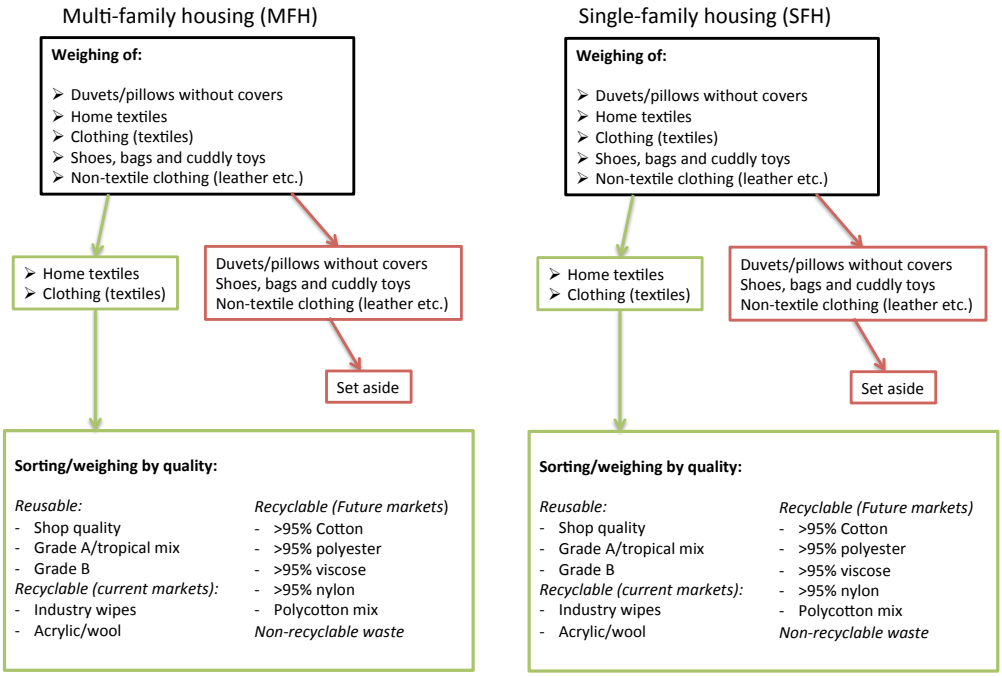
The quality grade for reusable textiles was determined according to existing markets. Recyclability was considered according to both existing and future markets. For example, used poly-cotton products that are determined not to be suitable as industry wipes, would today be discarded for incineration. However, there are a number of innovations currently under development that can chemically separate polyester (or its base materials) from cotton, making them available for recycling.

For products dominated by a single fibre type we accepted a maximum 5% mix with other types of fibres, when considering whether they are fit for future fibre-to-fibre recycling markets.

Each grade was weighed and an economic value given according to *current* global prices for the given grade. The average share of reusable and recyclable textiles in the two housing types were calculated along with the average economic value per kg and per household/year.

The data was then used to extrapolate to national level using data from Statistics Denmark on the numbers of each household type across the country as a whole. This gave estimates of total quantities of textiles discarded in mixed household waste each year and its total economic value if it had instead been donated and sold on global markets.

Figure 3.4: scheme for sorting and weighing



4 Results: Textile Flows in Denmark

4.1 Overall supply of new textiles

Table 4.1 presents the supply of textiles to Denmark in 2016. The figures in grey are less certain than those in black since the splits of total supply between households, government and industry and changes in stock have been estimated using Physical, Supply and Use Tables. The figures for total supply (first and fifth column), on the other hand, are derived directly from production, import and export data with some small adjustments as described in the methodology.

85 740 tonnes of textiles were supplied to Denmark in 2016, a 4% reduction since 2010 (see Watson et al, 2014). 77% of the supplied textiles comprise clothing with the remaining 23% being household textiles.

Of the 85 740 tons, 280 tonnes represent increases in stock held by retailers and other companies prior to sale. The remaining 85 460 tonnes represent actual consumption.

Households dominate consumption of textiles, absorbing 88% of the supply. The average Dane purchased 13.2 kg of new textiles (10.9 kg clothing and 2.3 kg home textiles) for private use.

Government and private sectors are responsible for the remaining 12% of textiles supplied to Denmark. The approximate 10 130 tonnes of textiles that are purchased each year by non-households can be split roughly half and half between public and private purchase (46% government, 54% private company). Table 4 presents the largest consumers of textiles by sector. All sectors with an annual consumption greater than 500 tonnes a year are presented.

It is important to note, that the split of clothing and household textiles consumption between sectors has been carried out using physical supply and use tables (see Box 1 earlier) that include relatively large potential sources of error. Moreover, it has not been possible to confirm consumption quantities of the sectors from surveys of companies and organisations within the majority of these sectors (see under Section 4.3 later). Thus care must be taken when making use of these figures. Table 4.2 does, however, give a good indication of the sectors where there should be focus in the future on collection, reuse and recycling.

Table 4.1: The largest sectoral consumers of new textiles and their approximate consumption both public and private (2016)

	Total supply (tonnes)	House-hold con-sumpti-on (ton-nes)	Govern-ment & industry consump-tion (ton-nes)	Chan-ges in stock (ton-nes)*	*Total supply (kg/capit a)*	*House hold con-sump-tion (kg/cap ita)*
Garments	**66 384**	**61 938**	**5 895**	**-1 454**	***11.6***	***10.9***
Overcoats, anoraks	4 357	4 107	214	34	*0.8*	*0.7*
Suits and blazers	3 038	2 808	177	53	*0.5*	*0.5*
Trousers and shorts	14 085	13 780	1 313	-1 008	*2.5*	*2.4*
Dresses and skirts	2 817	2 416	390	11	*0.5*	*0.4*
Shirts, blouses, tops	4 523	4 579	470	-526	*0.8*	*0.8*
Underwear, socks and nightclothes	6 486	6 259	218	9	*1.1*	*1.1*
T-shirts and vests	9 526	8 982	508	36	*1.7*	*1.6*
Sweaters and cardi-gans	8 548	8 283	224	39	*1.5*	*1.5*
Baby clothes	1 413	1 320	66	27	*0.2*	*0.2*
Sportswear and swimwear	5 725	4 043	1 786	-104	*1.0*	*0.7*
Garments impregna-ted with plastic	479	195	214	70	*0.1*	*0.0*
Handkerchiefs, ties, scarves, gloves and other	2 932	2 851	152	-71	*0.5*	*0.5*
Non-woven gar-ments	2 455	2 315	164	-24	*0.4*	*0.4*
Household texti-les	**19 352**	**13 387**	**4 231**	**1 733**	**3.4**	**2.3**
Blankets and rugs	1 537	1 258	98	181	*0.3*	*0.2*
Bed linen	6 440	2 622	2 877	941	*1.1*	*0.5*
Table cloths	1 000	1 003	39	-42	*0.2*	*0.2*
Towels, tea towels, cloths	4 187	4 093	104	-10	*0.7*	*0.7*
Curtains, drapes, other furnishings	6 187	4 411	1 113	663	*1.1*	*0.8*
Sum of new textiles	**85 740**	**75 330**	**10 130**	**280**	**15.0**	**13.2**

* 'Changes in stock' refers to the annual change in quantities of textiles that are stored by retailers and other companies prior to sale

Table 4.2: The largest sectoral consumers of new textiles and their approximate consumption both public and private (2016)

Sector	Clothing and workwear (tonnes)	Bedlinen, towels, cloths, curtains etc. (tonnes)	Total	*Share purchased by government as opposed to private organisations*
Households	61 940	13 390	**75 330**	**-**
Kindergartens, youth clubs and other institutions for children and day-care centres and home help services for the elderly	1 350	600	**1 950**	**84%**
Laundries, textile service companies, hairdressers	600	1 200	**1 800**	**10%**
Hospitals	450	900	**1 350**	**98%**
Defence forces, police and emergency services	850	30	**880**	**100%**
Nursing homes	520	320	**840**	**98%**
Hotels and restaurants	240	600	**840**	**0%**
Cleaning services	250	300	**550**	**11%**
Others	*1640*	*290*	***1 930***	***43%***
TOTAL	*67 840*	*17 620*	***85 460****	**-**

*Note that this total differs by 280 tonnes from the sum of new textiles in Table 4.1 since changes in stock have not been included here

4.2 Flows of used textiles from households

4.2.1 Overview

With private households consuming approximately 75 330 tonnes of new textiles each year in Denmark, it is of key interest what happens to these textiles, when the household no longer has a need for them. Are they donated, sold to another consumer, stored, collected separately by the municipality, or thrown in the dustbin and what happens to the textiles after that?

Figure 4.1 gives an overview of our best estimates for flows of textiles to and from households. The various flows are summarised in more detail in the following sections.

Both formal and informal reuse and recycling systems for textiles consumed by households seem to be functioning reasonably well. According to best estimates, between a fifth and a quarter of clothing and home textiles are re-circulated back to new users in Denmark. An estimated 7 600 tonnes of this is exchanged consumer-to-consumer (C2C) either directly or via C2C exchange platforms. Approximately 10 600 tonnes is re-circulated by charities and other collectors back to Danes for reuse. There is little recycling being carried out in Denmark; an estimated 320 tonnes.

In addition to reuse and recycling in Denmark, 21 800 tonnes is exported by collectors for reuse and recycling elsewhere. Approximately 70% (15 400 tonnes) of the exported textiles are reused somewhere in the world, and 19% are recycled (4 140 tonnes).

Box 3: Overview of uncertainty in flows

Of the flows given in Figure 5 a number are highlighted in italics to illustrate a relatively high level of uncertainty. These are as follows:

- **C2C flows** – both between friends/family and via platforms. In both cases we have relied largely on figures from other countries for these. Only a few C2C platforms in Denmark have data on transactions.
- **Textiles sold for reuse in Denmark by collectors** – collectors typical weigh exports of textiles, but often do not have an accurate picture of what they sell in shops in Denmark. Particularly, where clothing is received and then resold by the same shop.
- **Textiles in bulky waste** – this is uncertain because bulky waste in registered in many different places in the Danish waste registration system and secondly because very few picking analyses are available for bulky waste
- **Lint loss** – there are few if any useful studies in lint loss as a percentage of weight per wash or during the lifetime of a textile product
- **Theft from containers** – only one collector has attempted to quantify this and this was not carried out with scientific rigour

Other flows are less uncertain but still have issues:

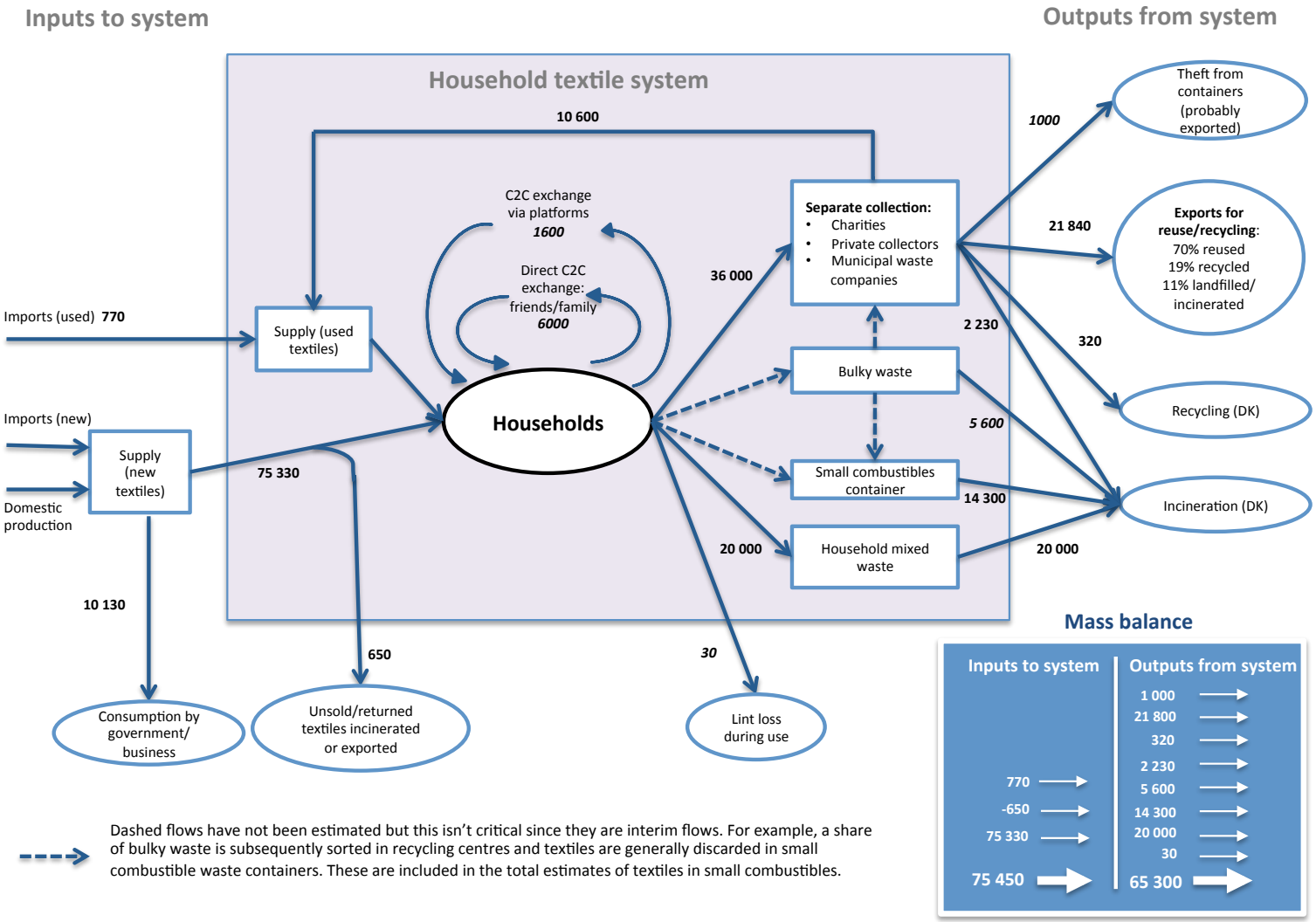
- **Textiles in mixed household waste** – we have many picking studies but the scatter in results is quite large. This is partly a result of differences in the definition of textiles and the fact that when mixed with kitchen waste textiles can become damp and much heavier
- **Textiles in small combustibles** – again we have many picking studies but the scatter is even higher than with mixed household waste. Moreover, our assumption that 100% of the textiles comes from households may be an overestimate.
- **Supply of textiles to households** - the split between supply to households and to businesses/government is based on physical supply and use tables. There are inherent uncertainties in the translation of economic flows to physical flows.

Separate collection of textiles is still largely being carried out by charities and traditional collectors, but new actors are coming on board, not least municipalities. Some of these have taken over collection of textiles in recycling centres from charities and other private collectors, and a few are engaging in kerbside collection directly from households.

Approximately 40 000 tonnes of textiles end in mixed household waste streams for incineration compared to 36 000 tonnes separately collected (this latter includes an estimated 1 000 tonnes that is stolen from containers). The lost value of these incinerated textiles is estimated later in this report.

There remain 10 150 tonnes of textiles that we cannot account for. Some of this may be a result of increased storage in households while some may be a result of uncertainties in estimates. Key elements of uncertainty in flows are summarised in Box 3.

Figure 4.1: Overview of flows of textiles to and from households



4.2.2 Consumer-to-consumer (C2C) reuse

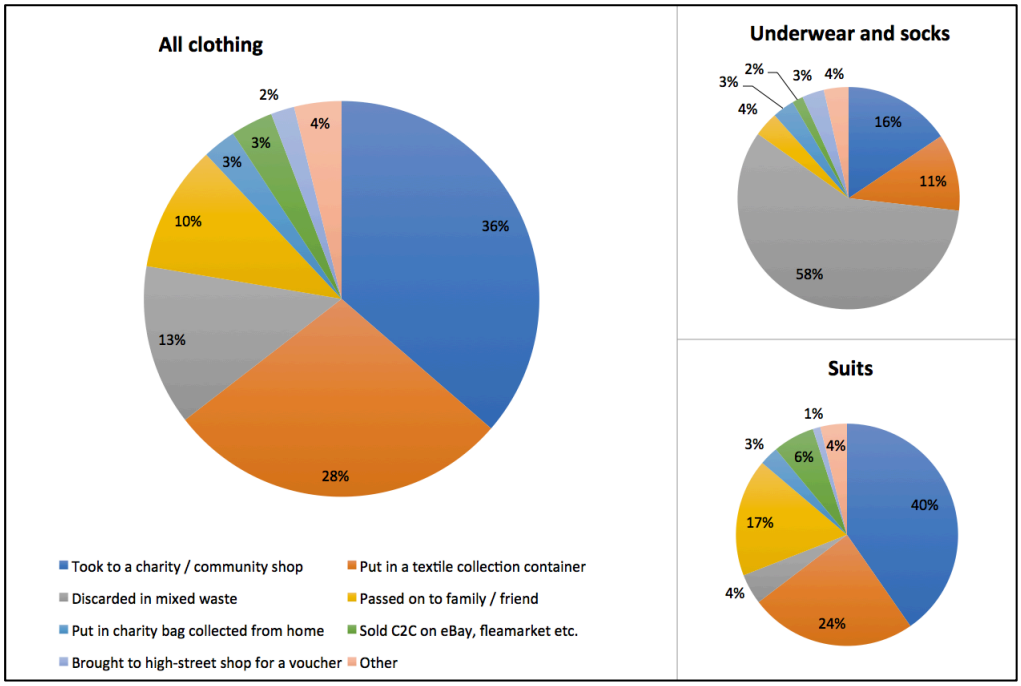
We estimate that around **7 600 tonnes** of clothing and textiles were exchanged both formally and informally between citizens in 2016.

Exchanges of reusable clothing and other textiles directly from one consumer/citizen to another can take many forms:

- Passing on of baby and children's clothing from an elder sibling to a younger one
- Passing on of clothing (again often baby and children's clothing) to wider family and friends
- Non-economic exchanges of clothing between strangers via swap markets and on line swapping platforms
- C2C sales of clothing via physical flea-markets or via other more formalised online and offline platforms such as Den Blå Avis, Gul og Gratis, Trendsales, Tradono, Re-shopper, ReSecond, Closay, Zadaa and Veras

Whereas the first two types of exchanges have been happening for generations, the final two have been growing, if not in volume of exchanges, at least in the numbers of online platforms that enable such exchanges. A new online site Deleportalen.dk was established in 2016 to give Danes an overview of the myriad of platforms available within the growing sharing economy. Box 4 gives an indication of the diversity of platforms.

Figure 4.2: Stated routes for discarding unwanted clothing, 2016



Source: survey carried out of 1000 adult Danes by WRAP UK as part of the European Clothing Action Plan

It has not been possible to gain a full picture of the quantities being exchanged C2C in Denmark. A survey carried out by UK WRAP in late 2016[11] found that 10% of Danes pass on clothing to family and friends while only 3% sell clothing C2C via offline and online platforms. Although this latter figure remains relatively insignificant, some collectors note increasing C2C sales as one cause of falling quality in the clothing that they receive via their collection systems (Watson et al, 2016).

Box 4: Examples of C2C exchange platforms

Closay is a C2C-hire platform where users can rent high fashion dresses from each other for special occasions. Rent periods are for either 3 or 6 days and cost 200-450 DKK. Closay takes a service charge for each hire. It also retains the right to exclude dresses that do not live up to their quality standards. Dresses that a user is offered are prioritised according to distance from their home. Collection and delivery is carried out by the renter or borrower.

Reshopper is a C2C exchange App for families with babies and small children. The App offers buying, selling or swapping of children's clothing along with other child gear like prams, pushchairs etc. The platform takes no share of the sales price, receiving its financing via advertising. The App prioritises sales close to the buyers home and collection and delivery is organised by the users.

Veras is a platform with a monthly subscription where users can trade their unwanted clothes in for credit points. These credit points can then be used to buy other's used clothing. Clothes are delivered by Veras to the users address or can be picked up in one of the physical stores. The service mainly targets adult females but has some male users.

Zadaa is a wardrobe based sales platform. Users set up a profile on the Zadaas website with size and preferred style. They can also upload garments from their own wardrobe for sale. Users are then matched with wardrobes that fit their personal tastes. Purchases are carried out via the App which also provides a delivery code for delivery via post kiosks. Zadaa takes a service charge for each purchase.

Bartlett et al (2013) estimated 119 000 tons of informal exchanges via friends and family in the UK in 2010. This represents 7% of total new textile purchases each year. 7% of Danish purchases would represent just over **6000 tonnes** of textiles exchanged between family and friends in Denmark.

Data on transactions via online platforms is typically only recorded where a business is earning money on each transaction made via their platform. It is many years since Denmark's largest exchange site - Den Blå Avis – earned money via each transaction. Rather the site raises money via premium services and advertising. The same is true for the transactions made via many C2C platforms.

Of the eight sites we contacted, only Tradono and ReShopper were able to give us transaction data. According to data provided by them we calculated[12] 100 tonnes exchanged via these sites in 2016. We do not have data that allows us to scale this figure up to the whole sector.

[11] Carried out under the European Clothing Action Plan. Kindly provided by Sarah Gray at UK WRAP

[12] A combined total of approximately 800 000 textile items were made via these sites in 2016. Assuming an average of 80 grammes for baby clothing exchanged via Reshopper and 300 grammes for clothing exchanged via Tradono this gives approximately 100 tonnes exchanged.

Elander et al (2014) estimated that in Sweden between 1 200 and 2 800 tonnes (130 to 300 g per capita) of textiles were exchanged via internet platforms in 2013. Bartlett et al (2013) estimate a minimum 3 000 tonnes (50 g per capita) in 2012 for the UK. The numbers of exchange and share sites have grown significantly in Denmark since the dates of these studies and we feel it safe to assume that exchanges will also have grown. We make a conservative assumption here of 250g per capita giving 1 500 tonnes for net exchanges.

We have no figures for exchanges via physical flea-markets in Denmark and neither Elander et al (2014) nor Bartlett et al (2013) attempted to estimate these exchanges for the UK or Sweden. We do, however, have data for quantities of textiles exchanged via swap markets. Swap markets became a significant national movement in Denmark from around 2010 onwards, with information on upcoming swap markets being spread via social media sites[13]. Funds were provided by *Grønne Ildsjæle* between 2013 and 2014 to coordinate and spread information on swap markets across the country. These activities have continued via for example Byttemarked.nu and various Facebook sites. Using data gathered under the Grønne Ildsjæle programme[14] we estimate that 100 tonnes of clothing was swapped in 2016[15].

Together exchanges via C2C platforms and swap markets amount to an estimated **1 600 tonnes.**

The ration between exchanges via C2C platforms and swap markets (1 600 tonnes) and via informal exchanges (6000 tonnes) agrees well with what Danes reported to UK WRAP (see Figure 4.2). 10% reported passing on clothing to family and friends and 3% via internet platforms and flea-markets (3%)

4.2.3 Separate collection of textiles from households

We estimate that **36 000 tonnes**[16] **of used textiles were collected from households** in 2016 (see Table 4.3. This represents 48% of textiles purchased by Danish households in 2016. In other words **just under half of purchased textiles are separately collected for reuse and recycling** when households no longer have a use for them.

Watson et al (2014) estimated 39 000 tonnes of separate collection, based on a smaller number of interviewed collectors and a higher degree of extrapolation. This figure included shoes and bags, however, giving an overestimation by 5-10%. Moreover, it appears that the 2014 study also overestimated the number of second-hand clothing shops run by smaller charities and private companies. This has led to an overestimation in seperate collection in 2010

Separate collection remains dominated by the traditional collectors (charities and long-standing private collectors) who are estimated to be responsible for more than 90% of collection. These are primarily collecting textiles via placement of containers (in municipal recycling centres, near/within supermarkets, on the street and other positions on public and private land) and across the counter in their own second-hand shops. Door-to-door collection by charities/private collectors is very limited due to high collection costs, and the risk of theft by illegal actors.

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[13] http://www.byttemarked.nu/hvad-er-et-byttemarked/baggrund/
[14] Evaluation of *Grønne Ildsjæle* project: https://docs.google.com/document/d/1GdokmZ9An_sAaRop5gyyHY7DohuNkwkgj5s7v1aIzxs/edit
[15] Incoming goods for exchange were weighed at 32 swap markets in 2013-2014 giving an average exchange per swap market 1.5 tons per market. Clothing dominates exchanges at swap markets and we assume 1 tonne per swap market. There were just over 100 swap markets involving clothing in 2016
[16] The 36 000 also include 1000 tonnes that is estimated stolen from containers prior to them being weighed – see later.

Table 4.3: Seperate collection of used textiles by charities, private collectors and municipal waste companies (2016, tonnes)

			Inputs (tonnes)			Outputs (tonnes)				
	Number of shops	Number of containers	Collected via containers and shops	Purchased from waste companies	Total collection (excluding shoes/bags)	Reuse (DK)	Recycled (DK)	Export (original)	Export (pre-sorted)	Incinerated (DK)
Private collector 1	0	1 600	4 520		4 181[4]			89%	9%	2%
Private collector 2		30	85	400	450[4]			100%		
Charity 1	0	920	2 015		1 770			100%		
Charity 2	125	200	950	650	1 360	6%	2%	74%	18%	1%
Charity 3	240	1 700	7 000		6 160	20%		2%	74%	4%
Charity 4	82	20	3 000	50	2 900	40%			55%	5%
Charity 5	248		5 000		4 625[4]	85%			5%	10%
Charity 6	25	1 200	6 000		5 700	25%	5%	50%	15%	5%
Charity 7	60	500	1 870		1 730[4]	11%		37%	43%	9%
Charity 8	73	95	1 740[1]		1 610[4]	*40%*		*0%*	*55%*	*5%*
Smaller collectors	158[2]	*250*	*3 670[1]*		*3 390[4]*	*50%*			*30%*	*20%*
Brands	102		420		420			100%		
Municipal waste companies[5]			2120[3]		*1920*	14%	0.4%	18%		4%
Sum					35 000[6]	10 620	320	11 340	10 500	2 220

[1]estimate based on number of shops and containers multiplied by reported collection rates in shops and containers by other actors

[2]numbers of second-hand shops run by members of ISOBRO other than those included above (Vibeke Andersen, pers. comm.)

[3] see Table 4.4 below

[4]Assumes 7.5% shoes by weight, based on average levels reported by other collectors

[5] Note that the percentages on the output side form municipalities only add up to 36%. The remaining 74% are sold to the collectors listed above and included in their accounts

[6]To avoid double counting this total only includes 36% of the textiles collected by municipal waste companies. The remaining 74% are sold on to the traditional collectors who have included them in their reporting in the rows above

The estimated 21 840 tonnes of used textiles that are exported by collectors agrees well with export data recorded by Statistics Denmark. The most uncertain figure in Table 4.3 is that of the quantity resold for reuse in Denmark. While exported quantities are weighed, sales of used textiles across the counter in collectors' own shops are not and this flow is based on rough estimates. The same is true for the estimated 2 230 tonnes of separately collected textiles that

are subsequently sent for incineration due to being of low quality, wet, mouldy or otherwise contaminated.

H&M has been collecting textiles in-store globally since 2014 in collaboration with private collector I:Collect and reached more than 400 tonnes a year in Denmark in 2016. Similar initiatives carried out by other high-street clothing brands including menswear brand JACK & JONES and children's brand, *name it*, were quickly dropped, however, due to lack of engagement by customers.

A further group that has relatively recently begun engaging in textile collection are municipal waste companies. One area of engagement is carrying out collection of textiles in recycling centres, sometimes replacing collection by charities and other established collectors.

Table 4.4: collection and processing of textiles by municipal waste companies as input to Table 4.3

Municipality	Quantity collected (2016)	Sold in shop (2016)	Sold to collector listed in Table 4.3	Recycled (DK)	Exported (unsorted)	Incinerated (DK)
Kara Novoren			*Started in 2017*			
Odense			*Started in 2017*			
Tønder Forsyning			*Started in 2017*			
Gladsaxe	61				61	
Affaldplus	500	40	*455*			5
AVV	200	100	*94*	6		
Horsens	174	46	*128*			
ARWOS	280	15	*215*			50
REFA	200				200	
Sum (with shoes/bags)	1415	201	*892*	6	261	55
Sum (without shoes/ bags)	1286	183	*810*	5	237	50
Share (%)	100%	14%	62%	0,4%	18%	4%

Nine of the 22 municipal waste companies that responded to our survey carry out their own collection, with three of these activities very recently established (see Table 4.4). Six separate the best quality textiles for sale in reuse shops they have established in recycling stations or elsewhere and sell the remainder on to the established collectors for further processing. The remaining three sell all of their collected textiles as 'original' (unsorted) to wholesalers.

Two further areas of engagement are kerbside collection and active encouragement of citizens to deliver their worn-out textiles along with their re-wearable products. Some examples are given in Box 5.

Kerbside collection remains relatively rare. In addition to Vejen as described in the box, we are only aware of kerbside collection being tested in Fredericia[17], Tinglev[18], both in southern

[17] Nynne Nørup, pers. comm.

[18] Stinne Stokkebo, pers. comm

Jutland, and in Rødovre[19] on the western edge of Copenhagen. In Fredericia and Rødovre, textiles are being collected as part of bulky waste collection.

In Tinglev they are being collected in the waste company's regular DuoFlex type wheelie-bin that ARWOS operate over the whole of Aabenraa municipality. The wheelie-bin has two compartments for recyclables; one for hard recyclables like glass and metal and one for soft recyclables including paper and soft plastic. In the Tinglev trial, residents are asked to put their textiles in a provided sealed bag that is then placed in the soft recyclables compartment (Rasmus Grønfeldt, pers. comm.).

Box 5: Municipal initiatives for increasing collection

Door-to-door collection in Vejen: Between June 2015 and June 2016, Vejen Municipality in Jutland in cooperation with Dansk Affald carried out a pilot project where textiles were collected along with other waste streams by the municipality waste company in kerbside collection. 550 households were included in the pilot. The municipality uses the DuoFlex® system developed by Dansk Affald; small household waste container system for dry recyclables such as plastic, glass, metal and paper. Under the pilot scheme a sealable bag was distributed to households, for packing with clothing and other textiles including textile waste, sealing and putting into the DuoFlex container.

The DuoFlex containers were emptied weekly. The system collected on average 4.7 kg of textiles per household over the year. Quantities collected weekly did not increase during the pilot period. The bag included a message encouraging households to deliver their reusable textiles to charities of their choice and to focus on using the bag for waste (non-reusable) textiles. However, 60-65% of the collected quantities were reusable clothing or shoes.

Collection of worn-out textiles: Both the City of Copenhagen and Kara/Novoren, a waste company operating in northern Zealand, have initiated pilot projects where citizens are encouraged to deliver their holey socks and other worn out textiles.

In Copenhagen, containers have been set up in the smaller local recycling stations that communicate via photographs that waste textiles are accepted. Similarly, containers marked as being for waste textiles have been established in Kara/Novoren's large recycling centres, adjacent to containers for small combustibles. These are positioned in a separate area to the containers for reusable textiles.

The message on worn out textiles seems to have worked: 57% and 43% of the textiles collected in the local recycling centres in Copenhagen and in the Kara Novoren recycling centres respectively are of reusable quality compared to more than 70% in containers elsewhere. This also has a strong impact on the economic value of the textiles for the collector.

By collecting textiles along with other waste fractions at the kerbside, the hope is that collection costs can be kept down. Some of the established textile collectors have tried kerbside or door-to-door collection in the past but found it to be excessively expensive compared to collection via containers (Steen Trasborg pers. comm.)

Communicating to citizens that they can deliver their worn-out textiles along with the reusable textiles is increasing amongst both municipal waste companies and the established collectors.

[19] http://www.glostrup.dk/politik/81/2287

This communication can be in response to requirements from municipalities or internally motivated despite the negative impact it has on the economics of collection (Watson et al, 2018).

A few municipalities have begun asking collectors to compete on the price they are willing to pay for textiles collected on public land. Elsewhere, collectors are viewed by municipalities as carrying out a public and social service.

4.2.4 What happens to the 36 000 tonnes of separately collected textiles?

Figure 4.1 gives an overview of the estimated flows of the approximately 36 000 tonnes of household textiles separately collected in Denmark.

It is in all collectors' interests to raise as much money as possible from the separately collected textiles. Since reuse raises a far higher price per kg than recycling, textiles are sold for reuse as far as possible. Collectors that have second-hand shops in Denmark, typically sort the best quality textiles out for resale in Denmark. This includes most of the charitable collectors but also some of the municipal waste companies that have begun collecting textiles.

The remaining lower quality textiles are sold for further sorting in other parts of Europe, typically the Baltic States and Eastern Europe, but there are also large sorting facilities in Germany, the Netherlands and Belgium. These wholesale sorting companies then sell the sorted fractions on for reuse and recycling on global markets. This activity is described in detail in Watson et al (2016).

Table 4.5: Fate of exports of used textiles from Nordic countries; original and pre-sorted

	Reuse			Recycling		Waste
	Cream (mostly Eastern Europe)	Grade A and B (Africa/Middle East/ Eastern Europe)	Third grade (Asia and Middle East)	Industry wipes (Global)	Mechanical recycling (mostly Asia)	Landfill and other (incl. cement furnaces)
10%	8%	11% (including 3% non-textile)	10%	8%	11% (including 3% non-textile)	10%
11%	9%	10%	11%	9%	10%	11%

**Pre-sorted textiles have typically had the best quality removed for sale domestically, and obvious waste is also removed and disposed of.*
Source: Watson et al (2016)

Some of the smaller collectors in Denmark sell the textiles that they can't sell in their own shops on to larger Danish actors, such as Danish Balkan Mission and Blå Kors, who then export to sorters in other parts of Europe. Dansk Affald carries out the same service for some municipalities.

Collectors without shops in Denmark, either sell all the textiles they collect completely unsorted (so-called 'original') to wholesalers/sorters in other parts of Europe, or carry out detailed sorting themselves and sell the resulting fractions on global markets. The latter is only carried out by a single organisation in Denmark, due to high costs of labour.

Watson et al (2016) mapped out the fate of exports of original and pre-sorted textiles from Nordic countries. Table 4.5 presents an overview. Assuming the same fate for the estimated 21 840 tonnes of textiles exported from Denmark in 2016 would give the results presented in Table 4.6.

19% of exported textiles are estimated as being recycled. According to European wholesalers, prices for recyclable textiles have reduced since 2016. These prices can only finance transport, if recycling facilities are reasonably close to the textile sorting facilities (Ljungkvist et al 2018). There are some exceptions such as white cotton for industry wipes and waste wool/acrylic for unravelling in Asia. 11% of exported textiles (2 300 tonnes) end in landfill or incineration in the sorting country.

Due to a lack of local markets recycling rates for textile waste that is gathered in Denmark during pre-sorting processes, are much lower than recycling rates for exported textiles. Collectors in Denmark who pre-sort collected textiles reported 2 230 tonnes of textiles for incineration in Denmark and just 320 tonnes sent for recycling. Even this low recycling rate is probably optimistic.

Some recent initiatives have attempted to tackle the problem of limited domestic recycling opportunities[20].

Table 4.6: Estimated end points for exports of Danish used textiles (2016, tonnes)

	Exports	**Reuse** (outside DK)			**Recycling** (outside DK)		**Other waste treatment** (outside DK)
	Total exports	Cream (mostly Eastern Europe)	Grade A and B (Africa/Middle East/ Eastern Europe)	Third grade (Asia and Middle East)	Industry wipes (Global)	Mechanical recycling (mostly Asia)	Landfill and other (incl. cement furnaces)
Exports of 'original'	11 340	1 130	5 220	1 700	1 130	900	1 250
Exports of pre-sorted textiles	10 500		5 560	1 790	1 160	950	1 050
Sum (tonnes)	**21 840**	**1 130**	**10 780**	**3 490**	**2 290**	**1 850**	**2 300**
Sum (share)	**100%**		**70%**		**19%**		**11%**

4.2.5 Flows of textiles in mixed household waste streams

There are several routes via which textiles end in mixed household waste streams. The routes include *residual household waste* collected directly from households, waste delivered by households to *small combustibles containers* in municipal recycling centres and finally *bulky waste* collected directly from households (in some municipalities). Textiles found in each of

[20] For example REALLY ApS and Advance Non-woven, both of which have received innovations funding from the Danish state

these are estimated under each heading below and are also shown as flows in Figure 4.1. They mostly end in incineration with energy recovery.

4.2.5.1 Household residual mixed waste

We estimate that **20 000 tonnes of textiles are discarded in household residual mixed waste** each year. This estimation was made as described in the methodology, by compiling data from 14 different picking analyses, from a total of 9 183 households and more than 20 000 inhabitants. The residual waste included in the 14 picking analysis studies comes from over 25 municipalities across all five of Denmark's regions.

Box 6: Potential errors in data on household residual mixed waste

In some of the picking analyses the definition of textiles has been uncertain. These analyses might have included leather or other type of textiles that are not included in our mapping. Furthermore, the picking analyses do not establish whether the textiles have been weighed in a dry or damp/wet state. We found that the difference between dry textiles and slightly damp textiles in some cases made a difference of up to 20% in weight.

Table 4.7: Textiles found in household residual mixed waste: results of picking analyses

	Single family housing (SFH) with garden				Apartments in multi-family housing			
Picking analysis	Households (number)	People (number)	Kg/household/ yea	Kg/person/ year	Households (number)	People (number)	Kg/household/ yea	Kg/person/ year
Viborg Kommune	198	477	5.7	2.7				
Aarhus	294	773	8.4	3.2	586	1043	9.7	5.4
ARC	405	1013	11.5	4.6	503	755	10.7	7.2
Odense	282	700	9.5	4	275	534	11.4	5.7
Haderslev	294	688	6.0	2.6	333	523	22.2	14.1
Sønderborg	269	611	9.6	4.2	120	196	5.5	3.3
Aabenraa	100	226	9.4	4.2	306	490	4.7	2.6
Tønder					120	194	8.3	5.1
DTU analysis from 11 municipalities*	2466	6613	9.1	3.4	320	488	5.3	3.5
PlanMiljø analysis from 7 municipalities* *	1171	3002	3.8	1.8	716	1359	6.0	3.2
Total/ *average*	**5479**	**14102**	***7.9***	***3.3***	**3279**	**5581**	***7.1***	***4.1***

*PhD project by UFF-Humana and DTU Environment (Nørup et al, 2018a)
**the textiles here were provided to PlanMiljø by Econet. Econet gathered them under a large picking analysis carried out in 2017/18 for the Danish EPA

We weighted the data from each analysis to take account of differences in sample sizes for the picking analyses.

Table 4.7 shows data and results from the analyses. A relatively large variation can be seen in the kg/person derived from each analysis. As described in Box 6 this can be caused by a number of issues including variation in the definition of what comprises 'textiles' and the possibility that some samples were wet.

Table 4.8 shows the results extrapolated to the whole of Denmark. There is a small difference in total quantities of textiles found in residual mixed waste depending on whether the data is extrapolated using the kg per capita or kg per household. The average figure lies at around 20 000 tonnes.

Table 4.8: Textiles found in household residual mixed waste across Denmark as a whole

	Number of households	Number of inhabitants	Textiles – extrapolated from number of households (tonnes)	Textiles – extrapolated from number of inhabitants (tonnes)
SF housing – DK total	1 553 175	3 754 694	12 200	12 374
Apartments in MF housing – DK total	1 056 135	1 847 494	7 492	7 642
SF & MF housing – DK total	**2 609 310**	**5 602 188**	**19 693**	**20 016**

4.2.5.2 Textiles in small combustibles

We estimate that approximately **14 300 tonnes of textiles from households are delivered as small combustibles** to municipal recycling centres in 2016. This includes textiles collected from households by municipalities in kerbside bulky waste collection, and subsequently transported to municipal recycling centres for sorting.

Our methodology was described earlier. 18 waste collectors that collect waste from 60% of the total population in Denmark, provided data on their annual quantities of small combustibles collected in municipal recycling centres. They collected just under 128 000 tonnes of small combustibles in 2016, giving an estimated 213 000 tonnes when scaled up to Denmark.

A review of picking studies conducted by Econet for Vestforbrænding in 2017[21] compared results from 26 different picking analyses on small combustibles from 14 different Danish municipal waste companies across Denmark. 25 of these had been conducted since 2011. The analyses were carried out on a total of 144 tonnes of small combustibles. We were also provided with two additional picking analyses from Kolding and Tønder Forsyning.

The picking analyses showed a very large variation in the shares of textiles in small combustibles, from just 1.3 % to 20.4 %. This is partially a result of variation in what was described as 'textiles' in picking analyses; in some tests this was just clothing, in others it included household textiles, duvets and pillows and in some cases even shoes. It may also be

[21] Econet, 2017, "Småt brændbart fra danske genbrugspladser".

a result of variations in the availability and accessibility of textile collection containers in recycling centres.

The weighted average was 6.7% textiles. When applied to the 213 000 tonnes of small combustibles collected across Denmark in 2016, this gives **14 300 tonnes** of textiles in small combustibles in 2016.

This is likely to be somewhat overestimated as some of the textiles are likely to come from small businesses that are given access to municipal recycling centres. Waste companies typically estimate that 80% of small combustibles in recycling centres have come from households and 20% from small businesses[22], but it is thought that the majority of the textile fraction comes from households. Waste company Affaldplus, for example, assumes an 80/20 distribution for small combustibles, but 100/0 for textiles. We have used the same assumption here.

4.2.5.3 Textiles in bulky waste

As described in the methodology, a share of bulky waste is sorted in municipal recycling centres, where clothing and household textiles are for the most part placed in small combustibles. These textiles are captured in the estimates on textiles in small combustibles carried out above.

Unaccounted for so far are the textiles in 1) bulky waste that is taken directly to incinerators after collection and 2) in bulky waste that are sorted in other sorting centres (*not* municipal recycling centres) prior to being incinerated. We estimate that this amounts to approximately **5 600 tonnes of textiles** each year. This estimate is based on a combination of estimates for total bulky waste following these two routes and picking analysis results on the share of textiles in bulky waste.

16 municipal waste companies, covering 49% of Denmark (by population) were able to provide us with data concerning quantities of bulky waste that followed the two routes. Scaled up to national level the results give an estimate of 62 000 tonnes of bulky waste sent directly to incineration and another 53 000 tonnes sorted in sorting centres. This gives 115 000 tonnes in total following the two routes.

Table 4.9 presents data from five picking analyses of bulky waste that were made available to us. They give a combined weighted average of 4.8 % textiles giving an estimated total of 5 600 tonnes textiles in bulky waste that is not sorted in municipal recycling centres.

These 5 600 tonnes are assumed to end in incineration. A handful of municipal waste companies reported placing bags of textiles that they found in bulky waste in charity containers or sorting the textiles themselves for sale in their own shops. This included both textiles sorted in their own recycling centres or in other sorting centres. This is reported by AVV in Aabenraa, Horsens Municipality, Tønder Forsyning and Odense Renovation. These flows have been included in reporting on separately collected textiles under 4.2.3.

The picking analyses presented in Table 4.9 indicate a high potential for more municipal waste companies to separate textiles from bulky waste. 68% of the textiles found in bulky waste were enclosed in clear bags protecting them from contamination and allowing easy identification and separation.

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[22] See e.g. Dansk Affaldsforening, 2015, “Anbefalinger om anvendelse af formlen i ressourceplanens bilag 5”. ARC uses a similar 24/76 distribution between business and households (Tanya Kofoed, pers. comm.)

Table 4.9: Share of textiles in bulky waste; results of five picking analyses

Picking analysis place and date		Black/coloured bags	Clear bags	Loose	Total
Solrød (2014)	Textiles	1	81	22	104
	Total waste	30	562	2063	2655
	% Textiles	**3.3%**	**14.4%**	**1.1%**	**3.9%**
Greve (2014)	Textiles	-	191	60	251
	Total waste	11	1884	3015	4910
	% Textiles		**10.1%**	**2.0%**	**5.1%**
Gentofte (2017)	Textiles	47	442	249	738
	Total waste	157	2102	6928	9187
	% Textiles	**29.9%**	**21.0%**	**3.6%**	**8.0%**
Tårnby (2016)	Textiles	18	218	14	250
	Total waste	129	1267	6781	8177
	% Textiles	**14.0%**	**17.2%**	**0.2%**	**3.1%**
Hvidovre (2016)	Textiles		157	80	237
	Total waste		1316	6400	7716
	% Textiles		**11.9%**	**1.3%**	**3.1%**
Weighted average share of textiles					**4.8%**

4.2.6 Leakages from the system

There are some other outputs from the household textile system that we describe as 'leakages' since they are difficult to follow and capture. We assume that the most relevant 'leakages' in Denmark are theft of donated textiles from containers, discards/incineration of unsold textiles by retailers and loss in weight of clothing due to lint loss in wear and laundry processes.

4.2.6.1 Theft of collected textiles

Theft of clothing from containers is reported by a number of collectors but we are only aware of one that has systematically investigated this issue. Some years ago UFF began an investigation that lasted more than a year. Marked bags of clothing were placed in containers aimed to be indistinguishable from the bags of used clothing subsequently delivered by citizens. It was observed that these sacks had often disappeared from the containers when they were emptied. Based on frequency of loss of the marked bags, UFF estimated that approximately 10% of the textiles delivered to their containers were being stolen (Kaj Pihl, pers. comm.).

Measures to combat this theft were subsequently taken, including use of more secure containers and variable pick-up routes and times. In one case it was observed that doubling the emptying frequency of a container almost doubled total collection volumes over the same period. Containers close to supermarkets and in other accessible places were found to be more susceptible to theft than containers in recycling centres that were locked at night, but even these experienced thefts.

UFF's 10% theft estimate was from a period where global prices for used textiles were higher than they are today and collectors have taken more precautions with respect to security. We assume 5% theft from containers. The share of textiles collected via containers by each organisation varies: some only collect via containers, others only collect via shops.

We estimate that just over half of separately collected textiles – 20 000 tons - are collected via containers. This gives a theft of approximately **1 000 tonnes** per year. This lies at the lower level of estimated losses for the UK (12 times the population of Denmark) by theft/bogus collection at between 10 000 and 60 000 tonnes per year (Bartlett et al, 2013), but kerbside collection is more prevalent in the UK than Denmark and is more prone to theft.

4.2.6.2 Discarding of unsold textiles by retailers

A share of the textiles that according to the import/export and domestic production calculations reported in Section 4.1 are purchased by households, in fact do not end in wardrobes. Some are returned after purchase due to faults, others are damaged in retailers and some others remain unsold.

Earlier, a large share of these textiles were most likely incinerated since retailers would make a VAT loss if they donated these textiles to charities/collectors for reuse/recycling, but not if they incinerated them, and the loss was considerably greater than the costs of incineration. This economic obstacle to donation was removed in 2016, however, through new interpretation of VAT rules and it is thought that incineration of returned or unsold textiles by retailers has reduced since then. H&M report for example that most of their unsold textiles are donated to the Danish Red Cross. This comprised 40 tonnes in 2016 (Reiersen-Møgelgaard pers. comm.).

There is little data available on the quantities of discarded unsold textiles by clothing retailers. H&M reported sending just over 9 tonnes for incineration due to contamination in 2016 (Reiersen-Møgelgaard pers. comm) and has sent 15 tonnes a year on average to incineration since 2013. Bestseller report that they send on average 28 tonnes a year for incineration and in 2016 exported 52 tonnes to Germany for recycling[23]. No figures are available for other retailers.

Together, H&M and Bestseller comprise just under 20% of the clothing market in Denmark. If their handling of unsold textiles is typical then the total quantities of unsold clothing incinerated may be in the order of **200 tonnes** a year with a further **450 tonnes** exported for reuse/recycling. These flows are shown to the bottom left of Figure 4.1 and **reduce flows of new textiles to households by 650 tonnes.**

4.2.6.3 Lint loss

Very few studies have been found of fibre/lint loss via laundering and wear. Lint loss is dependent on a wide number of factors including fibre type, yarn, fabric and weave properties, washing temperature, washing machine type, detergent and frequency, and finally use patterns of the product (see Kaynak & Topalbekiroğlu, 2008; Özdil et al, 2012; Hartline et al, 2016).

[23] https://politiken.dk/forbrugogliv/art6159279/HM-og-Bestseller-br%C3%A6nder-t%C3%B8j-i-tonsvis-p%C3%A5-danske-affaldsanl%C3%A6g

Outdoor clothing company, Patagonia, commissioned a study of lint loss from outdoor clothing during a single wash (Hartline et al, 2016). This found a loss of around 0.3% of the weight of the original garment during a single wash, with loss increasing as the garments became more used. However, the tested garments were fleeces and other garments including non-woven fabrics which tend to lose significantly more fibres than woven fabrics. UK WRAP uses 0.001% weight loss per wash in textile flow modelling (Sarah Grey, pers. comm.).

According to UK WRAP (2012) 24.7 million tons of textiles is washed by households each year. Assuming the same laundry habits in Denmark this would give 2.2 million tons of textiles washed in households per year. Using UK WRAP's 0.001% lint loss would give 22 tons lint loss per year, which if adjusted to include laundering in hospitals, laundries and other sectors might increase to **30 tonnes per year**. This is not a significant percentage loss from the system, but clearly more research is needed in this area to provide accurate figures.

4.2.7 Mass balance

Once all the flows have been placed in the system, the inputs to, and outputs from the 'household textile system' (the purple box) as shown in Figure 4.1 should ideally equal one another. Internal flows within the system i.e. C2C exchanges and resell of used textiles collected in Denmark back to Danish households are irrelevant to the mass balance since these remain in the system.

The box in the bottom right sums the inputs and outputs to the system and finds a **significant gap of 10 150 tonnes** in 2016. There can be several causes for a gap between inputs and outputs:

- increase in the quantity of textiles consumed year by year – since there can be a several year delay between purchase (input) and discard (output)
- increases in the amount of textiles that are stored in households
- underestimates in the various flow calculations

The first factor is not seen to be relevant since the total consumption of textiles to Denmark has remained relatively stable, fluctuating between 85 000 and 89 000 tonnes per year since at least 2010. The majority of clothing in particular is likely to have been in the system for shorter than this time period.

This is partially related to the ***second factor***; increased storage in households. Households can have a significant stock of clothing and textiles in wardrobes, lofts and storage companies[24]. Storage in households will only be a 'loss' factor to the mass balance system if the total quantity being stored increases over time. No studies have been carried out in Denmark that attempt to estimate this figure and Klepp and Laitala (2015) found no quantitative studies in the Nordics or elsewhere that can inform on growth in wardrobes.

Growth in housing area in Denmark may be one indirect indicator of increased storage space. According to data from Denmark's Statistics, this grew by 0.65% per year between 2011 and 2017. If Danes have equivalent average number of items of clothing as the British, at 115 items, at an average weight of 300 g, this would give an average wardrobe weight of 35 kg. An increase of 0.65% per year would give 0.2 kg per person, or roughly 1 300 tonnes across Denmark as a whole. This is a very rough and indirect calculation but may be our best guess at increased storage of textiles in households.

[24] Maldini et al (2017) for example, finds an average of 173 items of clothing per person in adults in the Netherlands while UK WRAP, (2012b) estimates an average of 115 items per person in the UK. In general about 30% of items are unused (Klepp and Laitala (2015)

The remaining gap can potentially be explained by the ***third factor***; uncertainties in estimates of various flows. Box 3 gave an overview of these. Greatest among these is the uncertainty in quantities of textiles in bulky waste for incineration. Given the small number of picking analyses carried out compared to the total flows of this waste stream, an underestimate of several thousand tonnes of textiles in this stream is possible.

Another uncertainty is the division in supply of textiles between households and sectors, which as described earlier is based on input output methods which have inherent sources of error (transferring of economic flows into physical flows).

A final, important uncertainty factor is the estimates by collectors of textiles that they resell in Denmark. These are returned to the system, and therefore are not included as an output in the mass-balance. Unlike exports these are not weighed but based on loose estimates. We consider it likely that these quantities may be overoptimistic while quantities being sent by the collectors for incineration may have been underestimated. Incineration is an output from the system.

4.3 Flows of used textiles from the public sector and businesses

4.3.1 Overview

We had less success in mapping out flows of textiles to and from public organisations and business as we did from households due to a number of causes:

- Unlike their municipal counterparts, private waste companies that carry out waste collection for these sectors were not willing to share information with us
- Textile procurers in companies could at best give us data on numbers of items of various textiles purchased but not their combined weight
- Central administrations of larger companies/organisations do not have detailed information on what happens to the textiles that their local branches discard

The final point is of key interest. Many large organisations did not appear to have central policy regarding how to treat used/unwanted textiles. Local branches are often left to determine this for themselves. This was equally true for hotels/restaurants chains as for laundries/textile service companies and individual hospitals in a region. This point affected our results because in order to cover as much of a sector as we could, we contacted the largest organisations/businesses within the sector.

The majority of the large companies we contacted reported that they lease most of their textiles from textile service companies/laundries. Smaller organisations within each sector are more likely to own textiles.

The exception is often uniforms. Most hotel chains, for example, lease their linen and other housekeeping textiles, but purchase staff uniforms.

The reuse value of uniforms is lower than for private clothing, due to lack of demand and the issue of logos. Both the military and police are unwilling to have others re-use their uniforms and have a policy of destruction through incineration. Health services are less sensitive and three out of five claimed to donate reusable discarded uniforms for use by health services in other countries. One hotel chain also donates uniforms for use in other countries following removal of logos.

Reuse and recycling seems to be the exception rather than the rule. The textile collectors surveyed under section 4.2 only reported small quantities of donations from private

companies, hospitals and other public organisations; less than 100 tonnes in total. None of the larger private waste companies in Denmark[25] claimed to separately collect textile waste from any businesses/organisation. Two recycling companies – Dantextil and REALLY - collect approximately 300 tonnes of bed linen and other cotton textile waste from hospitals and /laundries textile leasing companies per year.

We have no information on what smaller companies do with their textiles. Many are likely to dispose of these in mixed waste or donate them to collectors via schemes aimed primarily at households, containers in municipal recycling centres or elsewhere. This may especially be the case where employees have responsibility for disposing of their own work wear. We certainly found several examples of work wear in samples of mixed household waste from across Denmark (see Section 5).. Collectors we have spoken to have also reported that they receive work wear in their containers. These have already been recorded under the previous section as flows from households and we therefore discount this flow here to avoid double counting.

Table 4.10 gives our best estimates of textile flows to and from sectors, but for the most part these are very uncertain and should be treated with caution.

Table 4.10: Rough estimates of flows of textiles to and from sectors

Sector	Purchases estimated by PSUT analysis (tonnes)	*Recycling/upcycling in Denmark (tonnes)*	*Export for reuse/recycling (tonnes)*	*Mixed waste for incineration (tonnes)*
Kindergartens, youth clubs, day-care centres, nursing homes and home help services for the elderly	2 790			2 790
Laundries, textile service companies, hairdressers	1 800	50	500	1 350
Hospitals	1 350	50	400	900
Defence forces, police and emergency services	880			880
Hotels and restaurants	840		20	820
Cleaning services	550			550
Others	1 930			1 930

Purchases of new textiles are solely based on the PSUT analysis described under Stage 2 in the methodology with its inherent uncertainties. It was not possible to confirm these consumption levels with data from sector representatives. Due to the high reported use of leasing by all sectors we suspect that consumption by the laundry/leasing sector has been significantly underestimated by the PSUT, but we have no strong evidence basis for making adjustments to this.

Findings from the individual sectors are presented below.

[25] Marius Pedersen, Stena Recycling, Melgaard and RGS Nordic

4.3.2 Kindergartens, youth clubs, day-care centres, nursing homes and home help

Table 4.11: Leasing/ownership mix and routes of discarded municipal-owned textiles

Municipality	Ownership versus leasing	Who has responsibility for discarding owned textiles?	What happens to them?
Lemvig	The municipality owns all textiles in institutions	The individual institution	Discarded in mixed waste
Hvidovre	**Mix:** Linen and clothing are leased. Uniforms are owned by the municipality	Uniform depot	Incinerated in own incinerator or collected separately by waste company
Norddjurs	**Mix**: Towels, linen and work wear in nursing homes are leased. Textiles in other institutions are purchased by the municipality.	The individual institution	Discarded in mixed waste
Odsherred	**Mix:** Kindergartens own all their own textiles. Linen, uniforms and work wear in other institutions are leased.	Kindergartens are responsible for their own textile disposal.	Discarded in mixed waste
Helsingør	**Mix:** Work wear/uniforms for nursing homes and home help are owned by the municipality. Linen and towels, and work wear for kitchen and dentist staff are leased.	Used uniforms are disposed of by the responsible uniform depot.	Some in mixed waste, some in containers set up outside nursing homes and some other institutions for reuse/recycling
Fredensborg	**Mix:** Staff uniforms/work wear are purchased locally. All other textiles are leased.	The individual institution	Unknown
Aalborg	**Mix:** Work wear for cleaning and kitchen workers, and curtains are owned by the municipality. All other textiles are leased.	The individual institution	Unknown
Vejle	**Mix:** Differs by institution depending on whether the institution is part of the municipal leasing agreement or not.	The individual institution	Unknown
Halsnæs	**Mix:** Differs by institution depending on whether the institution is part of the municipal leasing agreement or not.	The individual institution	Unknown

This sector is predominantly (84%) run by the public sector at municipality level. We wrote to procurers in all 98 of Denmark's municipalities and received responses from 36.

71% (26 of the 36) of the municipalities lease all their textiles for all types of institutions, from a range of leasing companies. Just one of 36 municipalities purchases all its own textiles. The remaining 22% (8 municipalities) run a mixture of leasing and ownership.

What is leased and what is owned by these nine varies widely (see Table 4.11). For some it is differentiated by textile type, with uniforms often owned and linen etc. leased. For others it differs by institution type. For two municipalities it depends on whether the individual institution has chosen to be part of the municipal leasing framework contract or not.

Box 7: Collection of textiles in institutions

Helsingør municipality has a contract with a private municipal services company for setting up of containers for used textiles at schools, kindergartens and nursing homes in the municipality.

The collected clothes are donated to a local humanitarian organisation for sale for reuse and recycling.

In almost all cases where textiles are owned by the municipality, it is the responsibility of the individual institution to dispose of their worn-out textiles. Four of the municipalities don't have information on what happens to these. Of the five that do, three report that all textiles end in mixed waste bound for incineration and two report a mix of discarding in mixed waste and separate collection (see also Box 7).

4.3.3 Laundries/textile service companies

This sector is 100% privately run. There are some publically owned laundries that provide textile services for hospitals run by the respective regions; *Syddanske Vaskerier* for example that provides textile services for two of Region Southern Denmark's four hospitals and *Midtvask* that provides textiles services for hospitals in Region Central Denmark. These, are however, owned by the regions who run public hospitals and thus are included in the hospital sector later.

The laundry/textile services sector supplies a wide range of private and public organisations with services. Although the textiles themselves are often exclusively used by a single client organisation and carry that organisation's logo, the textile service company normally retains ownership of the textiles. This also means that they are (mostly) responsible for discarding these textiles when the client company no longer has a need for them.

Unlike for household clothing, this normally occurs when the textiles are no longer technically functional. However, textiles can also be discarded where a client company rebrands itself, wishes for a change in style of uniform or where the contract between client and laundry comes to an end and is not reviewed (Watson and Fischer-Bogason, 2017). It is not known the share of leased textiles which are discarded before their technical life is over. More research is needed on this. Watson and Fischer-Bogason (2017) make a number of recommendations to reduce this share; for example, using removable logos and writing in a service contract that a client's textiles may be transferred from one leasing company to another at end of contract.

Two textile service companies together run over 85% of laundry services in Denmark. Neither of these have figures for the weight of textiles that they purchase each year.

Data collected by the branch organisation BVT from roughly a third of the individual laundries in Denmark, estimated a total quantity of 500-600 tonnes of discarded textiles (Anne Sofie Wibe, pers. comm), which fits well with the purchases calculated via input-output methods of 1 800 tonnes per year for the whole branch (see Table 4.2 in Section 4.1).

Denmark's largest textile service company's central administration does not have a clear picture of what happens to all it's textiles, it loosely estimate that in 2016 over a third of their textiles were discarded in ordinary mixed waste for incineration, somewhere between 50-60% were collected separately by private waste companies and 2-3% were donated for reuse in other countries.

Denmark's second biggest textile service company was not able to provide any information on purchase of textiles, nor of what they do with their discarded textiles. Others reported that a proportion of the company's textiles have previously been upcycled into new products although on a relatively small scale, and that some is collected by Dantextil, REALLY and others for recycling. They also reported that a share of the company's healthcare uniforms and other textiles are donated to Doctors Without Borders for use in emergency healthcare activities in other countries. No information could be gained on the size of this share in comparison to textiles sent for incineration.

The smaller laundries reported differing approaches. One reported donating all of its textiles to a private collector for recycling as industry wipes, and the collector confirmed this. Another reported that they discard all their worn out textiles into mixed waste.

We contacted all four of the larger private waste companies in Denmark[26] and none of them claimed to collect textiles separately from any businesses/organisations including textile service companies/ laundries.

Private used textile collector and recycler Dantextil collects approximately 240 tonnes a year of worn-out textiles from laundries and hospitals which are exported to Poland for cutting into industry wipes. Dantextil is currently mostly interested in receiving cotton waste since the market for poly-cotton mixes has reduced in recent years.

One further recycling company that has begun taking waste textiles from laundries and hospitals in significant quantities is REALLY ApS. REALLY began operating at industrial level in 2017 where the organisation collected just under 50 tonnes of textile waste from five laundries (Anne Elisabeth Kargaard pers. comm.). More laundries are planning to send their waste textiles for recycling at REALLY in the future (Anne Sofie Vibe, pers. comm.).

4.3.4 Hospitals

The health sector is dominated in Denmark by the public sector. Public hospitals are run by Denmark's five Regions all of whom we contacted and received answers from in varying degrees of detail. Again there is a wide variation in approach both in gaining access to textiles and how they are discarded when they are no longer needed.

Three out of five regions both own and lease textiles, one only owns textiles and one only leases. The relatively low volumes of ownership (a total of 136 tonnes) from the three that both lease and own suggest that leasing dominates.

Two regions (Region Central Denmark and Region Zealand) claim to donate or sell all their used textiles for reuse in other countries, recycling as industry wipes or other uses (more recently including donation to REALLY for recycling in laminated boards for furniture).

Region Central Denmark has a special department for processing and finding a new home as far as possible from the region's discarded equipment including textiles from its laundry (see Box 8).

Half of the textiles discarded by the only region that owns all its textiles are similarly recycled, while the other half is incinerated in mixed waste. We do not have data for the weight of textiles consumed by this region.

[26] Marius Pedersen, Stena Recycling, Melgaard and RGS Nordic

Only one region discards the majority of its worn out textiles in mixed waste.

Table 4.12: Handling of hospital textiles reported by the five regions

Region	Ownership of textiles	Puchases (2016)	Estimated losses per year	Routes for discarded textiles (owned by the regions)
Capital Region	The region owns some textiles via its own laundry service and leases some from two private companies	8.5 tonnes: 1.5 tonnes uniforms 5 tonnes bedclothes, towels 2 tonnes patient clothing	4%	Most worn-out textiles are discarded in mixed waste streams A share of uniforms are donated to charity for use in other countries
Central Denmark	The region owns some textiles via its own laundry service and leases some from a private laundry	40 tonnes: 12 tonnes uniforms 12 tonnes duvets 16 tonnes Bedclothes, towels, patient clothing	No data	100 % is exported for recycling/reuse via the regionally owned organisation *InterGen*
North Denmark	All textiles are leased from a private laundry	N/A	N/A	N/A
Region Zealand	All textiles are owned by the region	No weight data – only economic	35%	50% in mixed waste; 50% sold for recycling
Southern Denmark	Ownership differs between the four hospital districts. Two of these lease textiles from private leasing companies and two of them own all their textiles via their own laundry service Syddansk Vaskeri	88 tonnes purchased by the publically owned laundry for two of the four districts	No data	Worn-out textiles are sold to private collectors for recycling as industry wipes Reusable textiles/uniforms are donated for use in other countries

Box 8: InterGen redistributor of hospital equipment

InterGen was established in 1994 by the Amt (county) of Aarhus to process and find a new home for the Amt's discarded equipment. Today, InterGen is part of the Central Denmark Region and receives and processes dicarded furniture, instrument and equipment from all hospitals in the region and identifies possible users for the both in Denmark but mostly abroad. This includes discarded textiles from the region's laundry service company Midtvask.

Over the years a large part of the equipment has been sent to Africa and Eastern Europe, for example. The region's own institutions are also the recipients of some discarded equipment although not textiles.

4.3.5 Defence forces, police and emergency services

Contact was made with the national police, the national defence as well as three regional fire/emergency departments.

We received four responses with only one fire/emergency department not replying. Common for all of the responses was that they purchase all their textiles; mainly uniforms that are manufactured for special purposes. None of the respondents have knowledge of the quantities of purchased textiles.

When no longer functional, textiles are incinerated along with other small combustible waste due to fears that discarded uniforms could be misused if they come into the wrong hands.

4.3.6 Hotels and restaurants

Contact was made with nine large hotel chains and eight chains of restaurants.

We received answers from four hotel chains representing 72 hotels. Again much of the textiles used by these hotel chains are leased from one of the large laundry service companies. Three out of four hotel chains lease all their housekeeping textiles (bed linen, towels etc.) and kitchen/dining textiles including kitchen staff uniforms, but purchase uniforms for the housekeeping and service staff. The fourth chain leases all its textiles.

Uniforms for housekeeping and service staff represent a small share of the total volume of textiles used by a hotel. One hotel chain reported that each member of staff has three sets of uniforms and that there is approximately one housekeeping/service person per every two beds. A further hotel chain reported one member of staff per five beds and that uniforms last approximately a year before they have to be changed. If we assume that all hotels in Denmark have similar conditions to these this would give an approximate total purchase of hotel housekeeping and service staff uniforms of 30 - 90 tonnes per year[27].

Hotel chain administrators reported that individual hotels or employees have responsibility for what to do with no longer functioning uniforms. None of the chains had a centralised take-back system but two of them did have a policy stating that the individual hotels should have a take-back system. In these hotels, uniforms that are felt to be reusable were donated for reuse and the remainder (approximately 30%) is either discarded in mixed waste or donated for recycling. One of the hotel chains reported removing logos prior to donation for reuse.

A further hotel chain manager had not considered a take-back system for uniforms but when we asked about this, determined that they should adopt such a system.

Of the eight chains of restaurants that were contacted, only one chain answered; a Danish-owned chain with 23 restaurants in Denmark. The chain leases approximately half of their textiles via their laundry partner while the other half is purchased. The leased textiles are mostly dishcloths and uniforms for cooks – their laundry partner washes 1.7 million dishcloths for the chain a year. Uniforms for other employees are purchased and owned by the restaurants. The chain's central administration is not aware how the textile waste is handled

[27] There are approximately 40 000 hotel bedrooms in Denmark (https://www.statista.com/statistics/613812/number-of-hotel-bedrooms-denmark/) giving approximately 60 000 beds. A range of 2-5 beds per staff and 3 sets of uniforms per staff gives 30 000 – 90 000 sets of uniforms. A uniform set is assumed to weight 1 kg.

and has no policy on this. Worn-out uniforms are the responsibility of individual restaurants. Without further information and in the light of this lack of policy from the central administration, we assume that worn out uniforms are disposed of in mixed waste for incineration.

Above we estimated 90 tonnes of uniforms for the hotel sector. Along with uniforms for the restaurant sector this could potentially reach the total of 240 tonnes of uniforms for this sector as estimated by the PSUT-analysis. With half of hotels we received responses from having a policy for their individual hotels on collecting and donating their uniforms for reuse, there seems some grounds for assuming that a reasonable share of the sectors 240 tonnes of uniforms are exported for reuse/recycling.

With limited data from individual hotels and no information from restaurants we must, however, be cautious, especially in the light of the fact that the charities/collectors that we have spoken to report on very limited collection of textiles from the private sector. Here we very roughly assume a 20% donation and 80% disposal in mixed waste.

In addition to the 240 tonnes of uniforms/work wear purchased, the PSUT calculations identified a further 600 tonnes of bed linen, towels and other household type textiles purchased by the sector. Since the larger chains of hotels and restaurants report that these textiles are leased not owned, we must assume that this purchase is by smaller individual hotels/restaurants. We feel that it is unlikely that these have individual agreements with collectors and we assume that all 600 tonnes ends in mixed waste.

4.3.7 Cleaning services

Contact was made with five major cleaning services that all operate throughout Denmark. We received answers from just two of these; one represents approximately 6-7% of the cleaning industry in Denmark and the other 10-15%.

The larger company leases approximately half of its textiles while the smaller leases only 5% and owns the rest. This smaller company estimates that it purchases 4 tonnes of textiles a year. This seems to be a low figure compared to the 550 tonnes a year for the whole sector as loosely estimated using the PSUT method (see Table 4.2).

With respect to the end fate of textiles, one disposes of its textile waste in its mixed waste stream, as it does not wish to have its discarded uniforms misused. The other cleaning service discards textiles via the disposal systems in their clients' buildings. The company does not have an overview of what these are. For lack of better information we assume here that the whole sector's discarded textiles end in mixed waste for incineration.

5 The lost value of textiles in mixed waste

As described earlier, we had at our disposal 235 kg of textiles that were separated from household mixed waste bins in picking studies carried out under a separate Danish EPA project. The waste was collected from seven municipalities, from four out of the five regions of Denmark during October 2017 to January 2018 (see Table 3.2 in the methodology section).

Textiles were washed three times to remove contamination, dried and sorted to separate products that we were interested in (clothing and household textiles) from other types of textiles and non-textile clothing etc.

Home textiles represented 31% of the 168 kg of clothing and home textiles found in the mixed waste, but only 18% of clothing and home textiles put onto the market (see Table 4.1 in Section 4.1). This suggests that households may be better at donating their used clothing to separate collection than their used home textiles. An explanation may be that households are more likely to use home textiles until they are worn out and then considered to no longer have value.

Table 5.1: Breakdown of 'textiles' found in mixed household waste

		Multi-family housing (MFH)	Single-family house with garden (SFH)
Within scope	**Home textiles**	**22%**	**22%**
	Textiles clothing	**51%**	**49%**
Outside scope	Shoes, bags, belts	23%	23%
	Duvets and pillows	4%	2%
	Non-textile clothing	0.5%	2%
	Cuddly toys	1%	2%
	Sum	**100%**	**100%**

The 168 kg of clothing and household textiles were then sorted by quality into reusable and recyclable fractions as described in the methodology. The results are presented in Table 5.2.

In our samples, people living in multi-storey housing discarded on average more than twice the textiles in mixed waste than those in single-family houses with gardens. Moreover, the quality of textiles discarded by apartment dwellers is significantly higher. According to our analysis, 33% of textiles discarded from apartments are reusable, compared to only 16% of textiles discarded by single-family housing.

For both types of housing, we estimate that around half of the textiles discarded in mixed waste could otherwise have been sold for reuse and recycling on existing global markets. Moreover, between 70% (apartments in mult-family housing) and 75% (single-family houses with gardens) of the leftover textiles have potential for recycling in the future since they contain relative pure fibre types or are poly-cotton mixes for which several chemical recycling processes are currently under development. It was clear that some of the textiles that had been discarded in mixed waste had already undergone some 'informal recycling' in the

households as rags for cleaning oil, polishing shoes, wiping floors etc. This was particularly noticeable for textiles discarded in single family houses.

Table 5.2: Clothing and home textiles found in mixed household waste, sorted according to quality

Grade		Multifamily housing (MFH)		Single-family house with garden (SFH)	
		Kg/person/year	Share (%)	Kg/person/year	Share (%)
Reusable	**Total**	**1.06**	**33.3%**	**0.24**	**16.4%**
	Shop quality	0	0%	0	0%
	Grade A	0.85	26.8%	0.18	12.0%
	Grade B	0.21	6.5%	0.06	4.4%
Recyclable – *current markets*	Total	0.66	20.7%	0.41	28.1%
	Industry wipes	0.57	17.9%	0.37	25.7%
	Wool/Acrylic	0.09	2.8%	0.04	2.4%
Recyclable – *future markets*	**Total**	**1.03**	**32.4%**	**0.60**	**41.0%**
	>95% Cotton	0.64	20.3%	0.44	30.0%
	Polycotton	0.10	3.0%	0.02	1.1%
	>95% Nylon	0.06	2.0%	0.04	2.6%
	>95% Viscose	0.06	1.9%	0.06	4.1%
	>95% Polyester	0.16	5.2%	0.05	3.3%
Waste *for incineration*		**0.43**	**13.6%**	**0.21**	**14.4%**
Total		**3.17**	**100%**	**1.45**	**100%**

In Table 5.3 we estimate the lost value of textiles discarded in residual mixed household waste across Denmark as a whole. We estimate[28] that at 2015 global market prices Danish discard about **6.5 million Euro** worth of used textiles in mixed waste. At current prices this would be a little lower since prices have dropped in the meantime for Grade B and recyclables (though not Grade A or Shop Quality).

One potential adjustment we can make to our results is seeing how it would change the total value if textiles discarded in single-family houses with gardens are assumed to be at the same quality level as those from apartments. This would be in line with the findings of our weighted mean averages of discarded textiles derived from all picking studies where kg/capita of textiles discarded in mixed waste from apartments (4.14 kg/capita) and houses with gardens (3.53 kg/capita) were much more similar than we found in our own picking and quality study. Making this adjustment would give a value of **9.4 million Euro**.

This gives a range of **6.5 to 9.4 million Euro** for the lost value of textiles discarded in residual mixed household waste.

[28] We applied the shares of Grade A, B, industry wipes etc. in mixed waste from single-family houses and from apartments in multi-apartment housing and applied them to the total textiles in mixed waste streams from these housing types given in Table 4.8 (see Section 4.2.5)

Table 5.3: Estimated lost value of textiles in mixed household waste

Fraction	Euro per tonne (2015 Prices)	Estimated quantities in mixed waste (Tonne)	Value (Euro)
Shop quality	5 500	0	0
Grade A	1 500	3 648	5 472 569
Grade B	250	1 075	268 794
Industry wipes	150	4 779	716 823
Wool and acrylic for recycling	150	536	80452
Other recyclables	0	7 918	0
Total		**17 957**	**6 538 639**

To this we should add the value of textiles discarded in other mixed waste streams, by household small combustibles and bulky waste.

We have estimates for quantities of textiles in these waste streams but not quality and have little information to base any assumptions of quality on. We therefore make a conservative assumption for indicative purposes that textiles discarded in small combustibles and bulky waste is of the same quality as that in mixed household waste. Nørup et al (2018b) supports this assumoption for small copmbustibles. Their study found similar quality levels of textiles in small combustibles as in mixed household waste. The assumption for textiles in bulky waste is considered to be conservative,, however, as we expect these to have a considerably higher quality. We have unfortunately no data to support this theory.

This conservative estimate would give a total value of **12-15 million Euro** for textiles discarded by households in residual mixed waste, bulky waste and small combustibles that end in incineration. This value is interpreted further in the discussion.

Comparison with other studies

We are aware of only one other study of the quality of textiles found in Danish household waste (Nørup et al, 2018b). Nørup et al conducted a quality survey of 264 kg of clothing and 118 kg of household textiles from 11 municipalities following a method developed in association with four international sorting companies (Nørup et al, 2018b).

Nørup et al (2018a) found almost twice the quantity of textiles per person in mixed waste from single familiy houses with gardens than we did, while quantities for apartments were similar to ours. Our result of 1.8 kg / person per year for sngle family houses lies at the lowest end of the range (see Table 4.7), whereas Nørup et al's 3.4 kg / person a year is close to the average. We have taken account of this above by adjusting our value calculations in the case that quantities of textiles in mixed household waste were closer to the mean found across all picking analyses. Both Nørup et al's and our quantities for apartments lie somewhat below the quantities found in other studies. However, there is some uncertainty concerning the other studies scope of textiles and whether they included wet weights.

Nørup et al (2018b) found a much higher proportion of textiles that would have been of reusable quantity prior to disposal than we did; 65 ± 8.0% of clothing and 65 ± 19.3% of home

textiles. Note that Nørups et al quality assessment did not diffeerrntiate between single family houses and apartments as the sample size for apartments were lower than recommended to achieve a 90% confidence level.

The higher shares of reusable textiles identified by Nørup et al (2018) can partially be explained by differences in sorting method. When evaluating whether textiles are reusable, we considered only textiles that can be resold on global reuse markets without repair. Nørup et al included products which can be reused after a repair operation such as replacing a zip which they assessed can also be sold on current markets. In addition, our decision to wash the textiles prior to sorting due to health and safety considerations, may have affected our subsequent quality assessment. This is probably why we found no textiles of shop quality in our sample. It may also have influenced the threshold for reusability and non-reusability for som delicate textiles made from kashmir or wool. Nørup et al did not wash textiles prior to quality assessments.

A third cause of differences in results may beo ur treatment of socks of which there was a considerable quantity in our samples. These were sorted according to fibre type for recyclability but in general not for reusability. We identified good quality pairs of socks that could be sold on reusable markets, but did not go through each lower quality sock to check wear and tear, since there are limited reuse markets for socks. Nørup et al undetook a more careful analysis of all textiles including socks. However, they did not find a significant share of socks suitable for reuse.

Finally, there are also differences in when the sorting was carried out, both in relation to the timelag between seperatuion of textiles from household waste and their subsequent quanlity analysis, but also the season during which the collection was made. Social conditions, as well as local opportunities for donating textiles, can be a further reason for differences between the studies. Both our study and Nørup et al's looked at textiles from a range of locations across Denmark and include over a thousand households (1800 households and 2800 households respectively). However, Nørup et a's sample (382 kg) is more than twice as large as ours (168kg).

Nørup et al. did not estimate the economic value of textiles in mixed household waste streams that we can compare with our results. However, in view of Nørup et al's higher share of reusable textiles, our estimate of 12-15 million Euro should be considered as conservative.

Studies from other countries have also found higher shares of reusable textiles than we found. Hultén et al (2016) judged 59% of textiles found in Swedish residual household waste to be reusable. This can partially be explained by lower separate collection rates in Sweden compared to Denmark which results in a higher share being discarded in mixed waste[29] including higher quality textiles. Morley et al (2008) notes that picking analyses in 2000 identified 59% of textiles in UK mixed household waste to be reusable but this had fallen to 43 % by 2008 due to increasing separate collection of textiles. At that point collection rates were still much lower than in Denmark today.

In addition to the national differences in separate collection of textiles, there are a number of methodological differences in how the sorting is done, both in terms of the textile definition and the quality assessment method, which varies between the studies. One must, therefore, be cautious when comparing results.

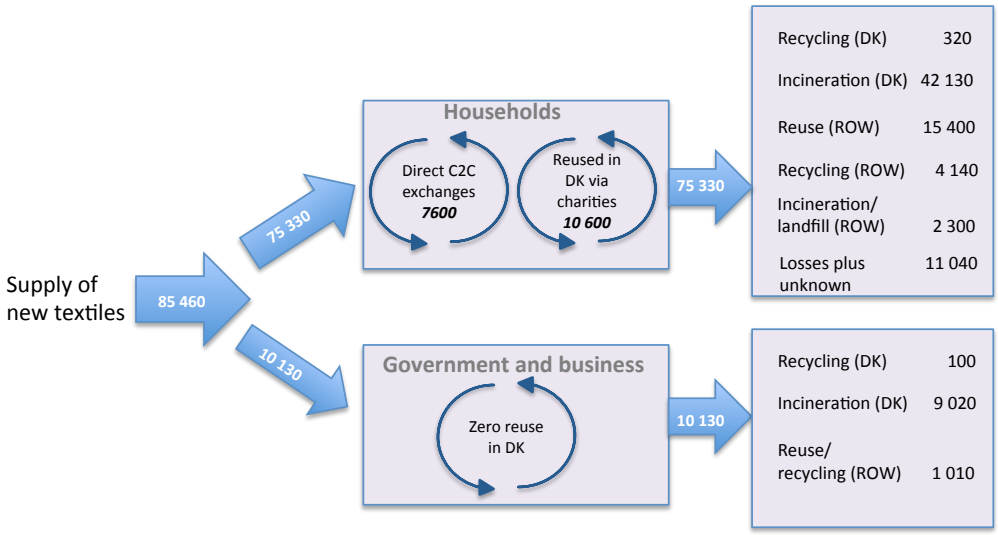
[29] 5.1 kg textiles in mixed household waste per person per year was estimated in the Swedish analysis

6 Discussion and conclusions

This is the most detailed mapping of the flows of textiles to and from households and other sectors carried out in Denmark to date and establishes methods that can be used in future mapping of the sector. It lays the foundations for the development of policy and initiatives to further improve collection, reuse and recycling of textiles in Denmark and for considerations on how to meet coming requirements on the separate collection of textiles under a revised EU Waste Framework Directive.

Figure 6.1 gives a simplified overview of flows of new and used textiles to and from households and other sectors in Denmark. For a more detailed overview of flows to and from households see Figure 4.1.

Figure 6.1: simplified overview of flow of new and used textile in Denmark



Notes: 1. reuse in Denmark is shown within the central boxes and not in the boxes to the right, since these remain in the system 2. ROW means Rest of World

Supply of new textiles

Consumption of textiles by Denmark as a whole has remained stable since at least 2010. Overall consumption in 2016 lay at just over 85 000 tonnes; approximately 75 000 tonnes to households, 5 000 to private businesses and 5 000 to government/municipal run organisations. Household consumption of textiles amounts to an average of 13.2 kg/person. Total consumption of textiles by all sectors comprises 15.0 kg/capita.

83% of textiles supplied to households comprise clothing with the remaining 17% being home textiles. The picture is very different in business/government use where there is a much greater balance between clothing and other textiles; 58% comprises work wear and 42% bed linen, towels, curtains and other non-apparel textiles.

Reuse and recycling of textiles from private households

Collection, reuse and recycling systems for the 75 330 tonnes textiles purchased by households seem to be relatively well-functioning. Between a fifth and a quarter of clothing and home textiles that are no longer wished for by the original owner, are re-circulated back to new users within Denmark. Part of this recirculation is carried out directly between consumers.

An estimated 7 600 tonnes of textiles are exchanged consumer-to-consumer (C2C) either between family and friends or with strangers via exchange platforms. A further 10 600 tonnes of the textiles collected from households by charities and other collectors and recirculated back to Danes via second-hand shops for reuse.

The 10 600 tonnes are part of an estimated 36 000 tonnes of used textiles collected from households in 2016. Collection remains dominated by the traditional collectors of used textiles - mostly charities but also some private collectors. Municipal waste companies have also begun to enter the arena in recent years in part inspired by Denmark's waste strategy – *Danmark Uden Affald 2013-18* – that raised awareness of the importance of reducing textile waste in mixed waste streams for many municipalities and their waste companies.

Of the 36 000 tonnes of separately collected textiles, a further 21 840 tonnes are exported for reuse and recycling elsewhere. Approximately 70% (15 400 tonnes) of the exports are reused and 19% recycled (4 140 tonnes) somewhere in the world. The remaining 2 300 tonnes are landfilled or incinerated in the sorting country. Recycling in Denmark is much more limited at 320 tonnes.

Despite the relatively good separate collection rates of discarded household textiles when compared to other Nordic countries, an estimated 54% (39 900 tonnes) of textiles supplied to households ends in mixed waste streams. Around half (20 000 tonnes) is discarded in residual household mixed waste; the remainder is discarded in bulky waste and small combustible containers in municipal recycling centres. The vast majority of this is incinerated. To this can be added a further 2 230 tonnes of waste textiles that are sent by textile collectors for incineration. This gives a total of 42 130 tonnes of textiles incinerated each year.

The lost value of incinerated textiles

An analysis of textiles separated from mixed household waste collected in seven municipalities estimated that 23% would have been reusable and 26% recyclable under existing markets prior to being discarded in mixed waste.with a further 37% being potentially recyclable under future markets. The reusable share is lower than found by other studies.

The total lost value of clothing and household textiles incinerated each year in Denmark is estimated at 12-15 million Euro a year at current market prices.This is the price that the textiles could have been sold for on global markets if they had been separately collected rather than discarded in mixed waste streams. The value of textiles found in bulky waste may be of higher quality than that in residual household waste which would raise this value. We did not have access to textiles to make such an evaluation. We recommend that such a study is carried out.

Although the *quantity* of incinerated textiles at 42 130 tonnes is a little higher than the 36 000 tonnes of separately collected textiles, the economic value is significantly lower. The 36 000 tonnes of separately collected textiles were sold for an estimated 65 million Euro[30]. In other words the quality, and thus the value, of textiles discarded in mixed waste (mean value of 36 Eurocent/kg) is much lower than the quality and value of separate collected textiles (mean value of 180 Eurocent/kg).

[30] According to Statistics Denmark's import/export data, the economic value of the exports of used textiles and rags from Denmark in 2016 was 12 million EURO. in addition to this we need to add the economic value of the approximately 10 600 tonnes of textiles resold in Denmark. Here we assume that all was sold at shop quality price (5 Euro per kg)

This illustrates that householders are making fairly reasonable decisions in terms of what they think has a value and should be donated/sold for reuse, and what they consider to be waste. If it was a simple case that some households dispose of all their used textiles in mixed waste and others donate all their used textiles for reuse and recycling then we would expect the value per kg of textiles in mixed waste to be similar to the value of donated textiles. Nevertheless, this loss of value and resources should be avoided.

How to increase separate collection from households

Gaining this lost value can either be carried out through increased separation at source i.e. in households or by separating textiles from mixed waste after they have been discarded. For the 20 000 tons of textiles in mixed residual household waste the only option is to increase separate collection since once textiles are discarded in mixed waste their value is lost through contamination by kitchen and other wet waste.

New collection and communication methods may be needed to increase separate collection rates. This can include methods that increase convenience for citizens and also efforts to communicate that all textiles are acceptable in separate collection schemes both reusable and non-reusable textiles. The latter can present some legal challenges for traditional collectors unless they register themselves as waste collectors.

Door-to-door collection and /or collection in multi-apartment housing waste areas would increase convenience but will also increase costs of collection per tonne. Moreover, as our picking analysis demonstrates, much of the additional textiles that would be diverted from mixed waste would have a significant lower sales value due to their typically lower quality. This would squeeze the economics of collection. Watson et al, (2018) has identified the same problem in a number of European cities.

Combining collection of used textiles with other recyclable streams in door-to-door collection can potentially reduce collection costs of this type of collection. This is being tested in a number of Danish municipalities. These are experiencing challenges in developing systems that both avoid contamination of textiles while not giving collection costs that exceed the value of the collected textiles[31].

Separating textiles from bulky waste

Although textiles cannot usefully be separated from residual mixed waste, the same is not true of textiles in bulky waste. Bulky waste may present an opportunity for diverting a significant share of textiles from incineration at the processing stage. 5 600 tonnes of textiles are found in bulky waste that is sent directly for incineration or for sorting in sorting centres. Several thousand additional tonnes are found in bulky waste that is sorted in municipal recycling centres.

It seems that the majority of these textiles are incinerated. A few municipalities and municipal waste companies have begun separating these textiles from bulky waste and placing in textile containers for reuse/recycling. The potential for this separation seems to be high. In the five picking analyses to which we gained access, 68% of the textiles were enclosed in clear plastic bags protecting them from contamination and thus preserving their value and allowing easy identification and separation. There are economic interests in this since the per kg value of textiles discarded in bulky waste is likely to be of higher quality than that in residual household waste.

[31] Presentations by Dansk Affald and Arwos at 3rd DAKOFA textile network meeting

Finding markets for recyclable textiles

Citizens are not so mistaken in their assumption that their worn out textiles have little value, which may be why many of these end in mixed household waste rather than in collection system. Prices for recyclable textiles are at rock-bottom and prices for lower quality reusable textiles are also falling as the global supply increases, but demand for them does not (Ljungkvist et al, 2018).

Most recycling options currently comprise downcycling. To change the economics of collection such that diverting more textiles from mixed waste via new collection modes becomes economically viable will require new outlets for the non-reusable fraction.

Many actors point to textile-to-textile recycling as the most important future opportunity, both economically and environmentally. Some Nordic and global brands are already engaged in making use of recycled materials in new clothing and textiles (Watson et al, 2017a). However, this area will require a number of technical developments, changes in product design processes and changes in management approach within the textile industry, before it becomes a significant purchaser of collected non-reusable textiles (Elander and Ljungkvist, 2016; Watson et al, 2017b).

Obligations to divert textiles from mixed waste

Until then, even if there is limited economic value in capturing the textiles lost in mixed waste, there are environmental benefits to be gained (Schmidt et al, 2016). In recognition of this, the recently proposed changes to Waste Framework Directive in implementing the EU's Circular Economy Package, will oblige Member States to ensure that there are systems in place for the separate collection of used textiles, including the non-reusable share.

Denmark could implement this in a number of ways; via derogating responsibility to municipalities to ensure separate collection, to producers via a producer responsibility scheme or a third alternative. Whoever is give the overall responsibility, existing collection actors have an important role to play since they already collect significant quantities of used textiles and have systems and contacts with global markets for their processing, reuse and recycling.

To be effective and ensure a viable system, collection and processing needs to be economically viable for the actors involved. Collectors claim that they are being squeezed economically at both ends; on the one hand some municipalities are asking payment for the collection of used textiles, on the other, global prices for collected textiles have been falling since 2014. Expectations that collectors should collect worn out textiles, would apply further economic pressure (Ljungqvist et al, 2018; Watson et al, 2018).

In France, Flanders and the Netherland attempts have been made by producers, regions and municipalities to tackle this through economic support for these operations. This has been provided in the form of wage support for staff employed in the collection, sorting and resale of textiles. By linking this wage support to the employment of long-term unemployed and disadvantaged groups, government can achieve both environmental and social gains (Watson et al, 2018).

Low reuse and recycling rates in non-household sectors

The separate collection, reuse and recycling of the approximately 10 000 textiles purchased each year by business and the public sector is less progressed than for textiles from households. Only an estimated 10% of this is reused or recycled following discarding by the first user. There are a number of potential reasons for this.

Firstly, textiles discarded by business and public organisations have lower potential for reuse. There is a higher share of linen, towels and other non-clothing textiles (42% compared to 17%

for households) for which there tends to be lower demand on global markets. Moreover, clothing often comprises work wear and uniforms for which there again is limited demand.

Secondly, not all organisations wish for their textiles to be reused, even if a reuse market could be found. This particularly concerns bed linen, uniforms and work wear that carry the organisation's logo. There are concerns that the logo could be misused. The military and police have a strong policy of destruction of their discarded uniforms for this reason.

Thirdly, while many large organisations have centralised procurement for textiles, individual departments and branches are responsible for discarding their own textiles. Moreover, for the most part, central administrations have no policy nor issue guidance on what should be done with used textiles. This is equally valid for regions and municipalities as it is for restaurant and hotel chains.

Fourthly, private waste companies report that they do not separately collect textile waste from their clients, although we have heard from other organisations that at least one of these is beginning to engage in this collection and is already finding recycling outlets for these.

How to increase collection in the private/public sector

Reducing the quantity of work wear, bed linen and other textiles disposed of in mixed waste by companies and the public sector requires that central administrations develop policy/guidelines on how to discard textiles more sustainably. They may also need to develop logistics systems to gather textiles from departments around the country for donation/sale for reuse and recycling.

Leasing of textiles from textile service companies/laundries certainly presents opportunities for a more sustainable and more coordinated treatment of used textiles, since collective logistics are already built in to these systems. All the sectors reported a high share of leasing from large and small textile service companies.

While the two largest textile service companies had limited information and no central policy on how their local departments deal with discarded textiles, the sector is moving forward in this area. This is in part due to the efforts of the Industry Association for Laundries and Textile Leasing (BVT) who has been investigating potential of increasing delivery of discarded bed linen and other cotton waste for recycling.

Public procurement contracts could be one powerful means for ensuring that textile service companies deliver their discarded textiles for reuse/recycling. Regions and municipalities could include a requirement in tenders and contracts that service providers must ensure separate collection and reuse/recycling of textiles provided under that service contract.

We also found a few examples of regions and municipalities that are more actively engaged in reuse/recycling of *their own* textiles. For example, some had found reuse opportunities for healthcare textiles in developing countries and by charities such as Doctors Without Borders. Region Central Denmark runs an organisation that is responsible for finding a second life for much of the region's discarded equipment, furniture and healthcare textiles. At the municipal level, Helsingør has established collection systems at nursing homes and children's institutions in partnership with a municipal services company who donates the textiles to a charity. Other regions and municipalities could establish similar initiatives.

Improving data availability

There is a gap of over 10 000 tonnes in our mapping of textiles. This is around 1.8 kg per person across the whole of Denmark. Part of this may be represented by increased storage of textiles in households. However, most of the gap is likely to result from uncertainties in our

data. If we wish to monitor the status of circular economy for textiles in the future then there is a need to improve data availability.

Particularly unreliable data comprises collection and resell over the counter in charity shops in Denmark, C2C exchanges, quantities of textiles in bulky waste collection, registration of total bulky waste quantities, textiles stored in households and data on the purchase and treatment of textiles by business and the public sector.

This situation could potentially be improved through:

- ***Requirement of codes of conduct for textile collectors*** including weighing and reporting on all flows of textiles. It would be a bureaucratic burden for them to weigh and report quantities delivered and resold in shops, but would fill a significant data gap and increase the transparency of the sector.
- ***Regular surveys of citizen behaviour*** similar to UK WRAP's 2016 survey of 1000 Danes under the European Clothing Action Plan. This would provide improved information on C2C exchanges and attitudes and hindrances to delivery of used textiles and purchase of second hand textiles
- ***Systemised picking analyses*** of bulky waste, small combustibles and mixed household waste to ensure compatible, reliable and regular data availability on quantities, and possibly also quality, of textiles in mixed waste. If evaluation of the quality of textiles in these waste streams was included in regular picking analyses this would require significantly greater allocation of resources.
- ***More systematic registration of bulky waste collection*** by municipalities and municipal waste companies in the national waste registration system (ADS). Current registration is very varied in terms of at what point in the system the waste is weighed and registered and where it is recorded in ADS.
- ***Requirements for registration of separate textile collection*** by municipal and private waste companies

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Appendices

7.1 Appendix A Clothing and home textile product groups for calculations and presentation

The Combined Nomenclature (CN) is a tool for classifying goods set up to meet the requirements both of the Common Customs Tariff and of the EU's external trade statistics[32]. The system has a number of different levels of aggregation of product types. The detailed 8-digit level comprises many thousands of different product groups while at the 2-digit level contains roughly 100.

The textile we are interested in for this project, clothing and home textiles and similar textiles used in public and private organisations and businesses are covered by 3 different 2-digit codes; 61, 62 and parts of 63. At the detailed 8-digit CN product disaggregation level, there are 438 products of interest. At this detailed level products are divided not only by type and function but also by fibre type. We have used this level of detail for calculations of textile supply

For *presentation* of results in Table 4.1 we use grouping some of these together. For example there is no need to distinguish between men's/boys' coats and women's'/girls' coats or between crocheted and non-crocheted coats. This is in line with Watson et al (2014).

We have used the following groupings:

4 digit code	Product group
6101 + 6102 + 6201 + 6202	Overcoats, car coats, capes, cloaks, anoraks, incl. ski jackets etc.
61031 to 3 + 61041 to 3 + 62031 to 3 + 62041 to 3	Suits, ensembles, jackets, blazers,
61034 + 61046 + 62034 + 62046	Trousers, bib and brace overalls and shorts
61044 to 5 + 62044 to 5	Dresses and skirts
6105 + 6106 + 6205 + 6206	Shirts, blouses and tops
6107 + 6108 + 6212 + 6115 + 6215	Underwear, nightshirts, pyjamas, bathrobes, dressing gowns plus bras, corsets etc. plus Pantyhose, tights, stockings and socks
6109 + 6207 + 6208	T-shirts, singlets and other vests
6110	Sweaters, cardigans, waistcoats
6111 + 6209	Babies clothing
6112 + 6211 + 6114 + 6214	Tracksuits, ski-suits and swimwear plus professional sportswear
6113 + 6213	Garments covered or impregnated with plastics
6117 + 6213 + 6214 + 6217 + 6116 + 6216	Handkerchiefs, ties, scarves, gloves and other
6210	Non-woven garments
6301	Blankets and travelling rugs
63021 to 3	Bed linen,
63024 to 5	Tablecloths
63024 to 5	Towels, tea towels and cloths
6303 + 6304	Curtains and drapes and other interior furnishings

[32] https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/what-is-common-customs-tariff/combined-nomenclature_en

7.2 Appendix B Methodology for calculating split between households and sectors using Physical, Supply and Use Tables

DANMARKS STATISTIK

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Assessment of supply and use of Danish textile products

Introduction

The assessment includes a quantification of supply and use of textile products in Denmark.

The methodology for the assessment of the physical flows has been developed as part of the general work at Statistics Denmark on detailed material flow accounts for Denmark for the year 2009. These accounts include data for supply and use of all types of products classified along 2000 different product groups in the same way as in the Danish national accounts.

In this project the assessment of flows characterised as textile products has been updated to 2016 based on more recent data.

Supply categories

The supply includes imports and Danish production of textile products by industries.

Use categories

The uses include uses by industries, private and government consumption, and exports, changes in inventories and investments, etc.

Material balance principle

The material flow accounts are constructed on the principle of material balances which means that for each type of product total supply must equal total use. The advantage of this approach is that it ensures that the assessment is consistent in the sense that the different data sources are confronted and conflicting data are considered and solved.

An example of a complete product balance is given in Table 1.

Scope of the textile flow assessment

Combined nomenclature and national accounts product classification

Approximately 550 products from the two digit CN (Combined Nomenclature[1]) codes 62 to 64 are included in the assessment. The 550 numbers has been aggregated to 40 textile groups according to the product classification used by the Danish national accounts.

Fished products/final uses of products

To a large extent, the selected products, corresponds to “finished” or processed products. This means that textile products like fabric and yarn has been excluded from the assessment.

[1] See http://www.dst.dk/en/Statistik/dokumentation/nomenklaturer/kn--den-kombinerede-nomenklatur

Industry/sector classification

The classification of economic activities follows the classifications used for the Danish national accounts. A distinction between 117 industries is made. In addition the classification includes categories for private and government consumption, investments (capital formation), inventories and the rest of the world (imports and exports). The classification is comprehensive but not all of the categories are of importance in relation to textile products, and the available data do not facilitate an exhaustive allocation of the uses of textile products on all categories. However, all important users of textile products should be covered.

Table 1. Product balance (supply and use table) for work clothes

Product: V621105 Work clothes		
Industry code	**Supply**	**Tonnes**
	Danish production	
140000	*Beklædningsindustri*	*326*
300000	*Fremst. af skibe og andre transportmidler*	*909*
	Total Danish production	**1.235**
	Imports	**935**
	Total supply	**2.170**
	Use by industries	
300000	*Fremst. af skibe og andre transportmidler*	*15*
330000	*Reparation og installation af maskiner og udstyr*	*10*
370000	*Kloak- og rensningsanlæg*	*199*
383900	*Renovation, genbrug og forureningsbekæmpelse*	*378*
490010	*Regional- og fjerntog*	*6*
490020	*Lokaltog, bus og taxi mv.*	*3*
530000	*Post og kurertjeneste*	*19*
780000	*Arbejdsformidling og vikarbureauer*	*30*
810000	*Ejendomsservice, rengøring og anlægsgartnere*	*185*
840010	*Offentlig administration*	*4*
850010	*Grundskoler*	*1*
850020	*Gymnasier og erhvervsfaglige skoler*	*1*
850030	*Videregående uddannelsesinstitutioner*	*1*
850042	*Voksenundervisning mv., ikke-markedsmæssig*	*1*
860010	*Hospitaler*	*47*
870000	*Plejehjem mv.*	*29*
880000	*Daginstitutioner og dagcentre mv.*	*80*
910002	*Biblioteker, museer mv., ikke-markedsmæssig*	*3*
960000	*Frisører, vaskerier og andre serviceydelser*	*592*
	Total use by industries	**1.604**
	Private consumption	**27**
	Changes in inventories	**81**
	Exports	**458**
	Total use	**2.170**

Reference year 2016

2016 is the reference year for all basic data on foreign trade and Danish production. The allocation of uses of textile products across industries is based on the structure of the allocation for the years 2009 (detailed material flow accounts, tonnes) and 2014 (national accounts, DKK).

Data sources

Imports and exports at tonnes

The Foreign Trade Statistics from Statistics Denmark (www.dst.dk/KN8Y) is the source of data on imports and export for each of the approximately 550 textile products. This statistics include information on both values and quantities (tonnes) of the imports and exports of products.

Industrial production statistics converted to tonnes

Danish production data are from the industrial commodity statistics (www.dst.dk/VARER1). In contrast to the foreign trade statistics, the quanties for textile products in this statistics are generally not counted at tonnes, but instead as pairs, etc. In order to arrive at tonnes also for the Danish production, a conversion of the values (DKK) has been done by assuming the same relation between tonnes and DKK for the Danish production as for the exports. This conversion has been done at the detailed level, i.e. for each of the 550 textile products.

Use of textile products

No basic statistics on the use in tonnes of textile products is available, and the assessment of the use has to be based on proxy data and assumptions.

Allocation according to national accounts' monetary values for use of textile products

The national accounts supply and use tables include information on the monetary value of the supply and use by 117 industries, households, etc. Based on this information an allocation of the quantities used has been made. First the total Danish use at tonnes is estimated as Danish production + imports – exports. Secondly the total Danish use is allocated by industries and households proportionally according to the monetary values for the use (this corresponds to the assumption, that all users pay the same price for the product).

Private consumption of textile products

For many of the textile products private consumption is the main use category, and special attention has been made to ensure that the private consumption data for each textile product appears reliable.

Generally the national accounts' data on household expenditures on textile products are based on the Household Budget Survey (HBS) from Statistics Denmark. An overview of the data in the HBS is presented at www.dst.dk/FU51, but for the national accounts and this project results from the survey at a level comparable to the national accounts product classification has been used. The HBS data for expenditures on textile products of an average household has been enumerated to all households in the Danish economy. This gives the expenditures at purchasers' prices, i.e. the prices paid by the consumer including taxes and trade margins. Subsequently, the expenditures at basic prices (i.e. the value of the product as it leaves the manufacturer) is obtained by subtracting taxes and trade margins form the values at purchaser's prices.

Specific adjustments to the national accounts' data

In especially one case, the initial allocation of the use of the textile products based on the national accounts' monetary information seemed somewhat unrealistic. This was the case for "bed linen, etc.". An alternative estimation of the households' use of "bed linen, etc." were therefor made from the number of households/persons, and assumptions on the average weight of the products and the number of products bought per year. Due to this procedure the private consumption of "bed linnen" etc. was adjusted from 4 863 tonnes to 7 760 tonnes.

Use by 810000 Service to buildings, cleaning

Information from Planmiljø on the textile use by one of the major companies within industry *810000 Service to buildings, cleaning,* was used to adjust the initial data based on the national accounts since the initial data seemed quite

out of proportion. The total input of textile products was adjusted from more than 7 000 tonnes to 563 tonnes. In combination with the adjusted private consumption of "bed linen, etc." it seems to give an overall more reliable allocation of the textile use.

Removal of textile products from the assesment

Product inputs, which are assumed to be for further processing or sale has been eliminated as far as possible. Thus, the amounts of all textile products used by industry *140000 Manufacture of wearing apparel* has been eliminated from both the supply (imports) and use. The background for the elimination is an assumption that the inputs have been used for processing or sale and not as work wear by the employees in the industry. In total 1 248 tonnes of textile products were removed from the supply and use for this reason[2].

Similarly, the supply and use of "other furnishing textiles" was adjusted from 5 222 tonnes to 3 907 tonnes. The adjustment was in this case made because the basic data on import showed that part of the import was used with the purpose of further processing.

Unspecified uses of textile products

The initial national accounts data for use of textile products includes a category of unknown uses. This is the total uses by a large number of industries, for which no specific information about the uses exist. The total unspecified uses were 3 500 tonnes. This corresponds to 1.7 per cent of 202 100 tonnes of total uses of textile products. In order to arrive at a full specification of the uses, the unspecified uses has been allocated to the specific uses by assuming that it is used proportional to the other uses. Although it leads to some overestimation of the uses of the specific industries and the households, the advantage is that the the quantity of the total uses corresponds to the quantities of the total supply.

Uncertainties

It should be emphasised that the uncertainty of these data is big.

The imports and exports data are the most reliable. Data on Danish production is estimated from monetary data and some extra uncertainty are therefore added to the quantity data. Uncertainties on the basic data on foreign trade and Danish production spills over to the estimation of the total domestic Danish use of textile products (Danish production + imports – exports).

The allocation by households and manufacturing industries are to some extend covered by statistical data (survey of use of products by manufacturing industries) and Household Budget Survey), although a conversion from monetary units (DKK) to quantities (tonnes) are involved.

The allocation by other industries (agriculture, service industries, etc.), government consumption, investments and changes in inventories are made based on the allocation of monetary values as described in the monetary supply and use tables of the Danish national accounts. The allocation of the physical use of textile products based on the monetary values for these categories involves very big uncertainties. First of all the monetary information from the national accounts is not always based on recent basic statistics but rather on older surveys,

[2] The removal of all textile products from the inputs is however not entirely correct, since it is likely that some use of work wear takes place in the industry. But overall, it seems more correct to make the adjustment since the inputs are to be interpreted as physical use of textile products.

assumptions and imputations, which may be out-dated. Further, the conversion from monetary data to phyical data involves an assumption of homogenous prices for all uses of a specific textile product at the national accounts' product level, i.e. 44 textiles products groups. Although the assumption is probably not that far from reality, since basic prices (i.e. excluding taxes, VAT and trade margin.) are used for the allocation, it may involve some misallocation, since the product groups are not completely homogenous.

Use and analysis of the resulting data should be done with these big uncertainties in mind. **The data represents some orders of magnitudes only.** Although the data has been collected and estimated at a very detailed level, interpretation of the data can only be done at a much more aggregated level. For instance, the distinction between use of textiles by hospital activities and residential care activities in the detailed data are very uncertain. Thus, it is more sound to look at the total use of textile products by all human health activities.

Mapping of textile flows in Denmark

The report gives a detailed overview of flows of new and used textiles in Denmark. The scope covers clothing and household textiles (bed linen, towels, tablecloths, curtains, etc.) purchased by households, business and the public sector. In 2016, total consumption of new textiles in Denmark amounted to 85 000 tonnes, of which households purchased approx. 75 000 tonnes, business 5 000 tonnes, and the public sector approx. 5 000 tonnes. Household textile consumption is equivalent to every inhabitant purchasing 13.2 kg of textiles on average, while total textile consumption across all sectors amounted to 15 kg per person.