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Swedish Chemicals Agency

Chemicals in a circular economy

Case studies of closing the loop

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Swedish Chemicals Agency

The Swedish Chemicals Agency is supervisory authority under the Government. We work in Sweden, the EU and internationally to develop legislation and other incentives to promote good health and improved environment. We monitor compliance of applicable rules on chemical products, pesticides and substances in articles and carry out inspections. We review and authorise pesticides before they can be used. Our environmental quality objective is A Non-toxic Environment.

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Preface

This study was commissioned by the Swedish Chemical Agency and conducted by IVL Swedish Environmental Research Institute.

In this study cases of (almost) closed material loops have been identified and described. The cases include loops with collection and recycling of products and materials that have reached the end of their life cycle, with little or no down-cycling of the material in the loop. The aim of this report is to support further policy developments in the field of a non-toxic circular economy.

The scope and the focus of the report has been defined by the Swedish Chemicals Agency in collaboration with the Swedish Environmental Protection Agency, but the study has been conducted by IVL. There has been a continuous dialogue between the consultant and the agencies throughout the project period. However, the analysis, reasoning and conclusion presented in this report is the sole responsibility of the authors, IVL. Any opinions and conclusions expressed in this report are those of the consultant and do not necessarily reflect or represent the views or opinions of the Swedish Chemicals Agency and/or the Swedish Environmental Protection Agency.

IVL would like to acknowledge the significant contribution from all the companies that have participated in the surveys and interviews organized throughout this project.

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Glossary

ABS	Acrylonitrile butadiene styrene
AFIRM	The Apparel and Footwear International restricted substance list Management
APEOs	Alkylphenol ethoxylates: compounds used (outside of the EU) in detergents, cleaning agents and textile or leather production, most often used in the textile industry are nonylphenol ethoxylates and octylphenol ethoxylates
DINP	Diisononyl phthalate
EPEAT	EPEAT is a leading global ecolabel for the IT sector
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
EU	The European Union
EUMEPS	European Manufacturers of Expanded Polystyrene
FNI	Property related collection (Fastighetsnära Insamling)
GC	Gas chromatography
HP	Hewlett Packard
ITE	Information Technology Equipment
IVL	The Swedish Environmental Research Institute
PA6	Polyamid 6, one of the most common polyamides
PA66	Polyamid 66, one of the most common polyamides. Often used when PA6 reaches its temperature limit
PAH	Polyaromatic Hydrocarbons
PC/ABS	Acrylonitrile butadiene styrene/ polycarbonate blend
PE	Polyethylene
PET	Polyethylene terephthalate
PFAS	Per- and polyfluoroalkyl substances
PfR	Paper for Recycling
PMMA	Polymethacrylic acid
POP	Persistent Organic Pollutants, as regulated under the Stockholm convention
PP	Polypropylene
ppm	Parts per million
PS	Polystyrene
PVC	Polyvinylchloride
R&D	Research and Development

REACH	Registration, Evaluation, Authorisation and restriction of Chemicals, an EU regulation
RISE	Research Institutes of Sweden
RoHS	Restriction Of the use of certain Hazardous Substances in electrical and electronic equipment, an EU directive
RSL	Restricted Substance List (a list of chemicals that should not be included in a certain product or material, common for example in the clothing and apparel industry)
SGÅ	Svensk Glasåtervinning AB
SIPTex	A Vinnova financed project that is responsible for developing the world first full-scale automated textile sorting facility, located in Malmö, Sweden
UBC	Used beverage cans
UK	United Kingdom
WEEE	Waste Electrical and Electronic Equipment
XRF	X-ray fluorescence
ZDHC	Zero Discharge of Hazardous Chemicals, a not for profit organization focused on the use of safe chemicals, smart processes and safer and cleaner products within the fashion and footwear industry

Sammanfattning

I detta projekt har IVL på uppdrag av Kemikalieinspektionen identifierat och beskrivit flera (nästan) slutna materialkretslopp för att bättre förstå hur dessa kretslopp är uppbyggda, vilka drivkrafter som funnits för att skapa dessa kretslopp och hur företag hanterar den potentiella förekomsten av oönskade kemikalier i materialströmmarna i dessa kretslopp. Uppgifterna i detta uppdrag kommer från undersökningar och intervjuer som IVL har genomfört med företag som arbetar med (nästan) slutna kretslopp inom följande branscher: Elektronik, emballage för mat och dryck, papper och kartongprodukter, bygg- och konstruktionsprodukter samt kläder. Företag som är verksamma i Sverige och EU prioriterades.

De vanligaste drivkrafterna för att sätta upp dessa kretslopp inkluderade:

1) Ett ekonomiskt incitament eftersom det återvunna materialet är billigare än jungfruligt material
2) Ett behov av att följa regler och uppfylla utökat producentansvar
3) En intern önskan inifrån företaget att bli mer hållbart

För vissa företag drevs initiering och hantering av dessa kretslopp av en mindre grupp inom företaget, medan andra företag hade hela sin affärsmodell byggda kring återvinningsprocessen.

Kretsloppens struktur och antalet intressenter skilde sig också mellan de exempel som presenteras i denna rapport. I de mindre kretsloppen hanteras ofta mer specifika material som kan komma från ett begränsat antal källor. I dessa kretslopp hade säljaren av det återvunna materialet ofta större kontroll över det material som ska samlas in och hur och var det ska bearbetas igen. I de större kretsloppen ses materialet som ska återvinnas mer som en traditionell vara som säljs från en leverantör till en producent. Anskaffningen av material för att omarbeta i dessa större kretslopp är bredare och flera olika strömmar av återvunnet material accepteras.

I de flesta kretslopp som presenteras i denna studie kan oönskade kemiska ämnen förekomma i inkommande material. Detta kan inkludera farliga ämnen som producenten inte vill ha i sin slutprodukt eller ämnen som hindrar återvinningsprocessen. Urvalet av företag i studien var för litet för att dra generella slutsatser för hela marknaden om efterlevnad av lagar och regler, dessutom frågades endast de företag som intervjuades om detta. Dock gav dessa intervjuade företag intrycket att de hade kännedom om och levde upp till lagar och regler kring kemiska ämnen i deras produkter och material. Oftast är det den som ansvarar för att omarbeta materialet från avfall till ny råvara som har den bästa kompetensen i denna fråga och som säkerställer att materialet uppfyller de (kemiska) kraven från kunden. Insamling och sortering spelar en avgörande roll för att säkerställa att inkommande material inte innehåller oönskade kemiska ämnen. Företag som arbetar med helt slutna kretslopp där de samlar in och bearbetar sina egna material har fördelen att de har väldigt god kännedom om sammansättning av inkommande material.

Flera utmaningar, som kan påverka skapandet och/eller existensen av ett kretslopp, identifierades i denna studie. Dessa utmaningar inkluderar lagstadgade krav, den administrativa bördan med att upprätta och underhålla ett kretslopp, att ha ett insamlings- och sorteringssystem på plats som kan leverera det erforderliga materialet till rätt kvalitet och volym, konsumenternas uppfattning om återvunnet material (främst plast) och volatiliteten i priserna för jungfruligt och återvunna material.

Många av företagen som intervjuades påpekade att deras mål var att bli mer hållbara och att de siktar på att öka sin användning av återvunnet material. Flera av dem som skapat (nästan)

slutna kretslopp för vissa av sina produkter undersökte också möjligheterna att utöka med nya kretslopp även för andra produkter.

Summary

In this project, IVL has upon request of the Swedish Chemical Agency, identified and described several (almost) closed loops of materials in order to better understand how these loops are built. A special focus was given to identifying the driving forces for creating these loops and how companies deal with the potential presence of unwanted chemical substances in the material streams in these loops. The data gathered in this study comes from surveys and interviews that IVL has held with companies working with (almost) closed loops in the following industries: Electronics, food and beverage packaging, paper and cardboard products, building and construction products and clothing. A priority was given to companies active in Sweden and the EU.

Common motivators for setting up these loops included:

1) An economical incentive as the recycled material is cheaper than virgin material
2) A need to comply with regulations and fulfil extended producer responsibility
3) An internal desire from within the company to become more sustainable

For some companies, the initiation and management of these loops is handled by a small group within the company, while others have their entire business model built around the recycling process.

The structures of the loops and the number of stakeholders involved in the loops also differed between the examples presented in this report. In the smaller loops, more specific materials are often handled which can come from a limited number of sources. In these loops the seller of the recycled material often has a greater control of the materials that are collected and how and where to re-process it. In the larger loops, the material to be recycled is more seen as a traditional commodity that is sold from one supplier to a producer. The sourcing of material to re-process is wider and several different streams of recycled material are accepted.

In most of the loops presented in this study unwanted chemical substances can be present in the incoming materials. This could include hazardous chemical substances that the producer does not want to have in their final product or chemical substances that hinder the recycling process. The selection of companies within the assignment was too small to draw general conclusions on compliance with rules and regulations for the entire market, in addition only the interviewed companies were asked about this. However, the interviewed companies gave the impression that they were aware of and lived up to laws and regulations regarding chemical substances in their products and materials. Most often it is the party responsible for re-processing the materials from waste to new raw material that has the best expertise on this matter and that assures that the materials comply with the (chemical) requirements of the customer. Collection and sorting play a crucial role in ensuring that the incoming materials do not contain unwanted chemical substances. Companies working with entirely closed loops in which they collect and reprocess their own materials have the benefit that they have a very good knowledge of the composition of the incoming materials.

Several challenges were identified which can affect the creation and/or existence of these loops. These include regulatory requirements, the administrative burden of setting up and maintaining a loop, having a collection and sorting system in place that can supply the right quality and volume of the required materials, consumer perception of recycled materials (especially plastics) and the volatility of the prices for virgin and recycled materials.

Many of the companies interviewed indicated that their goal was to become more sustainable and that they are aiming at increasing their uptake of recycled materials. Those that have

created (almost) closed loops for their products were also looking into possibilities to setting up new loops for other products in their portfolio.

1 Introduction

With regards to implementing a circular economy in which materials and products are recycled, it is important to take into account that these materials and products can contain hazardous or other unwanted chemicals that should be removed from the loop. This could for instance include chemical substances that are banned for use today, but which were not regulated at the time or place at which the production of these products and materials took place. Unwanted chemicals could also include chemical substances that are harmless from the perspective of human health or environmental impact, but which could negatively affect the properties and quality of the new materials. This includes for example, chemicals that influence the colour, smell or strength of the newly produced materials.

Today, the collection of waste is often done in broad categories in which materials with different properties and compositions are mixed, to ensure that that a large enough volume of waste is collected, so that the collection and recycling of these materials becomes economically viable. The downside of this strategy is that materials that once might have had the ideal composition for a certain type of product, e.g., food packaging material, are in this way mixed with other materials that might make it impossible to use the recycled materials as food packaging ever again, unless their waste streams are thoroughly sorted or pre-treated.

One way of assuring traceability and maintaining the high value of materials is by implementing (almost) closed loops, in which certain products are collected as separate waste streams and then recycled into new versions of the same product or new products with a similar value. A classic example of such a loop are bottle deposit schemes in which consumers return their PET bottles to separate collection points, after which the materials can be shredded, washed and turned into new PET flakes and eventually new PET bottles.

In this project, IVL has upon request of the Swedish Chemical Agency identified and described several (almost) closed loops in order to better understand how these loops are built, what the driving forces are for creating these loops and how the involved companies deal with the potential presence of unwanted chemical substances in the material streams. The goal with the project was to increase the understanding of these systems in support of policy development to achieve a non-toxic environment in a circular economy.

2 Method

The project was initiated by the creation of a priority list of industries and products that should be included in the project. This list was made in collaboration with the Swedish Chemicals Agency. Based on this priority list, companies with relevant loops were then identified by desk research.

A priority was given to examples from Sweden and the EU and an effort was made to include examples from different industry sectors.

A survey with 20 questions was then created in Microsoft Forms and sent out by email to the relevant companies to do an initial mapping of their loops. An overview of the questions included in the survey can be found in Annex 1. Based on the results from the survey, a sub selection was made in order to decide which loops should be investigated further. Companies involved with these loops were then asked to take part in an interview with IVL.

A loop was considered of relevance for an interview if it gave the indication to comply with the following requirements:

- The products within the loop should not be niche products / produced in small volumes
- The loop has to be functional, i.e. not in the planning phase
- The products collected in the loop should be recycled to products with an equal or higher value
- The loop should not include products in which circularity is achieved solely by: 1) the biological degradation of these products, 2) the recycling of industrial chemicals within an industrial setting, 3) the re-use of production waste within an industrial setting, 4) the repair of products or the re-use of component or parts of the products.

The interviews were conducted to get an understanding of what drives companies to set up these loops, how these loops are constructed and how companies deal with the potential issue of unwanted chemical substances. It was not part of the project to identify and discuss specific regulatory requirements for the respective products and materials, or go into details of the analytical tests that the companies do to check that unwanted chemical substances are not present in the final product above certain concentrations.

3 Results

3.1 Priority list of industries

The following industries were prioritized in this project:

- Electronics
- Food and beverage packaging, including aluminium cans, PET bottles, glass bottles and cardboard
- Paper and cardboard products
- Building and construction products, including concrete, asphalt, gypsum, flooring, pipes, glass, and isolation
- Clothing

In total 56 surveys were sent out to companies thought to be involved in (almost) closed loops in the prioritized industries. Of the surveys that were sent out, 25 answers were received, leading to a response rate of 45%. The companies found relevant for the study and that gave the approval to have the results made public, are included in the following sections.

Based on the results from the survey, 14 interviews were also held with companies whose loops were prioritized for further analysis. Two of the interview results were later left out as they were found to be outside the scope of this study.

3.2 Examples of (almost) closed loops

Below, a summary is given for each of the loops identified with the help of the surveys and interviews. These summaries reflect the opinion of the companies interviewed and not those from IVL. In several cases, the companies have indicated that they would prefer to remain anonymous, in that case their name and other sensitive information that could be used to identify the company has been removed. An overview of all the interview and survey included in this study is presented in table 1.

Table 1: Overview of loops included in this report. Please note that this overview only focusses on selected topics of the surveys and interviews. More details and other topics regarding the loops are presented in the summaries for each loop.

Category	Loop	Company name	Handling of chemicals	Challenges mentioned	Survey/Interview results*
Building and construction industry	EPS insulation and packing material	BEWi ASA	Testing of incoming materials	EPS is not sorted out enough, demand for recycled material needs stimulation, negative consumer attitude towards plastic	Interview
Building and construction industry	Plasterboard	Anonymous	Testing of incoming materials	Not mentioned in the survey	Survey
Building and construction industry	PVC and textile flooring	Tarkett AB	Not mentioned in the survey	Not mentioned in the survey	Survey
Clothing	Cotton and viscose	Renewcell	Certification of suppliers, testing of product and wastewater	Sorting out the right materials that they can use as input	Interview
Clothing	Jeans/denim	Nudie Jeans	Strict chemical policy to suppliers, intake of recycled materials limited to own products	Sorting of materials, Product development, limitations on styles and quality	Interview
Clothing	Wool	Filippa K / Manteco	Continuous testing of incoming fabrics, strict chemical policy to suppliers, intake of recycled materials limited to own products, testing of waste water effluent	Potential for unwanted chemicals in post-consumer textiles, Product design to allow for recycling, administrative costs	Interview
Clothing	Polyester/cotton	Anonymous	Not mentioned in the survey	Not mentioned in the survey	Survey
Clothing	Polyester / wool	Houdini Sportswear	Not mentioned in the survey	Not mentioned in the survey	Survey

Electronics	Ink and toner cartridges, printers, computer casings	Hewlett Packard (HP)	HP only uses materials from its own products so they have good knowledge on the composition. Unwanted chemicals not considered an issue.	Collecting enough materials, customer demand for recycled plastics	Interview
Electronics	Plastics from electronic waste to new electronics	Recipo	Substances limited by RoHS and the POP convention are checked for and removed during the recycling.	Adjusting the recycling process to the incoming material	Interview
Electronics	PP from food packaging to household products	AB Electrolux	In-going material tested to be RoHS-compliant, strict control on incoming materials	Not mentioned in the survey	Survey
Food and Beverages	Aluminium cans	Novelis Europe	Decoating of incoming materials, routine testing of materials, control systems on incoming materials	Not mentioned in the interview	Interview
Food and Beverages	PET bottles	Veolia PET Svenska AB	Use of recycling method assessed by EFSA, requirements for chemical analyses and migration tests, separate collection of the materials	Negative consumer attitude towards plastic, Technical challenges with recycling other materials	Interview
Food and Beverages	PET bottles	Petainer	Supplier certifies that materials meet requirements for food contact materials, migration tests, strict control of other chemicals used in the production process (e.g.	Decreased supply of recycled material if demand rises	Interview

			cleaning products for the tools), separate collection of the materials		
Food and Beverages	PET bottles	Orkla	Separate collection of the materials, chemical analysis, certification of materials, migration testing	Takes resources and time to replace a virgin material in a product with a recycled one, use of other recycled polymers than PET in food packaging	Interview
Food and Beverages	Glass packaging	Ardagh group	Suppliers sort materials, Internal and external analyses of materials	Global harmonization of chemical legislation	Interview
Food and Beverages	PET bottles	Anonymous	Use of recycling method assessed by EFSA, Continuous testing with chemical analyses	Not mentioned in the survey	Survey
Other	Aluminium for automotive applications	Anonymous	Not mentioned in the interview	Not mentioned in the survey	Survey
Paper and cardboard	Paper for print	Anonymous	Incoming materials are sorted, chemical analyses of rejected streams	Rapid changes in the legislation and specific requirements make it difficult to navigate, relies on the sales of newspapers and magazines	Interview
Paper and cardboard	Cardboard	Fiskeby AB	Regulation on incoming materials, pre-treatment of materials to remove unwanted materials	Not mentioned in the survey	Survey

** Survey results usually do not cover how chemicals are handled nor what the challenges were in setting up the loop / maintaining it.*

Apart from the more detailed description obtained through interviews with the companies the results section also includes shorter summaries of cases in which only the surveys were used to collect information. These summaries are often limited to a description of the loops and production volumes and do not include aspects such the driving forces behind setting up these loops, or challenges that needed to be overcome, as these aspects were not included in the survey. The results from the survey were included to give an example of other loops that are in existence. It was not possible within the framework of this project to describe these loops in more detail.

3.2.1 Electronics

3.2.1.1 Hewlett Packard (HP) (Interviewed)

HP uses recycled plastics in many of their products, with 9% of all plastics used in production in 2019 being recycled plastics. The goal for 2025 is that this fraction is increased to 30%. Some of HPs most established closed loop programs are those for supplies such as toner and ink cartridges which often contain a single type of plastic in combination with an electronic component.

The collection of these products has been in place since 1991 under the Planet Partners program, which offer a no-cost return and is currently available in 68 countries. Commercial companies or public sector organizations with large offices often collect the used products and then ship larger amounts by truck, while private consumers have the option to send in their used products by mail. HP then ensures that these products are recycled and not sent for landfill. Partner companies that recycle these products (in Europe, toners are recycled in France and ink cartridges are recycled in Germany) have a contract with HP, which states that they should follow HPs global standard for vendor requirements for hardware recycling. This standard outlines amongst other things how different components should be handled and ensures that the materials are recycled in a correct way.

As of 2011, HP also uses the recycled materials directly in the production of new toners and ink cartridges, thereby effectively closing the loop. This required the development of a cartridge disassembly machine and overcoming the logistics of a reverse supply chain. In addition, there was a need to team up with a skilled plastics compounder that could turn the resin with new and recycled content into a material that could meet the technical specifications for the intended application. As HP currently only uses materials from its own products, it has a good overview of the chemical composition of the incoming materials. The presence of unwanted chemical substances is therefore not a large concern.

In addition to re-using materials from toners and ink cartridges HP also uses materials from recycled PET bottles, ocean bound plastics (i.e. plastics that are at risk to end up in oceans, e.g. littered plastic bottles) and clothes hangers to produce new toners and ink cartridges. Over 80% of HP ink cartridges and 100% of their toner cartridges currently contain recycled plastics. The fraction of recycled post-consumer plastics can range from a few percent in toners to 70% in ink cartridges. The recycled content in toner and ink cartridges is outlined in specific documents available at HP.com. The amount of recycled content for hardware products (such as printers and computers) is made public in a products' ECO declaration.

More recently HP has also looked at the collection and recycling of printers, which contain larger amounts of plastics than toner and ink cartridges and PCs, and often have a similar composition even when produced by other companies. In 2017, HP produced the first printers containing recycled materials from collected printers. Plastic that has been used in IT products and then recycled and used again in the same type of IT product is referred to as ITE derived post-consumer recycled content, which is a criterion in EPEAT, a global ecolabel for IT products. EPEAT is managed by the Green Electronics Council. The recycled materials are often shipped to Asia where most of the production takes place.

The main motivation for HP in setting up these loops is to increase the fraction of recycled materials in their products to reduce their climate footprint and their overall resource consumption. Setting up these loops can be a challenge. HP has taken on a strategy to start simple, looking at toners and ink cartridges and then moving to more complex products such as printers with outer cases in plastic. But even so, their first closed loop took 5 years of development and the next one close to 4 years. On an organisational level this requires a collaboration between HPs sustainability teams and inhouse experts on plastics, toners, ink cartridges and the development of take back systems.

An example of a challenge mentioned by HP in setting up these closed loops are the taxes on chemicals in electronics which are required in Sweden. These do not seem adapted for refurbished products, as the producer of these products would have to pay taxes twice. Once when the product is produced for the first time and once again when a refurbished product is put on the market. To make these loops financially feasible also requires that large volumes of materials can be collected and that customers are driving a demand for recycled plastics.

3.2.1.2 Recipo (Interviewed)

Recipo is part of a loop for electronics that helps companies comply with their extended producer responsibility. Recipo recycles the plastic components of the electronic equipment. The collection and dismantling take place in Sweden followed by recycling to plastic pellets in Latvia. The recycled plastic pellets are then sold to electronic companies in China which use them in the production of new electronics products. The fraction of recycled materials varies with the products they are used for.

Recipo only collects electronic waste according the WEEE directive[1] (Waste Electrical and Electronic Equipment) for different electronics companies. The electronic waste is sent from stores to two partners, Mirec and Kuusakoski who pre-treat and sort the electronic waste in different fractions, e.g., dismantling and separation of metals. The plastic fraction is then sent to Recipo's facility in Latvia where it is recycled. The waste is first size reduced through shredding, then washed and then sorted by plastic type using density bath and electrostatic sorting. After extrusion of the various fractions, plastic pellets of ABS, PS, PC/ABS or PMMA are obtained. Out of these, ABS and PS are the easiest to obtain. Recipo states that the recycled plastic pellet is at least 98% pure after the process (e.g. 98% ABS content). Substances regulated by the RoHS and the POP convention are checked for and separated during the recycling. For example, about a fifth of the in-going material is made up of a high-density fraction, e.g. plastic treated with brominated flame retardants, which is separated in the density baths and sent for incineration. No specific analyses are made to check for additives outside of these regulations.

Recipo's prognosis is that they will handle 500 tonnes of raw material per month, which translates to 6 000 tonnes per year, out of which 3 000 ton of plastic pellets are produced. The rest of this fraction will be incinerated. Next year the production is planned to double.

The main reasons for establishing the loop is that Recipo enables producers to fulfil their extended producer responsibility, but also the fact that the recycled material is cheaper than

[1]European Parliament and the European Council (2012), Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) Text with EEA relevance, OJ L 197, 24.7.2012, p. 38–71

pellets from primary sources. According to Recipo there is no down-grading of the material which is recycled, as it is sold to be used in new electronics. What is uncertain at the moment is how often a material can pass through the same loop with this recycling method while still resulting in high quality materials.

The preparation for setting up the recycling has been ongoing for almost two years. Recipo stated that one of the challenges was that the process had to be adjusted depending on the quality or composition of the incoming material delivered. The waste from the two dismantlers (Mirec and Kuusakoski) also differed, which meant that the entire process in Latvia had to be adjusted depending on supplier streams.

Environmental compliance has so far been achieved by taking in consultants, but there are plans to recruit an environmental compliance officer by the beginning of next year to get a closer control on required documentation, e.g., to comply with RoHS legislation[2].

In the future, Recipo would like to develop the process and add the recycling of PP and PE. They also want to keep developing the existing process to recycle as much as possible and produce a high-quality material.

3.2.1.3 AB Electrolux (Survey results only)

AB Electrolux uses polypropylene (PP) from food packaging together with calcium carbonate to produce a construction material used in the production of household products. The materials from the manufactured household products can be re-used afterwards in similar applications. However, as the lifetime of these products is more than 10 years, they have not had the chance yet to collect them. Food packaging collection is part of the producer responsibility in the southern Europe. The collected materials (non-coloured food packaging material) are processed by a recycling company and Electrolux compounds via a third company in Italy and Poland, with ca. 5 000 tons produced in 2019. The materials that are produced from recycled plastics are currently only used in parts of the construction, but Electrolux is aiming at increasing the fraction of recycled content in their products by also using the material in detail work. The incoming recyclate is tested before use with regards to RoHS compliance. The materials also need to comply with specific requirements from AB Electrolux on traceability and the presence of chemical substances. No treatment of the materials is considered needed to remove unwanted chemicals.

3.2.2 Food and beverage Industry

3.2.2.1 Aluminium cans

3.2.2.1.1 Novelis Europe (Interviewed)

The company Novelis Europe is a producer of aluminium can body sheets from used beverage cans (UBC), and other aluminium products recycling and production. There are three main types of aluminium: cast, extruded and sheet applications. Novelis only deals with sheet aluminium, such as the type used in drink cans, automotive body panes (not engine blocks), train sidings, etc. Aluminium can body sheets are a semi-finished product that is subsequently converted by specialist can-making companies to make new aluminium cans. Novelis Europe only works with aluminium and focuses on the buying and recycling of scrap

[2]European Parliament and the European Council (2011), Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, OJ L 174, 1.7.2011, p. 88–110

(no mining nor midstream). Primary (virgin) aluminium is also used, but it is not their specialty.

Novelis collaborates with the Swedish company Returpack to collect and transport the used beverage cans. The collection of used beverage cans (UBC) is done in Sweden. The re-smelting and production of aluminium can body sheets is done in the Nachterstedt recycling/reprocessing facility in Germany which is the world's largest single site for aluminium recycling with an annual production capacity of 400 000 tons. The average recycled content of post and pre-consumer aluminium in European production is 80% in accordance with ISO 14044 (LCA). The ingoing material needs to be treated before re-smelting due to paints and lacquers present on the used beverage cans. To achieve this the paint and lacquer are removed by blowing hot air (around 550°C) through shredded aluminium on a slowly moving insulated conveyor. The exhaust gases from the process are first passed through an afterburner, before being used to heat up incoming process air using a heat –exchanger, thus minimising the energy requirements of the system. Any waste gases from this decoating operation is removed from the plant and treated in a purpose-built emission abatement facility. Novelis Europe indicated that there is no risk of having unwanted chemicals in the material collected.

As a material used in applications, aluminium is always alloyed. Different applications use different types and ratios of alloys, which is why it is important for these waste streams to be separated properly from each other (and from other metals and materials). An example where this does not work properly is for vehicles where e.g. the engine block, copper-based alloys in body panels, and other parts are shredded together. If not separated properly, mixed aluminium waste can cause problems in this regard.

The whole infrastructure is built on the idea of recycling the scrap consumed and minimizing virgin aluminium. Novelis Europe’s goal is to source the scrap. As a company with no primary aluminium activities, it is financially more attractive as well as environmentally sustainable to use scrap than purchase primary aluminium from competing companies. Novelis’s ultimate goal is sustainability, which benefits both the environment and business in the case of aluminium recycling. One driving force is the high commercial value of recycled aluminium, which is even higher than that of recycled plastic, steel, or glass. Those elements sustain the well-functioning system. There is also a lack of complexity in aluminium cans as they contain similar alloys in every EU member state. Although the can producers have different suppliers, the can itself is very uniform. In the last years, an effort has been made to reduce the amount of material needed to produce the product, and there is the hope of future innovations in which both the alloys in the body and the ends can be homogenized to further increase their recyclability.

When more actors are involved in the different stages of recycling it means that each actor gets a smaller portion of the total value of the recycled material, due to e.g. more touch points for quality control. Shorter value chains, such as for UBC, ensure a high quality and a high return according to Novelis.

Novelis states that on average, 59 % of aluminium is sourced from scrap and the rest from primary sources. Cans contain an especially large fraction of scrap material, 80-90 %, while other applications, such as automobiles (55 %) or aerospace, contain much smaller fractions.

Novelis has ten plants around the world and their goal is to aim for 100 % collection of used beverage cans. Collection today is 75 % in Europe, although some of the remainder is probably recycled anyway. The UBC business is a growing market, especially in Spain and France in which Novelis will need to invest more into collection.

Paint and lacquer are unwanted, but do not produce any dangers after being removed in the oven reaching 700ºC. There can also be other forms of branding, which requires removal processes. To make the cans suitable to contain beverages they need to be lined with a coating, which also needs to be removed before recycling. Scrap contaminated with oils can be recycled but will contain a larger fraction of aluminium oxide. Lead is prohibited today, but there could be older scrap that might still contain it. Lead is not present in the food-packaging segment. Novelis pointed out that routine tests are made to make sure that the materials meet quality standards. The testing is motivated primarily to avoid the economic losses of a bad batch. There are also specific requirements when it comes to radioactive materials such as those used in fire alarms, as they could make their way into the waste stream. Control systems are in place to ensure the removal of these radioactive materials before re-melting

3.2.2.2 PET-bottles

3.2.2.2.1 Veolia PET Svenska AB (Interviewed)

Veolia PET Svenska AB produces (PET) flakes from post-consumer PET beverage bottles. They collaborate with Returpack that collects and sorts PET bottles in Sweden. The production of (PET) flakes amounts to 25-28 thousand tons/year and the flakes are sold to producers of preforms. Veolia has a very well-functioning loop with a collaboration, which has been going on for a long time. There is a shared responsibility on all decks, meaning volume wise, quality wise and financially wise. Veolia's part of the responsibility is to process the bottles into a food-grade recycled PET and ensures that the secondary raw material does not contain any unwanted chemical substances that have migrated in the material. What is to be controlled is governed by legal requirements that the industry needs to comply with (e.g. food packaging legislations, EFSA safety assessment of recycling processes and EFSA opinions on substances to be used in food contact materials). Veolia says that there are requirements that at least 95% of the recycled plastic must come from original bottles that contained beverages (from food containers), and max 5% bottles from (other feedstock) containers that have contained shampoo or detergent is tolerated by EU regulation (EC 282/2008[3]).

There are no unwanted chemicals in the material collected according to the company and regular cross-measurements are done by external labs to verify this. One chemical substance that must be checked for, is for example benzene, which could migrate from the ink at the labels of PET bottles or PVC in the recycled product. Benzene can migrate and accumulate into PET. Due to that reason Returpack does not allow any PVC labels on their bottles. Veolia controls all batches and measures quantities to ensure the regulated substances are below limit values (analysed using GC), thus benzene, for example, is not a problem for the company since the regulated levels in the plastic are never exceeded. Veolia analyses the material continuously and has its own laboratory, as required by EU legislation. Analyses are done in own labs as well as in external labs. Veolia is obliged to send a certificate to the customer, where the analysis results are included for the specific batch (declared that they are below any limits). Aside from working with external labs, Veolia possesses all the expertise needed.

Veolia states that the model that exists today for PET bottles has successfully enabled the re-use of PET in a bottle. Returpack combines the interest of the bottle producers in the market with regards to sustainability on all levels. The system has a very well-functioning loop and is

[3] The European Commission (2008), Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006 (Text with EEA relevance), OJ L 86, 28.3.2008, p. 9–18.

not concerned with any obstacles. However, the attitude among consumers to plastic and plastic use is crucial for the loop to work as it does today. It is important that consumers understand how PET can be reused. In comparison to other packaging materials, such as aluminium and glass, less energy is needed to recycle a PET bottle according to Veolia.

The company strives to recycle more and not only the bottles. E.g. the bottle caps included in the collected material are based on PP or HDPE and since the caps are made from a different plastic a different recycling loop is needed. This is not yet a cradle-to-cradle loop, but it could be produced from recycled material. Veolia is a large company and has activities with PP, PE, HDPE as well. However, these materials are more difficult to recycle. Materials such as HDPE tend to absorb and migrate substances to a greater extent than, for example, PET material which is more chemically inert. HDPE also tend to absorb odours. Veolia is working on the technical challenges that exist to overcome these problems.

3.2.2.2.2 Petainer (Interviewed)

Petainer is a Swedish company that produces PET preforms and PET bottles from virgin resin and recycled PET bottles. The companies Returpack and Infinetum (Norwegian) collect and sort the PET bottles from the return deposit schemes. Veolia then processes the PET bottles to produce recycled PET flakes, allowed for food contact materials, while Petainer used the PET flakes to produce PET preforms and bottles with up to 100% recycled PET material. In 2019, the production of preforms and bottles was 5 260 tons. In 2020 the production is higher. According to Petainer the material is processed to get rid of unwanted chemical substances, in the recycling processes used at Veolia PET[4] and other recycling plants. Petainer works closely together with Returpack and Veolia. The Bottle-to-bottle co-operation group addresses the challenges facing the various actors. This has led to a good understanding of how different actors affect one another and that they can do a better job. There is a flow of information of for example quality issues and other aspects that may affect the recycling process. Returpack and Veolia have made large investments in quality (e.g. in improving the sorting processes), based on the outcome of the bottle-to-bottle group.

From a company perspective, Petainer strives to be environmentally efficient and have a sustainable and safe product. Two types of materials are used in the production of recycled PET bottles; PET from Veolia and a PET material already pelleted. The PET flakes from Veolia are washed, coated with a solution of caustic soda, extruded to pellets and finally polymerized together with the recycled pelleted PET material. Petainer uses a combination of both to get a 100 % recycled product

According to Petainer, the properties of the PET bottles do not appear to deteriorate during recycling in tests, aside from getting a slightly yellower tone after several loops. PET properties can be boosted during process and trials are on-going to validate the degradation of PET during recycling process. Virgin material is quite clear, while recycled material allows the product to become greyer. Petainer explained that a certain amount of foreign material is allowed in the specification for recycled material, e.g. small amounts of PVC or PP. This can contribute to visual defects but does not affect the function of the PET bottles. It is up to the consumer to accept a visually different product.

It is up to the supplier (Veolia) to send documentation (certificates) to their customers ensuring the products meet the existing requirements for food contact materials says Petainer. External laboratories perform some of the company's tests, e.g. migration tests when changing

[4] An overview of Veolia's recycling process for PET bottles can be found here: http://www.cleanaway.se/urrc-en-gb/

the process. It is important that all chemicals (e.g. tool cleaners) used in the process of PET production are approved for food contact materials and follow the standards and requirements that exist for the industry. The end users (those who place the PET bottles on the market) are responsible for showing that the products comply with the regulations. Petainer has the required expertise with regard to relevant legislations.

For Petainer, the driving forces to set up the closed loop with PET bottles are both intra-corporate and market driven. The company strive to have a product as sustainable as possible with minimal environmental impact. Petainer also wants to show that they have a sustainable product, given peoples view on plastic as sustainable or unsustainable. Customers' desire to have an environmental profile increases, which leads to an increased demand for a 100% recycled product. Most customers will want part of their product portfolio to be 100% sustainable. An additional driving force is for customers to be able to market themselves as a producer that has sustainability in mind. Petainer sees itself as a customer of the recycling system. Petainer depend on consumers continuing to order their products and on quality. At the same time, there is also a concern for the possibility that if more customers want to add recycled material, the less material will be available on the market. In that case there will likely be a need of supplement of virgin materials to some extent. Furthermore, the greater the demand, the more players there are, and the risk of fraud increases (even in the production stage). Petainer works closely with their suppliers to ensure the origin of material.

3.2.2.2.3 Orkla (Interviewed)

Orkla uses recycled PET-bottles as containers for some of their products. Orkla buys preforms, which are then blown onsite into new bottles. These bottles are sorted (by the consumers) and will eventually come back to the company as new preforms (PET). The collection, sorting, distribution and processing is done by several actors. The PET-material comes from Sweden and Europe. The recycling and production take place in Sweden. Some of the PET bottles are produced from 100 % recycled material, but for other products/bottles the recycled fraction is smaller (due to challenges with barrier materials). According to Orkla, the leadership of the company is very committed to sustainability and recycling and Orkla possesses the skills in-house needed to manage this loop. Further, Orkla is represented in several industry organizations that work with the issue of recycling. They are part of industry forums and have good contact with both customers and suppliers in the matter.

The collection of PET bottles takes place in a controlled manner, which makes it possible to use PET as food packaging says Orkla. The PET system is based on the fact that all companies that are part of the system need to account for the materials they use and what the bottle has contained. Only bottles that are approved (and with the resin identification codes) are included in the deposit system. This means that companies have very good control over which materials that enters the system. In the food industry, there are strict rules regarding food packaging. Recycled packaging materials that are not traceable must not be used. Those who produce granules from collected PET bottles are required to check, analyse and certify (via certificates) what the composition of the PET granules is. Food producers are required to certify that their packaging is approved according to current legal requirements, standards. Orkla identified that there might be problems with unwanted chemical substances in the material such as dyes. This issue is addressed by those companies in the loop that collect and supply the recycled materials. These companies perform migration tests on all packaging[5]

[5] See annex 1 in EU regulation No 10/2011 which gives an overview of specific migration limits. The European Commission (2011) Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food Text with EEA relevance. OJ L 12, 15.1.2011, p. 1–89.

(certified external laboratories that perform the tests). Voluntary migration tests during the inflation of the preforms are made to ensure that no chemical substances leak during the inflation process.

The driving forces for Orkla to work with closed loops come mainly from within the company. Orkla has set a sustainability goal to use more recycled materials in its packaging. They want to become a more sustainable company in the long run. Orkla is currently working to increase the amount of recycled material in their packaging. However, resources and time are needed to change the processes for switching to packaging with recycled material. For some packages, it is necessary to add barrier substances in the PET bottles to prevent air from penetrating the bottle. Adding these substances to the recycled plastic can create optical effects in the PET material that are not desirable. This is a development issue for the company, and solutions are being sought.

No major obstacles are experienced at Orkla in working with recycled material. Technical challenges have been encountered when inflating the preforms for new PET bottles, but this is seen more as a normal development work in the process. However, obstacles remain concerning the ability to use other polymers in food packaging, such as polypropylene and polyethylene, as these are not traceable in the same way as PET for which a separate collection system exists. It would have been desirable if it were possible to develop a system for these plastics as well, where the requirements placed on food packaging could be ensured.

3.2.2.2.4 A beverage producer (Survey results only)

A beverage producer currently uses PET bottles with up to 100 % recycled content, for which they work together with two other companies. They buy recycled materials at EU level, which is then used in their production facilities. Quality requirements for these materials are high, the recycling procedure is assessed by EFSA and the chemical requirements set up by the company are more stringent than those needed to comply with EU legislation. Continuous testing is used to ensure that the products do not contain unwanted chemical substances. This testing program is adjusted for the products made from recycled PET.

3.2.2.3 Glass

3.2.2.3.1 Ardagh Group (Interviewed)

Ardagh Group is a Swedish glass manufacturer who uses recycled glass (cullet). They buy crushed glass from Svensk Glasåtervinning AB (SGÅ) who collects, transports and sorts the glass as an assignment for producers and the state. The glass is collected from Sweden and most of it is recycled and produced in Sweden. A smaller amount of sorted crushed glass is shipped abroad. Just under 200 000 tons per year of new glass products are made from the recycled glass. In these products on average about 50% of the material originates from recycled glass. The fraction of recycled glass used varies depending on the colour and the available supply, as well as national legislations which sets limits on substances such as heavy metals (e.g., lead). For green glass the fraction of recycled material can be 80-90%, if more than 90% recycled glass is used the process becomes unstable due to viscosity issues in the forming process. About 10% of virgin material is needed to control the process, by compensating for the varying chemical composition in the recycled glass. For transparent glass, the recycled fraction can be 65-70%.

According to Ardagh Group, glass can be recycled because it is not destroyed or degenerated by the recycling process. It is therefore infinitely recyclable and thus save resources. The alternative to recycling the glass is to put it in landfills. Since the glass has already been melted once, the energy consumption is reduced, and it is easier to melt. In addition, there is an advantage in reduced CO_2 emissions from the melting process, both from the reduced amount of carbonated virgin raw materials needed and the reduced energy demand.

Contaminants in the glass can for example come from crystal glass, lightbulbs and bottles from abroad explains Ardagh Group. Batteries or unsolvable substances are handled by SGÅ and they therefore have some hazardous waste they must handle. The recycled glass is sorted by colour and physical contaminations (such as ceramic, plastics, metal and organic materials) are removed from the glass. Glass with higher concentrations of lead oxide are removed by advanced automatic sorting equipment. Discoloration can be a problem in uncoloured glass as green glass can enter the process (Chromium oxide (Cr_2O_3) is used as a strongly green colorant). This often limits how much recycled material Ardagh Group can use because the company must adhere to customer specifications regarding colour.

Furthermore, Ardagh Group states, lead can come from crystal glass and light bulbs. It is therefore important that the consumer only recycles container glass at the sorting station. To be able to use as much recycled material as possible it is also essential to sort coloured glass and uncoloured glass correctly. The glass is not actually affected in practice as the substances cannot migrate in the glass, but since the glass is subject to the Packaging convention, the limits of the Packaging Directive[6] apply in which the sum of heavy metals (lead, mercury, cadmium and hexavalent chromium) must not exceed 200 ppm. Ardagh Group is equipped to do their own analyses in their central lab in Germany. Raw materials and products are sent there for analysis every week. External analyses, using certified methods, are also performed by RISE.

Property-related collection (FastighetsNära Insamling - FNI, in Sweden) is done to facilitate collection, but this often leads to poor quality of the glass. Ardagh Group says that this is reflected in the materials the company gets out from the sorting process and which eventually end up in the product. There are also obstacles concerning heavy metals. Legislative requirements are relatively harmonised within Europe, but globally other countries have different requirements (including USA). When the company sells products that are on the US market, their legal requirements must be followed (100 ppm lead instead of 200 ppm lead). Thus, Ardagh Group cannot use as much recycled material as desired. The lack of global harmonization is one of the biggest problems today, for example the demand on max 100 ppm of heavy metals from the American market.

Ardagh Group is SGÅ's largest customer and sets requirement specifications. They are also co-owners of SGÅ and part of their board. When it comes to collection from consumers, the responsibility lies at SGÅ. With the producer responsibility, there are targets for the amount of material collected. The company was involved in launching Swedish glass recycling, where manufacturers of glass and their customers as well as the grocery trade are involved. The funding of the recycling system has two parts; customers pay (the material) as well as a packaging fee (on all glass containers placed on the Swedish market) which goes to the recycling system. The biggest driving force for Ardagh Group is the financial aspect of the loop, as it is a private company. But the use of recycled materials also contributes to their environmental profiling. Other driving forces are government requirements for emissions of certain substances and the trading system for CO_2 emissions.

Ardagh Group sees no problem with the loop in the future. On the other hand, one can always discuss the distances that the glass is transported in Sweden and whether it is defensible environmentally. The company further could get problems getting enough material. Right

[6] The European Parliament and the European Council (1994), European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste, OJ L 365, 31.12.1994, p. 10–23.

now, however, the recycling rate is high. The company is constantly working to develop their process and to use residual products from other processes. A solution not used in greater scale today, that might be interesting, is the process where drinking water is descaled, after which the lime can be used in glass production. Today, lime is taken from lime quarries. The use of lime from descaling processes is done today in Holland and they are also investigating the possibility to do the same in Denmark. Ardagh Group furthermore has an idea of investigating the usage of slag products from metalworking from northern Sweden, which potentially can be used when making coloured material.

3.2.3 Paper and cardboard

3.2.3.1 A large paper producer (Interviewed)

A large paper producer (hereafter referred to as "the company") collects paper from newspapers and magazines (Paper for recycling, PfR) to produce standard paper that can be used to print newspapers & magazines. Production volumes were 365 000 tons in 2019 (of which 40% recycled) and are estimated to be around 260 000 tons in 2020 (of which 30% recycled). In 2021 however, the part of the company that handles recycled raw material will be shut down due to a global decline in paper for printed newspapers. The fraction of recycled content has declined from 2019 to 2020 due to a decreased availability of collected paper waste.

The company explains that since the mid 1990's when Extended Producer Responsibility (EPR) was put into effect, the major paper producers have ensured that paper waste in Sweden is collected and recycled, for the forest companies (Skogsbolagen), through contractors for each county. In total there are 25 parts of the country which have collectors who collect and sort the newspaper & magazine waste, which the company pays for. Currently, producer responsibility for newspapers & magazines is being discussed and whether it should be abolished for newspapers & magazines in order to reduce their costs, says the company. Generally, there is one legal actor, one collector & sorter (usually the same), one producer, one printer and finally the consumer. It is important that the consumer is also an individual that recycles. The company's approach is to work with renewable materials and outcompete fossil raw materials. Generally, there is not much change due to the loop being well-established. But one possibility are "brown" qualities of paper, for which there is a factory in Poland. It depends on the consumers, what the demand is for these types of papers.

For the company, the driving force for recycling newspaper and magazine waste is that they contain valuable raw material, making it financially profitable for the actors involved. The loop is well proven to work. It is said that the fibres can be used 6 to 7 times and the process is constantly improved, potentially increasing the times the fibres can be reused. The reusability largely depends on the effectivity of the sorting. It is financially profitable to use the material again, so every actor works to make it go as far as possible.

Recycled paper is a raw material that is global, but the process works a little differently in different countries explains the company. Finland, for example, also has requirements for producer responsibility and the same method for the collection of waste (newspapers & magazines separated from other waste). In other countries, the municipality is often responsible for waste handling and sells the fractions on the open market as best they can. It thus works in the same way with the distinction being the differing laws and the collection systems have emerged.

Regarding the potential presence of unwanted chemical substances in newspapers and magazines, this is largely determined on the sorting and not by the inclusion of unwanted or hazardous substances in the newspaper and magazine waste itself says the company. Consumers are good at sorting newspapers & magazines separately and it is a generally pure fraction if it is sorted correctly. If incorrect sorting happens, it is with other waste streams such as plastic, metal and corrugated cardboard, which are generally not considered hazardous. Metals are sorted out with a metal detector, which can be recycled and can be sold as an additional source of income. Fractions that are not fibre (e.g. plastics, milk cartons) are sorted out separately in a waste stream and are mainly incinerated. This waste fraction is handled by the county's contractor for a cost to the recycler. The material is sampled and inspected before incineration.

In Sweden, the company says, there is a system where contractors are appointed to sort the material before it is sent to recycling and production. Therefore, very few dangerous or unwanted substances are found when it arrives at the company. The producer takes samples of the rejected streams to find out if there is a risk of dangerous or unwanted substances, and it is sent along to the waste handler. In the contract with the recyclers, the contractors (collectors and sorters) have a maximum limit of 1.5% for the weight of allowed "unpure" (e.g. plastic or metal) waste in the newspaper & magazine waste stream. The actual number is closer to 2%. About 80% of that is brown fibres, according to the company, usually corrugated cardboard or cardboard. The company can dissolve those materials as well without major problems, except for so-called stickies, which is a material that becomes sticky when the temperature is raised. These are found in e.g. glued cardboard boxes or sealable envelopes. Since they are not easily separated during the recycling, they pass through with the recycled fibres and can cause problems in the process equipment during production of new newspapers & magazines. The company treats the stickies by screening the materials, adding talc and interfering substances such as alum. Also, the colour can be a little different. However, the company´s quality controls do not enable those problems to arise. Thus, the company purchases service/competence to solve the issue of dangerous or unwanted substances, although the responsibility still lies with the producer as per the EPR.

One obstacle that the company points out is that there is no long-term vision for how the recycling should be handled. The company says that the rapid changes in the legislation and specific requirements make it difficult to navigate. Many rules require costly investments, which cannot be done properly in 2 years. The producer says that an investment requires 3-5 years for it to be done properly. This places the burden on the recycler, which must adapt by writing extra clauses and ”what-ifs” in their agreements with other actors. One example of this is the uncertainty caused by the discussion of keeping or discarding the EPR for newspapers & magazines, which is in the hands of the legislators. Since the newspapers & magazines must be profitable for the business to survive and thrive, it has a big effect on the producer's survival. The company admits that it is just the undecisive and short-term thinking that is the problem, not that there are ambiguities in the interpretation of their requirements.

As long as paper newspaper & magazine are sold, the loop should keep working, the company says. However, there is a risk that, in the future, fewer newspapers & magazines will be consumed. The recycling will adapt to the change in the amount of waste if this happens. In the future, they state, if the amount used by households decreases, consumers may instead throw them in the ordinary household rubbish.

3.2.3.2 Fiskeby AB (Survey results only)

Fiskeby AB produces cardboard from recycled cardboard. Fiskeby collaborates with other companies that collect the recycled cardboard. The recycled cardboard comes from Sweden and other Scandinavian countries. The production of the new cardboard takes place in Sweden (by Fiskeby) and they produce about 170 000 tons/year. The fraction of recycled materials in the cardboard is 100%. The recycled cardboard is pre-treated in water (in a large barrel) to dissolve the fibres and to remove plastics that are present in certain cardboards. If any unwanted chemical substance enters the process, the dilution effect is so large that the risk of contamination is minimal. There are rules for what may be left for recycling and Fiskeby only buys selected qualities of recycled fibre, as approved according to EN 643[7].

3.2.4 Building and Construction Industry

3.2.4.1 EPS insulation and packing material

3.2.4.1.1 BEWI ASA (Interviewed)

BEWi ASA produces and uses expanded polystyrene (EPS), also known as styrene foam, to produce building insulation, components, and packaging. Through the dedicated unit BEWi Circular (established in 2018) the company collects, compresses and recycles EPS. Through its engagement in collecting EPS for recycling, BEWi, according to the company, contributes to a more circular economy, and to making sure that EPS goes back into the economy and does not end up in nature. EPS is 100% recyclable, and it is therefore a resource that should be kept in the economy and not sent to incineration or disposal. BEWi is currently in a process to test and develop its products to increase the content of recycled materials. In some products, 100% recycled material is used, in others only 30% is used to be able to keep the same quality (e.g. insulation properties and compressive strength) of the products. The share of recycled material versus virgin material also depends on the customers' demand.

BEWi Circular's vision is to collect 60 000 tons of EPS annually (equal to the amount of packaging materials BEWi supply to the market each year). BEWi's first circular project was the recycling of fish boxes in Poland, also known as "fisklånet", in which a few tons of EPS from fish boxes were washed, compressed and extruded. The pellets were then shipped to Finland where they were extruded into new raw materials used in e.g. building insulation. During this project, BEWi saw that a requirement for success was that the supply chain works together. Therefore, BEWi has, over time, acquired several recycling companies in Europe or established own recycling facilities (in Portugal and Denmark). BEWi now has 8 recycling facilities for the collection, compression, grinding and extruding of EPS into new raw materials. Today, BEWi has a capacity of recycling 20 000 tons of EPS and they expect to reach their target of 60 000s ton in 2021.

BEWi states that circular economy is integrated in the whole value chain in BEWi, from the production of raw materials, through design and production of products, collection and finally recycling of EPS back to raw material that BEWi will use in their products. BEWi has the expertise themselves through their director of sustainability, their legal unit and their environmental managers at an operational level. BEWis key performance indicators (KPIs) include for example: Kg of material collected, kg of material recycled, and recycled content used.

Regarding contamination or hazardous chemical substances in collected materials for recycling, BEWi has high quality requirements in line with national and international regulations. For example, the fish boxes in Poland need to be washed before being compressed and extruded to remove the fish residue. BEWi can currently not use the recycled materials in the production of fish boxes, this due to the potential risks of unwanted chemical

[7] Swedish Institute for Standards (2014), Swedish standard EN 643:2014 Paper and board – European list of standard grades of paper and board for recycling, STD-100793

substances.[8] However, the material can be used in other products such as insulation material. BEWi is working on being able to use recycled content also in packaging for food.

According to BEWi, in Sweden and the other Nordic countries, there are no substances of very high concern used in EPS and the materials can therefore safely be recycled. However, in other European countries, brominated flame retardants such as hexabromocyclododecane (HBCD) could have been added to the EPS, especially in products within the construction sector. Today, HBCD is placed on REACH annex XIV and on the EU legislation for Persistent Organic Pollutants (POPs) and is not used anymore. However, EPS collected from older materials (especially from construction sites) might still contain HBCD that should not be leached and should be treated as hazardous waste. Today, there is a European pilot plant, funded by the association for European Manufactures of Expanded Polystyrene, with the purpose of extracting HBCD through chemical recycling. To secure that EPS with HBCD does not enter the collection stream, BEWi has a quality system in place to ensure the contents of the collected material. This is done by testing the materials either at the companies where the materials are bought or at BEWis own facilities. The tests are either done at a chemical lab or with a portable XRF instrument.

BEWi mentioned several challenges. One of them is that EPS today, is in many cases not sorted out for recycling but disposed of as residual/mixed waste. In order to ensure that the loop functions as it does, it is crucial that EPS is being sorted out as a fraction that can easily be collected for recycling. BEWi thinks that a tax on residual/mixed waste should be introduced, so that the price of residual/mixed waste can be increased, which will in turn stimulate the sorting of plastic. The EU's circular economy plan sets clear ambitions for increased circularity of plastics, where they will set requirements for recycled content in products. BEWi states that they are of the opinion that if we are to succeed in increasing the circularity of plastics, increased requirements and incentives for use are crucial. Recycled raw material will then have an increased value, which will solve many of the challenges related to sorting, various qualities and design, etc. Today, there are no instruments to stimulate increased use of recycled raw materials. Recycled plastic is in general more expensive than new fossil plastic, says BEWi and the competitive situation has further deteriorated recently due to low oil prices. To accelerate the circular value chain, they state that the demand side must be stimulated. Manufacturers should therefore be required to use a given proportion of fossil-free plastics (recycled or renewable raw materials).

BEWi also mentioned that 20 per cent of all plastic consumption is used in construction, mainly in long-lasting products such as insulation, moisture barriers, pipes, etc. Both renewable and fully recycled products are starting to appear on the market, but the prices are still higher. Through public demand, it will be possible to bring new products to the market and start production lines for products with recycled content such as insulation. Governments should be given the task of carrying out pilot projects with the intention of incorporating them into the guide for public procurement.

Finally, BEWi brought up the fact that plastics have received a lot of negative attention, due to plastic littering. According to them, plastic is a fantastic material that enables an infinite number of applications that humans use daily. EPS has a lot of positive benefits compared to other materials due to its weight and insulation properties: keeping food fresh, reducing food waste, lighter transport that leads to less emissions, insulation that leads to more energy efficient houses etc. Today, decisions about whether to use plastic in products are in many cases based on what is believed to be most environmentally friendly, or by the fact that plastic

[8] Recycled materials that are to be used in food contact materials need to be assessed by EFSA.

has been labelled as an environmental nuisance. There is a need for scientific documentations that addresses the environmental impact throughout the life cycle of a product and do not only concentrate on the material itself.

3.2.4.2 PVC and textile flooring

3.2.4.2.1 Tarkett AB (Survey results only)

Tarkett AB is a flooring producer that recycles (amongst others) waste from installation of PVC- and linoleum floors and post-consumer vinyl floor and carpet tiles.

Homogeneous PVC-flooring becomes new PVC floors with no downgrading. The waste from other PVC-floors is made into new Tarkett flooring, sometimes the backing[9] and sometimes the bulk material. The collection of PVC installation waste happens in Northern Europe, as well as in France, Germany, Benelux, the UK, Spain, Portugal and Italy, with new recycling systems under way for Poland and the Baltic states. Collection and handling are often done by flooring contractors or demolition companies says Tarkett. Where inspections or analyses are required, Tarkett does this before collection. Transports (including load carriers) of the material is handled by Tarkett, with a rented transporter. Sorting is done by Tarkett in their own facilities. PVC recycling is done by Tarkett AB in Sweden and Luxemburg and production takes place in France and in the UK.

Tarkett points out that 466 tons of waste from installation of PVC flooring was collected in the Nordics in 2019. About 25% of that collected material stays as waste, and the rest is used to create new floors, about 115 000 m^2 worth. The waste collected is expected to rise to 550 tons in 2020. Tarkett's homogeneous PVC floors have been DINP free since around 2009-2011 but floors produced before that still contain this chemical substance, which doesn't fulfil todays requirements on chemical content from the market in Sweden. This in turn puts a stop on the recycling of a large potential material stream for flooring, Tarkett says.

The installation waste from linoleum flooring is made into new linoleum flooring where the acoustic backing become the endcaps of the new floors.

For the textile floor plates, the yarn is separated from the backing and the yarn is depolymerized and used to create new yarn. Some backsides can also be recycled into new backing for textile tiles. Recycled calcium carbonate is also used sometimes as a filler in the backing. The calcium carbonate in this case, is a residual product from softening drinking water. In textile floors, the company Aquafil is able to depolymerize PA6. About half the textile tiles have PA6 and the rest PA66[10], which is more difficult to depolymerize. Tarkett inspects the materials in buildings to make sure they do not take in materials that are difficult to recycle, e.g. carpets with PA66.

3.2.4.3 Plasterboard

3.2.4.3.1 Plaster producer (Survey results only)

A company that produces plaster from recycled plaster. The company collaborates with municipalities, builders and retailers to get the recycled plaster. Another company sorts and crushes the plaster. The production of plaster is between 150 000- 200 000 tons/year. The recycled fraction in the plaster is around 15%. The recycled plaster is tested to make sure that no unwanted chemical substances are present. This includes testing for certain hazardous

[9] The bottom layer of the flooring
[10] Polyamide 6 and polyamide 66 are 2 commonly used polyamides (nylon). Polyamide 66 is stiffer and is preferred for applications exposed to water or high temperatures.

chemical substances as well as chemical substances that can interfere with the quality of the recycled materials.

3.2.5 Clothing

3.2.5.1 Renewcell (Interviewed)

Renewcell is a company that produces dissolving pulp in Sweden, which is made entirely from recycled textiles and clothing that are purchased from countries in Europe and Asia. From the dissolving pulp a viscose fibre can be produced. The dissolving pulp and viscose fibres are sold to companies in different countries and used in the production of new clothes. An example of a product that was produced from these materials include a dress that was made in collaboration with H&M. This dress was made with 50% viscose derived from FSC wood and 50% recycled viscose pulp from Renewcell.

Today Renewcell has a smaller production plant in Kristinehamn which is used to develop the process but also to produce commercial pulp. In the future, this plant will be more focused on research and development purposes (R&D), including for example "special" textile blends/experiments. Renewcell is currently building a new factory in Sundsvall which will be ready for production in 2022. In this factory they will be able to increase production to 60 000 tons/year.

Renewcell is a small business and therefore does not have all the skills in-house to do environmental assessments and chemical analyses. On the other hand, they have expertise in water purification and environmental permits as well as chemistry. They also participate in some collaborations and interesting projects and have an ongoing dialogue with authorities (for environmental permits) and consultants.

The process of making dissolving pulp is a similar process used in the paper industry, explains Renewcell: It is a water-based process where they use cellulose from cotton and a small amount of polyester. The pulp is dissolved, bleached, dried and baled. The dissolving pulp can then be used to produce viscose fibres. When a customer buys dissolving pulp from Renewcell, they receive a certificate of analysis that informs the customer on quality parameters such as viscosity and brightness of the materials.

Renewcell accepts coloured fabrics which can contain indigo and other textile dyes. Their process therefore includes decolourisation steps. The chemicals used are the same as those used in paper and pulp production. Renewcell follows the AFIRM restricted substance list and they are strict with which raw materials they use. Brominated flame retardants and metals can still be found, as many clothes can be old and from outside the EU. The company has an environmental permit (may discharge their treated water to the recipient without sending it on to municipal treatment plants). They regularly check the water for the presence of heavy metals and monitor the concentrations of nutrients, nitrogen, phosphorus, COD and BOD. Renewcell can carry out certain analytical tests inhouse (on the pulp itself) while most water analyses are done by external labs. New suppliers need to be certified before their raw materials can be used, meaning that tests will be made to ensure that their materials have the right quality.

When Renewcell was founded, technical solutions were the main driving force to set up this loop. In the fashion industry, sustainability is in demand and this creates an additional driving force for Renewcell to contribute to producing fabrics in a sustainable and circular way. Renewcell does not want to contribute to increased consumption. Renewcell’s technology should be seen as one of the last steps in the waste hierarchy, after alternatives to new purchases such as repair, second-hand markets and other possibilities to extend the life of textiles have been exhausted.

Other small innovation companies are investigating the possibility of using other fibres (in addition to cotton and polyester) says Renewcell; however, this requires that sorting processes are improved in order to supply the materials needed to upscale these processes.

Renewcell does not see any direct obstacles for maintaining their loop. Their hope is that new legislations, such as the extended producer responsibility for textiles in combination with goals for the re-use and recycling of these materials, will help to lead to better collection and sorting processes.

One challenge now is to work with suppliers and customers to ensure that the incoming products have the right quality says Renewcell. Being able to sort out the right materials is a big challenge, and they are therefore grateful for projects like SIPTex which focus on this issue. The better the incoming flows are sorted, the easier it becomes for Renewcell to recycle the materials as their process is limited by how much unwanted materials are present. Currently Renewcell can handle a maximal polyester fraction of 2%. However, they preferably would like the incoming material to be pure cotton, as they have to remove polyester and recycle only the cotton fraction to viscose or lyocell. To ensure that incoming materials do not contain more than 2% polyester, they require their customers to comply with this limitation, but they also perform their own analyses. In the new factory (Sundsvall) they should be able to handle up to 10% polyester if needed. Another challenge according to Renewcell, is that the incoming materials will vary in their quality and that the processes used by Renewcell have to be flexible enough to handle these variations.

3.2.5.2 Nudie Jeans (Interviewed)

Nudie Jeans produces and recycles jeans/denim. The jeans are collected in their own stores globally and sorted or used for different uses, such as material used in the repair service, sold again as second hand, to use the denim to create accessories, or to recycle through mechanical methods. When recycling the jeans to new fabric, the denim scraps are exported to their fabric supplier Bossa in Turkey, and from there to their subcontractor Gama for shredding. Thereafter, Bossa mixes the recycled cotton with 79% organic cotton and 1% elastane to create new denim fabrics. About 20% of the new material is made of recycled material, but this can change in the batches. The denim fabrics are shipped to Tunisia where new jeans wear is sewn. In 2019, 3 657 pairs of jeans and 199 denim jackets were made abroad. Some companies are working in similar ways as Nudie Jeans, for example Mudjeans in the Netherlands, where customers are leasing their jeans. Levi’s has also started selling second-hand jeans, but there is probably no one else who collects their own jeans and recycles them in the same way as Nudie Jeans.

Nudie Jeans says that it always had the idea to take responsibility for the impact they create. The repair service started with regular customers who asked to change the length of their jeans and in 2011-2012 they started to repair and collect Nudie jeans instore. After the opening of the London store in 2013, the Repair Shop concept was launched to clearly communicate the circular activities that took place in the stores. Nudie Jeans collected the fabric for patches used in the repair service and to create smaller accessories. Responsibility is taken when they repair products for customers using the product (repair holes) and post usage, when they no longer want the clothes. As early as 2013, a recovery attempt was made with Bossa. The products were sold but with an average result as the colour setting differed from the rest of Nudie jeans denim products. But recycling techniques and Bossa's knowledge have developed and at the end of 2019, the Rebirth collection was launched. Nudie Jeans has internal goals for pushing recycling e.g., to use recyclable fibre in one style of jeans per year or to use a small percentage of recycled fibres in several styles. The company is also working with other recycled fibres, such as recycled wool for knits and jackets.

Nudie Jeans has worked very closely with Bossa and developed an understanding of the challenges during their contact. To stay updated on technical developments and to gain new knowledge Nudie Jeans is members of different networks They are a member of the alliance for responsible denim (Amsterdam-based network) where recycling techniques are discussed. They are also part of the chemicals group at RISE to seek expert knowledge. Nudie Jeans has not collaborated with consultants or authorities, apart from climate work. This is due to their direct contact with knowledgeable suppliers, which makes their work easier. Nudie Jeans tries to collaborate with their suppliers as partners.

Nudie Jeans uses a restricted substance list based on AFIRM that all suppliers involved in Nudie jeans production are required to follow. In addition, they require that the chemicals used in the production are compliant with manufacturing restricted substance list from ZDHHC and that their suppliers to be compliant with EU chemical legislation.[11] To only use their own jeans as recycled input for the recycled denim made, is simplifying the chemical control as the recycled fibres are from their own products, made under strict restrictions.

The obstacles Nudie Jeans have dealt with are partly that the stores had to understand the importance of sorting pure cotton and mixed textiles. When the stores did not do so, extra work was required to sort the material. The customs rules for import/export to Turkey restricts the company since Bossa can only accept denim scrap instead of whole garments and Nudie Jeans is required to hire an actor who could cut the material. Nudie jeans does not want to change supplier even if it could have been easier, as they value and want to develop that relationship with Bossa. Another obstacle concerned the first test batch (before Rebirth) with Bossa. It did not contain 100% cotton, and it was thought that a maximum of 3% elastane in the jeans would work fine. The elastane began to release in small amounts however, and they had to work with Bossa to solve the problem, which they did. Improvements to the colour were also implemented. Today, time (within the company) is a limiting factor for the amount of recycled material used (designers and product developers mostly drive the decisions concerning which products to make) and the access to recycled fabrics is still limited today says Nudie Jeans. Also, the number of styles and quality are limiting factors (max. 20% recycled cotton, otherwise it will affect the stability density of the fabric). Nudie Jeans does not want to mix in polyester and wants to keep the material as clean as possible.

3.2.5.3 Filippa K and Manteco (Interviewed)

Filippa K has been working with collecting and recycling woollen garments for multiple years in collaboration with several partners. From 2016-2019 they have been active in collecting cutting wastes from their own production of woollen outerwear and suit garments. As the producers are used to sorting the cutting wastes by type, these materials are of high quality (purity) and relatively easy to recycle. The motivation for setting up these loops was mostly an internal drive to make their woollen garments more sustainable, as the investment was larger than the return. Filippa K did not produce any new materials from the cutting wastes they sent.

[11] Including REACH regulation EC No 1907/2006, the Stockholm Convention on Persistent Organic Pollutants via (EC) 850/2004, the Biocidal Product Regulation EU No 528/2012 and the EU Directive 94/62/EC for packaging materials, from Nudie Jean’s Chemical Policy

Since fall/winter 2020, Filippa K has started a new collaboration with one of their long-term partner fabric mills, an Italian company called **Manteco**, which has several decades of experience in producing and recycling woollen fabrics. Filippa K is sending cutting wastes from their production in order to develop a new recycled woollen material, that will be used in new garments starting in 2021. The recycled material used in these fabrics will originate mostly of materials collected by Filippa K, thereby creating a closed loop. The first batch will be a sample roll of approx. 75 meters of fabric with on average 70-80% recycled wool, with the remainder coming from recycled or virgin polyamide and virgin wool. This composition ensures that the fabric complies with the characteristics, look and performance required by Filippa K. The motivation for creating these loops is still an internal drive to find a way to make more sustainable woollen garments while creating a unique material that they can share with their customers. Filippa K also sees a strong interest for more sustainable clothing among their customers.

While the aforementioned loop is under development, Manteco as a textile company has decades of experience in working with the collection, sorting, recycling and production of woollen fabrics. Their process starts with the collection phase in which they buy used wool from legal authorized partners coming from pre- and post-consumer wool scraps. The scrap material originates mainly from the USA and North Europe. Manteco tests the recycled wool scraps continuously before allowing it to enter into the production chain to ensure that they do not contain unwanted chemicals. The origin of the materials can influence which chemical substances are checked for. One example could for instance be fabrics imported from the US which could contain alkylphenol ethoxylates (APEOs). Products that do not comply with their requirements on chemical contents (e.g. according to ZDHC guidelines) and fibre quality, are sent back to the supplier and are not used in Manteco's production process. The recycled wool is produced as follows: The scraps (fractions of wool) are sorted (by hand) according to their composition, quality and colour. They are then shredded and recycled to fibres by using a mechanical approach, sometimes in combination with water. No chemical substances are used in this process. When the fibres are ready, they are spinned to create new yarns. There is no chemical dying process, instead, fibres with different qualities and colours are blended physically during the yarn production to ensure that the new fabrics comply with customers' requirements. The yarns are then ready to be woven and finished to create a new recycled fabric. The fabric finishing processes are in accordance with ZDHC[12] guidelines. These fabrics then undergo a quality control in which the composition, quality and chemical composition of the fabrics is analysed. Both REACH as well as individual restricted substance lists from customers determine which chemicals are checked for. Chemical analysis is done both inhouse as well as by external labs. The wastewater from Manteco is treated by the municipality and adheres to the ZDHC Wastewater Guidelines.

Several challenges have been identified in setting up these (almost) closed loops for woollen fabrics, says Manteco. This includes for instance the fact that post-consumer textiles can come from many different sources and production years, which means that they could have been produced under different chemical regulations and therefore contain unwanted chemical substances. A strict and continuous testing scheme helps ensure that the incoming fabrics comply with requirements. Some of the unwanted chemical substances include for example heavy metals, alkylphenol ethoxylates (APEOs), azodyes and perfluorinated chemicals. The lack of REACH provisions specific for recycled materials was also mentioned as a challenge. Currently REACH treats virgin and recycled fabrics in the same way, even though their raw

[12] Zero Discharge of Hazardous chemicals (ZDHC), an industry group focused on elimination and substitution hazardous chemicals from the global textile, apparel, leather and footwear value chain.

materials and production processes are completely different. At the same time, certain chemicals substances are forbidden for new textiles (including those with recycled fibre content) but allowed in second-hand garments. To reach the concentration limits set forth for fabrics with new fibres, can be more difficult to achieve with certain chemicals (e.g. APEOs) when using recycled materials.

Aside from the presence of unwanted chemical substances, Manteco has also identified that the presence of certain bacteria in post-consumer wool can influence the strength of the fabrics and their resistance to discoloration by exposure to light. Manteco therefore implements a patented procedure that uses sonication process to sanitize the materials.

Another challenge in working with post-consumer materials, and one of the largest according to Manteco, is the fact that garments need to be designed in the right way to ensure that recycling is possible. Garments containing linings, embroideries and prints for example can not properly be recycled. To support this vision and overcome this challenge, Manteco teaches the concepts of sustainable design to students of fashion academies across the world. Having recycle friendly designs was also confirmed as a challenge by Filippa K, which needs to get their design team on board with their plans for setting up a closed loop. Having a design that allows for easy recycling could limit esthetical options.

Fibre content on the other hand does not play such a big role in determining the recyclability, says Manteco, as fractions with lower content of wool could still be recycled into fabrics with a lower quality.

While Manteco’s entire business plan revolves around recycling fabrics and making sustainable fabrics, it is a much smaller core team at Filippa K that works with these questions, led by a sustainability manager which sits right under product development and design. For such a small team, the administrative work to set up a closed loop could be a challenge. In the case of Filippa K, this challenge was overcome by Manteco taking over a large part of the administrative work.

3.2.5.4 Clothing company (Survey results only)

A company that produces and sells clothing has used recycled polyester mixed with cotton to produce new fabrics. About 50% of the new circular developed fabric and product consisted of recycled polyester. There are no unwanted chemical substances in the material collected according to the clothing company. The company wants to increase the mixture/use of recycled fibres in their products and hopes that this could be possible with the SIPTex sorting.

3.2.5.5 Houdini Sportswear (survey results only)

Houdini Sportswear produces and sells clothes. Houdini collects all Houdini products, which then either go to reuse or recycling depending on their condition. Products that are not yet included in an existing loop are put into storage while they follow or actively work with the development of recycling technologies and the phasing out of textile fibres for which they see the least potential for circular options, such as elastane or lycra. The majority of their products are produced with as much recycled material as possible or made with renewable materials (e.g. wool and tencel). The clothes are collected in recycling stations located at the shops, or via e-shops and the sorting of the clothes is done in-house. The collection takes place in all countries where Houdini has a market (roughly 20), where their recycling stations are accepted. The recycling to new fibres and the production of new clothing from these materials takes place in Japan (for polyester) and in Italy (for wool). These clothes can contain 50-100% of recycled materials. Previously, Houdini Sportswear says, there were more materials with 100% recycled fibre (PET), but the supplier's argument for this being reduced is competitiveness, pricing and lack of demand as the cost of virgin raw material has become cheaper. Some treatment of the clothes with synthetic fibres is necessary according to Houdini Sportswear. Fluorocarbon-free durable water repellent (DWR) treatments, adhesives for membranes and taping as well as dyes are removed in the chemical recycling of PET. The woollen fabrics can be recycled without removing the colours.

3.2.6 Other

3.2.6.1 A company (Survey results only)

Another company works with the production of metal parts and metal recycling. Power lines and aluminium printing plates are used to produce materials for automotive applications. The collection of these materials takes place in Europe and the sorting of the material takes place in northern Europe. Re-melting and rolling of material take place in-house. The production of products containing recycled materials is 50 000 tons/year of which about 30% consists of recycled material. Unwanted chemical substances are not considered to be present in the process.

3.3 Overview of other relevant loops

Table 1 contains an overview of other companies that are involved in (almost) closed loops and which came up during the project. They are either part of the loops discussed above or have similar loops in place. Contacting these companies was outside the scope of this project.

Table 2: Overview of other relevant companies

Category	Loop	Company name
Clothing	Denim (cotton)	Bossa, Turkey
Clothing	Denim (cotton)	Mudjeans, Netherlands
Clothing	Cotton / Polyester	Södra – Oncemore, Sweden
Clothing	Cotton	Tencel – Refibra, Austria
Clothing	Wool	Green Line Recanti, Italy
Clothing	Wool	Nuova Boretti, Italy
Clothing	Wool	Stelloni, Italy
Clothing	Various textile products	Wolkat, Netherlands
Glass	Fibre glass	Isover, Sweden
Glass	Foamglass	Hasoper, Sweden

4 Discussion

Based on the results from the survey and the interviews held, some overarching observations were made. In the sections below these observations are discussed under different themes.

4.1 Common motivators

When asked what motivated companies to set up and maintain the (almost) closed loops presented in this study, different actors pointed out different reasons. Overall, these can be summarized as:

- An economical incentive as the recycled material is cheaper than virgin material
- The need to comply with regulations and fulfil extended producer responsibility
- An internal desire from within the company to become more sustainable

The latter point is also linked to an increased demand from customers and end-users for more sustainable products. As stated by one of the actors being interviewed:

"To survive today you have to be environmentally sustainable"

It was found that for some actors the driving force to establish the loops had come from single persons or small dedicated groups within the company that took it upon themselves to set up the loop, convincing other to take part. This seems to be more common in larger organizations where recycling is just one part of many aspects that the company has to handle. Some of the other companies on the other hand could have a business model fully built around the recycling process making the existence of the company fully linked to and depending on the loop.

Setting up a closed loop requires both technical know-how on the materials and on how to set up the logistics to collect and transport the materials. It also requires a good legislative understanding of chemicals and waste regulations and a competent design team that can help make products easier to recycle or adjust products so that they can be made with recycled materials. In the examples listed in this study, this expertise was found both in-house and from consulting external experts. In several cases, companies worked together on a project basis with other partners to develop a loop.

4.2 Structure of the loop

The structures of the loops and the number of stakeholders involved in the loops differs greatly between the examples that were presented in this report. In the smaller loops, more specific materials are often handled. These specific materials come from a limited number of sources such as one waste collector or even collected by the company selling the products itself. In these loops the seller of the recycled material has a greater control of the material to be collected and how and where to re-process it. However, an external partner is often required for expertise on re-processing the material. Examples of this are some of the clothing brands which have their own ideas on how to increase the circularity of their products and team up with a partner that has the expertise to re-process the material they need. In these cases, it is the clothing brands that seem to be the main driver for setting up the loops.

In the larger loops, the material to be recycled is more seen as a traditional commodity that is sold from one supplier to a producer. The sourcing of material to re-process is wider and several different streams of recycled material are accepted. Here, every party operates in their field and takes on a material from point A to B to supply the next party in the loop.

In the more established loops, such as those for PET, a close collaboration has been set up between the actors involved which has given these actors a joint understanding for how to establish a well-functioning loop. In this loop, product design and material content has been adjusted to enable an efficient recycling process.

For loops which are based on a more varied waste composition, the re-processer has clear ideas of how the material ideally should look like to best suit their process but struggles with reducing heterogeneity of the starting material. Here the correct sorting of material is important in order to get a feedstock that is optimal for the recycling process. In the cases where incoming materials, despite the extra sorting, still vary significantly from batch to batch, the recycling processes need to be flexible enough to cope with these materials and variations.

4.3 Unwanted Chemical substances

Most of the loops presented in this study mention the possibility of having unwanted chemical substances present in the incoming materials. This could include hazardous chemical substances that the producer does not want to have in their final product or chemical substances that hinder the recycling process.

It was beyond the scope of this study to consider each regulation that companies in the different industries had to comply with and how they practically did their controls or measurements. However, the overall impression obtained from the examples in this study, is that the interviewed companies are well aware of legislative requirements on which they base their chemical monitoring strategies and have optimized their sorting and decontamination processes thereafter. Several companies have for example indicated that they actively look for chemical substances that could be present in their incoming materials due to contamination with other materials or the fact that their materials were produced under different chemical legislations.

A few of the companies also indicated that their chemical requirements went beyond that of EU chemical legislation. This was valid for example for the textile companies that were included in this study that used a restricted substance list. The companies involved in such loops, also used these restricted substance lists in their products made with virgin materials.

As it was not specifically asked for during the interviews, it is unclear if the companies interviewed are aware of other potentially hazardous chemical substances present in their products aside from those for which concentration limits exist in REACH or that are present on a restricted substance list. Such chemicals could for example include those recommended for substitution by the Swedish Chemicals Agency or those present on the SIN list by ChemSec.

The companies interviewed often expressed that they take measures to control the presence of these substances either when selecting materials for their loops, when analysing the incoming materials or by designing the processes in the loops so that regulated chemicals are reduced or removed. Most often it is the party responsible for re-processing the materials from waste to new raw material that has the best expertise on chemical legislation and which types of analyses that are required to ensure that unwanted chemicals stay below the threshold concentrations set forth by authorities. Brand owners, with their restricted substance lists, can also influence which chemicals are considered unwanted. Some of the smaller companies involved in setting up these loops have indicated that they rely on external expertise to handle regulatory issues related to chemical content.

In comparison with quality assessment tests of the produced materials, which are often done in-house (especially by larger companies), the analysis of hazardous chemical substances in the materials seems more likely to be outsourced to third party analytical labs that offer standardized tests. In several cases, portable analytical instruments such as portable XRF instruments for screening the presence of heavy metals or brominated flame retardants were also mentioned during the interview. Similar instruments can also be used on conveyor belts to automatically sort out unwanted substances.

In contrast to companies producing products with virgin materials, waste that is to be recycled can come from various sources and contain various unwanted chemical substances. Processes to remove unwanted chemical substances can be present at several stages of the loop. Collection and sorting play a crucial role in ensuring that the incoming materials do not contain unwanted chemical substances. Companies working with entirely closed loops in which they collect and reprocesses their own materials benefit from knowing the composition of the incoming materials much better. Companies relying on materials from various sources on the other hand need to have more strict routines in place to ensure that unwanted chemicals do not make it into the loop. This could include the need for extra steps in the sorting process to remove materials that are more likely to contain unwanted chemical substances. Examples for this could be batteries from electronics or light bulbs, which can contain lead, that can then end up in glass waste. The re-processor can also decide to work exclusively with certain suppliers which have proven that they can deliver a material that meets their quality criteria (e.g. by the use of certificates). At the re-processors, fractions that contains restricted chemicals, such as RoHS chemicals in electronic plastic waste, can be separated and sent for destruction.

4.4 Effects of repeated recycling

Companies working in more established loops have a better understanding of the effects repeated recycling has on the quality of the materials. For instance, for loops of PET, glass and paper the number of possible repeated recycling loops has been studied and effects on quality loss after repeated recycling have been identified, e.g. for PET is known that the material can gain some discoloration after repeated recycling.

In more novel loops or those where the product has a longer lifespan the impact of repeat recycling on the material quality is less well known. Especially hard to assess are loops where the recycled materials are used in durable products, such as EPS for construction or polymers used in household product. These loops have a long life span, which means that the possibility to investigate the effects of repeated recycling might not be known for some time.

4.5 Quality control

The quality of the final product in the loops presented, goes hand in hand with the quality of the incoming materials.

More mature loops like that for PET bottles ensure a quality of the incoming materials by maintaining tight control of the products through the take-back system. The PET that reaches the re-processor is known to suit the recycling already from the design of the material. Other examples like this include loops set up by textile brands, which in some cases only work with their own clothing waste or production scraps and electronic companies, that have separate collection programs for their own products.

Loops with more heterogenous waste streams, on the other hand, have to work harder with adjusting their processes to the type of material they get. A heterogenous supply of materials from different sources can for some operators also mean that different re-processing techniques and pre-treatment steps are required to produce material of the desired quality and that the company will have to adjust their processes continuously based on their analysis of the incoming material.

4.6 Challenges

Several challenges were identified is this study, which can affect the creation and/or existence of these loops.

Regulatory requirements were mentioned by several stakeholders as one of their largest challenges. This could for example include staying up to date with changing chemical regulations in different regions of the world, which requires that the right expertise is brought into the company. Another example that was mentioned included how waste is classified. Nudie Jeans for example had to cut their jeans intended for recycling, before shipping them to Turkey as they couldn’t send whole garments across the border, but they could send raw materials.

The administrative burden of setting up a loop, e.g. to organize the collection, sorting, recycling, new production and quality assurance steps, was also mentioned as a challenge. In some of the examples, this administrative burden could be transferred from the brand owner to the recycler (e.g. in the collaboration between Filippa K and Manteco), allowing the brand owners to focus more on sourcing materials and implementing design changes that make it easier to recycle the products.

Another challenge that was mentioned repeatedly is the importance of having a collection and sorting system in place that can deliver clean fractions of the desired materials with the right quality. A close collaboration between partners in the loops seems to be the easiest way to ensure a better quality of the recycled material. Deposit systems such as that for PET, also help to get cleaner flows of products. In addition, these systems come with a built-in incentive for consumers to leave their products at the collection point. Examples were also found where the company interested in getting a recycled product even acquired a recycling company to ensure better control of the incoming materials (e.g. for EPS). Materials collected from post-consumer waste can be more difficult to sort, requiring that the recycling processes are able to handle (slightly) impure material.

Consumer perception can also be a challenge. In certain cases, the visual aspect of a recycled product can be different compared to the one made from virgin materials. This could occur for example with PET bottles in which repeated recycling might affect the colour of the materials. As companies start to include their plans for the recycling of their products already in the design phase, this could limit what these newly designed products could look like.

A challenge or worry that was also mentioned by several companies was the public’s perception of plastics as something bad. Getting the general public to consider the unique benefits of plastics over other materials in certain applications, and how they can be circular under the right circumstances, is important according to several of the companies interviewed in this study.

The volatility of the market can also be a challenge, as the value of recycled materials competes with that of virgin materials. The price of virgin plastic for example is strongly coupled to the price of oil which has seen large fluctuations in price. This can make it difficult to keep the loop financially feasible or to keep using high fractions of recycled materials in the production of new products.

4.7 Outlook / dependencies to keep loops running

The companies are in almost all cases optimistic about the future of their loops and circular business models. Several of the actors mentioned how and where they want to expand their current operations and have plans and ideas on how to take on new materials. Companies that have experience of setting up a loop, also seem to require less time to set up their second or third loop, indicating that it might be reasonable to expect more and more loops from these companies in the future. Only one company, involved in paper and cardboard recycling, noticed a decrease of their production, mainly due to lower demand of paper prints.

However, a risk that several actors mentioned, is the potential lack of materials with the right quality that might arise if the demand for these become too high or if consumers are not willing to keep sorting their materials in separate fractions (e.g. PET bottles). This could on the other hand also lead to an increased demand for the product, which in turn could lead to increased collection and sorting efforts, such as those found in projects like the automated textile sorting of SIPTex.

5 References

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The European Commission (2008), Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006 (Text with EEA relevance, OJ L 86, 28.3.2008, p. 9–18.

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6 Annexes

6.1 Annex 1: Survey questions

1. What is your name and which company do you represent?
2. At which email address can IVL contact you?
3. Does your company work with products or materials that are part of a (almost) closed loop? E.g. Do you work with collecting / recycling / producing materials with recycled materials (to produce similar products or products with a similar value)?
4. Which products / materials do you collect or work with?
5. Which products or materials do you produce with the recycled materials?
6. How does the collection, sorting, transport and recycling of the mentioned products and materials take place? (e.g. within the company, in collaboration with one other actor, in collaboration with multiple other actors).
7. In which country does the sorting of the mentioned products and materials take place?
8. In which country does the recycling of the mentioned products and materials take place?
9. In which country does the production of the products and materials take place? (those that are produced from recycled materials)
10. How large are the production volumes for the products and materials that are produced from the recycled material? (You can provide a range, e.g. 100 - 200 ton / year)
11. On average, what is the percentage of recycled material in the products and materials mentioned? (e.g. 50 % of the product comes from recycled materials)
12. Can the amount of recycled materials vary in your products / materials?
    a. If yes, please explain how?
13. Is there a risk for having unwanted chemicals in the materials and products you collect / work with? (e.g. certain additives that could make it more difficult to recycle the materials, hazardous chemicals that should be looked at, colouring agents that need to be removed, and so on...)
    a. If yes, which chemicals are of concern?
14. Does the ingoing material need to be treated due to the potential presence of chemical substances, before it can be used to produce new materials / products?
    a. If yes, please explain the treatment process and motivation.
15. In which way can IVL use your data in this project? (For increased transparency and for the possibility to refer to companies that have a good knowledge in working with (almost) closed loops, we would like to ask that you give IVL permission to share all information with the Swedish Chemicals Agency and other government organisations.
    a. If something else: Please explain what IVL can/ can't do with the information you provided.
16. Do you give IVL permission to store your contact information (GDPR) with reference to this project?

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