RECYCLED LEATHER

A PRIMER FOR INDUSTRIALS TO BETTER UNDERSTAND ALTERNATIVE MATERIALS TO VIRGIN LEATHER

EUROPEAN OUTDOOR GROUP

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EDITORIAL INFORMATION

About this report

This document is the result of recent developments by the textiles and fashion industry to create a material standard for leather, similar to those that exist for down and wool.

Experience shows that at the rate that certified virgin material becomes available, the questions about the viability – economically, ecologically, and in terms of quality – of recycled materials start to emerge.

With this report Air Coop and the EOG would like to give those interested in the topic a head start by providing qualified information about the current situation, as well as ongoing developments in this area. And in this way encourage brands, designers and manufacturers to experiment further and push the boundaries of current practice.

In recent years, leather has been the focus of many associations and companies concerned about the sustainability of this material. Related discussions have taken place at a much stronger and more sophisticated level than ever before, covering topics such as animal welfare, environmental and social impact issues (health of the workers who transform hide to leather in the tanneries).Work done in this area on behalf of end-consumer brands which focuses on the traceability of leather, have further fostered and strengthened the discussion. Unlike many other materials used for clothing, leather waste and used leather products have long been sent to landfill or incineration and were not really compatible with both open loop and closed loop recycling processes. These materials were usually not commercially exploited as a raw material to manufacture other products. The questions that have been worked on for materials such as cotton, polyester, nylon and even down and wool are now being asked also for leather: Are recycled leather fibres materials, rather than virgin leather, a viable and desirable ingredient, both from a product as well as sustainability point of view?

Broadly, this document covers the following areas:

- Background: Terminology and legal setting
- Supply chain and production processes
- Sustainability benefits and challenges.

It is important to state however, that this present document does not cover a scientific and nuanced discussion of environmental and/or social benefits or challenges comparing virgin vs recycled leather fibres materials. The principle reasons for this decision is the lack of available and peer reviewed data, as well as methodological questions related to LCA framing.

Important note for the reader

It is important to note that this report only deals with leather derived from animals raised mainly for their meat. It therefore excludes leather from wild or exotic animals.

This document is a 'living document'. It is a representation of the current knowledge at the time of writing. Therefore, we proactively invite input, feedback, and improvement suggestions from experts, in order to keep readers up to date with the latest findings and information.

The document will be re-disseminated following relevant updates.


EUROPEAN
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ABOUT THE EUROPEAN OUTDOOR GROUP (EOG)

The European Outdoor Group is the membership association of internationally operating outdoor brands, retailers and technology brands, in Europe.

The association exists to represent the common interests of the European outdoor industry and was founded in 2003 by 19 of the world's largest outdoor companies, who recognised the need for a cohesive, cross border approach to representation of the outdoor sector. Our membership consists – as at writing – of approximately 100 corporate members (brands, retailers, and technology brands) in addition to 10 national associations.

The origins of the outdoor industry lie in the enthusiasm and value sets of individual entrepreneurs who have challenged themselves in the outdoors and in the development of their business.

The EOG strongly believes that increased participation in outdoor sports will benefit both individuals and society as a whole. We share a vision to encourage people of all ages and in all locations to be active outdoors. As an industry we are also committed to maintaining 'our roots': The natural environment and society we draw our inspiration from.ata, as well as methodological questions related to LCA framing.

TABLE OF CONTENTS

Glossary 7

1. Introduction 9

2. Background 12

2.1. Leather lifecycle: Waste overview 13

2.1.1. Core processes 15

2.1.2. Downstream processes 16

2.1.3. Waste synthesis 17

2.2. Legal context 19

2.2.1. Leather waste 19

2.2.2. Chemicals management and legal requirements 21

2.2.2.1. Chemical approach in tanning 22

2.2.2.2. Chemical approach in dyeing 24

2.2.2.3. Chemical approach during other lifecycle stages of leather 25

2.2.2.4. Post-production or post-consumer primary material for recycled leather fibres materials? 25

2.2.3. Compliance and traceability: Third party standards 27

2.2.3.1. Labels dealing with harmful substances: OEKO-TEX® Association 28

2.2.3.2. Labels dealing with circular economy: RCS 100 (Recycled Claim Standard) and GRS (Global Recycle Standard) 30

3. Leather recycling processes: An overview 33

3.1. Recycled leather fibres materials: An introduction 34

3.1.1. Terminology and public perception 34

3.1.2. Material and process presentation 35

3.1.3. Performance and durability 37

3.1.4. Material availability 38

3.1.5. Lead times 39

3.1.6. Environmental and social impacts 39

4. Comparison of the recycled leather fibres materials producers 40

5. Recycled leather fibres materials producers: products illustration 45

7. Summary and conclusion 54

Annex 55

Annex 1: Recycled leather fibres materials producers: logo 55

Annex 2: Leather alternatives of vegetable or other origin 56

Annex 3: Other approach (The TAIMEE project) 57

References 59

GLOSSARY

Leather

Hide or skin with its original fibrous structure more or less intact, tanned to be imputrescible (not liable to decomposition or putrefaction), where the hair or wool may or may not have been removed, whether or not the hide or skin has been split into layers or segmented either before or after tanning and where any surface coating or surface layer, however applied, is not thicker than 0,15 mm.

Note 1: If the tanned hide or skin is disintegrated mechanically and/or chemically into fibrous particles, small pieces or powders and then, with or without the combination of a binding agent, is made into sheets or other forms, such sheets or forms are not leather.

Note 2: If the grain layer has been completely removed, the term leather is not to be used without further qualification, e.g. split leather, suede leather [EN 15987:2015].ta, as well as methodological questions related to LCA framing.

Hide

The outer covering of a mature or fully grown large mammal (cattle, horse, etc.).

Skin

The outer covering of small mammals and other vertebrates (pigs, sheep, goats, fishes, etc.) or of the immature animal of the larger species.

Bonded leather fibres material

Material having a mass fraction of dry leather fibres of at least 50%, obtained when tanned skins are mechanically and / or chemically decomposed into fibrous particles, small pieces or powder, and then, with or without the addition of a chemical binder, transformed into a sheet [EN 15987:2015].

Bonded leather fibres material (also known sometimes as Salpa) may have other names:

- English: Reconstituted leather, Blended leather
- French: Synderme
- German: Lederfaserstoff (also called Lefa).

Pre-consumer material / post-production material

Material diverted from the waste stream during the manufacturing process. Excluded is the reutilisation of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it [TE RCS].

Post-consumer material

Material generated by households or by commercial, industrial, and institutional facilities in their role as end-users of the product that can no longer be used for its intended purpose. This

includes returns of materials from the distribution chain [TE RCS].

Life-cycle assessment, LCA

LCA, also known as life-cycle analysis, ecobalance, and cradle-to-grave analysis, is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling [Wiki LCA].

Fleshing

Mechanical removal of excess flesh and fatty substances. The residues arising from this operation are called fleshings and consist of residual flesh, subcutaneal and adipose tissues.

Splitting

The horizontal splitting of hides and skins into a grain layer and a flesh (split) layer.

Tanning

Tanning is the process that converts the protein of the raw hide or skin into a stable material which will not putrefy and is suitable for a wide variety of end applications.

Retanning

Process carried out after the tanning stage. It is intended to improve leather properties such as feeling at touch, embossability and breaking strength, as well as to provide a tight and uniform grain surface for leather finishing. Besides, at this stage, leather is subjected to various treatments in order to provide it with special features such as colour, waterproofness, fire resistance, etc.

Wet-blue

Leather after the chromium tanning process which leaves the leather, once tanned, a pale blue colour (due to the chromium).

Wet-white

Wet white leathers are produced by combinations of synthetic tannins, vegetable tannins, glutaraldehydes and minerals, such as aluminium and zirconium. Wet white tanning allows making chromium-free leathers with the same equipment that a chrome tannery uses.

1. INTRODUCTION

Before discussing recycled leather fibres materials, it is important to talk about leather to better understand the topic and the issues related to social and environmental impacts throughout its supply chain.

Leather is the oldest material used by human beings to protect themselves from the climate and from the elements (skins obtained from hunting and livestock were used for clothes, shoes or tents). But untreated hide is biodegradable, so different tanning processes have been discovered and developed in order to avoid this natural biological process and at the same time to make the leather durable. [Leather Resource]

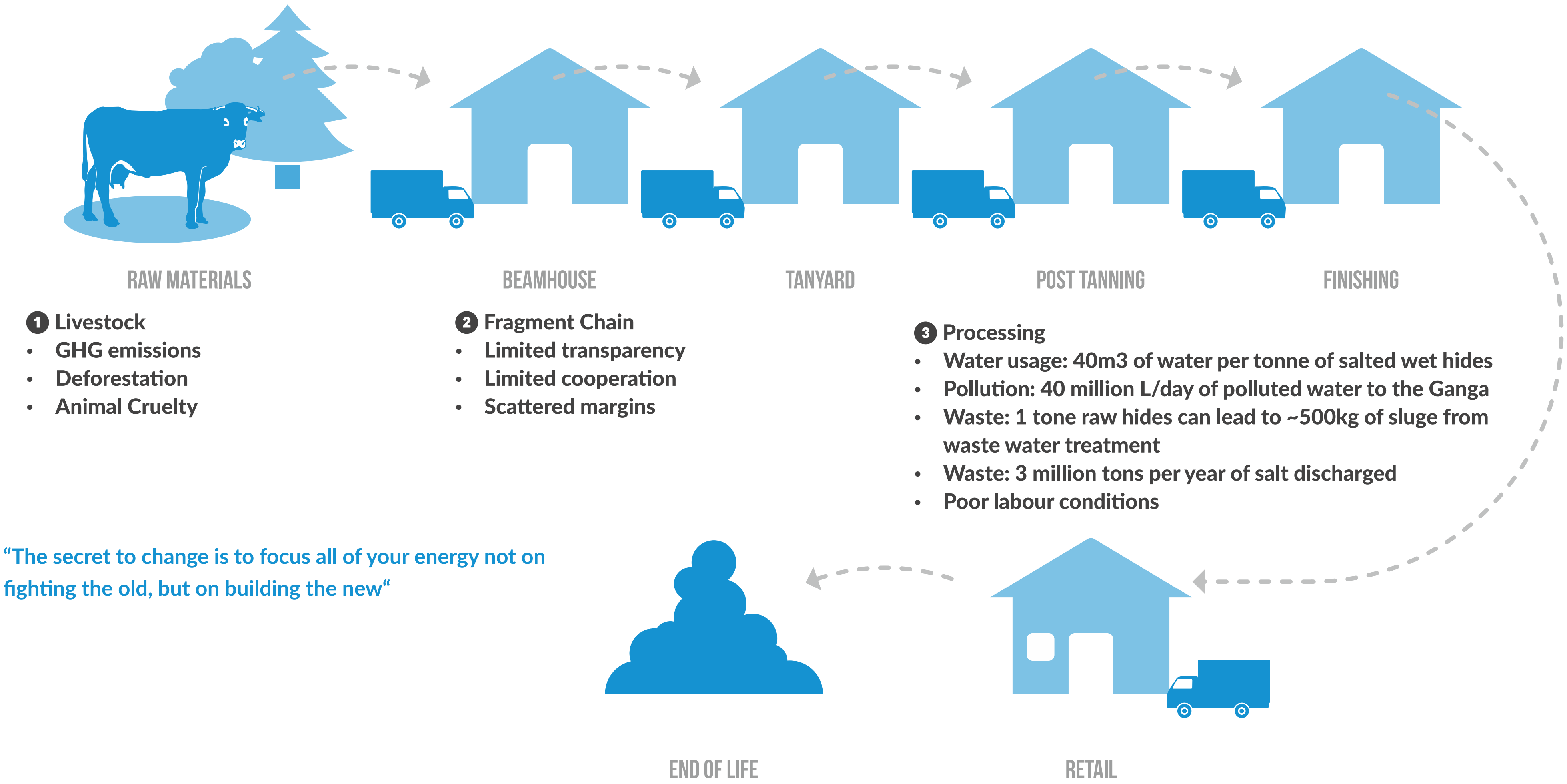
As with all manufactured materials, the environmental and social impact of leather is not neutral. Firstly, leather production is dependent on livestock. Hereunder is a short overview of the impacts of livestock farming.

- The environmental impact factors of livestock ought to be considered, specifically in regard to: Biodiversity and deforestation due to extensive cattle rearing; land use to produce feed stocks; and water use. The environmental degradation by unsuitable livestock management may lead to resource scarcity (first and foremost mainly fertile land), which in turn may have social impacts on farmers and indigenous peoples in the most dominant concerned regions (such as: China, Bangladesh, Pakistan, India, Brazil) [Gombault et al., 2013].
- Livestock environmental impacts also concern climate change (livestock is responsible for 90% of the total greenhouse gas (GHG) emissions [Redwood, 2013]), pollution of water and soil [Gombault et al., 2013].
- Furthermore, animal welfare is an important subject that leather manufacturers should take into account when they evaluate their suppliers or their whole supply chain.

Animals are usually bred for their meat and milk and leather is considered as a by-product of livestock. For this reason, the environmental and social impacts of agriculture and animal farming are normally allocated to meat and milk [Brugnoli et al., 2012] [Kral, 2017]. In this context, while environmental and social impacts of animal farming are relevant impacts of leather in the bigger picture, they are explicitly out of scope for the current report.

Secondly, the transformation of hide into leather needs many operations [Leather Resource]. Each operation, and mainly the tanning step, has environmental and social impacts:

- The tanning process itself is responsible for an important use of water and chemicals, some of which pose significant environmental management challenges [Stevens, 2018]: see chapter 2.2.2 for more details.
- Health and safety risks in the tanneries are also a cause of concern with regards to workers' well-being and require a high-level of protection gear and training.



"The secret to change is to focus all of your energy not on fighting the old, but on building the new"

Figure 1: Leather Value Chain with environmental and social concerns (Redrawn from [ENVIU])

If we look at the principle initiatives to reduce environmental impacts of leather production, we can see that most initiatives and improvements are done during the processing phase because this is where there are the main environmental impacts [Chowdhury et al., 2018].

However, a chain-wide approach is key to creating fundamental changes and more initiatives should be done from a circular economy point of view; recycling leather waste and manufacturing scraps to produce recycled leather fibres materials is an interesting field to study to reduce material destruction, to reduce demand for virgin leather and of course to reduce chemicals, water and energy consumption.

Only mechanical production of recycled leather fibres materials is studied in the report - chemical, thermal and biological processing are excluded (see chapter 3). Indeed, mechanical treatments are the most industrialized process currently offering the largest number of products on the market.

For the remainder, this document broadly covers the following areas:

- Background: Terminology and legal setting
- Supply chain and production processes
- Sustainability benefits and challenges.

The following aspects are currently and explicitly beyond the scope of this document:

- Comprehensive coverage of best available techniques/technologies at every stage of sourcing and/or processing of recycled leather fibres materials.
- A comprehensive coverage of all legislation that applies to the sourcing, processing, trading (import, export) of recycled leather fibres materials (although the report covers some of it)
- A comprehensive and in-depth coverage and comparison of currently available (proprietary, second party, third party) certification standards
- Labour conditions in factories and all related issues, challenges and topics.

The aim of this report is to present challenges of leather production and to present opportunities to use leather waste and scraps (leather by-products and post-consumer waste) as a way to reduce the economic, environmental and social impacts of this material from an eco-design point of view.

This report is designed to outline and summarise relevant information, which may be usable and useful for brands that want to consider integrating recycled leather fibres materials into their materials portfolio. In short, it is intended to foster the dialogue and relationship building between brands and the recycled leather fibres materials supply chain (suppliers regularly innovate to improve the performance of their products in order to overtake virgin leather performances).

2. BACKGROUND

Leather is produced from hides and skins which are by-products from the meat and dairy industry. On one hand, the manufacture of leather avoids the destruction of raw hide that would otherwise be sent to landfill or incineration [EU Indus].

On the other hand, leather production is responsible for the production of many residues that usually have no use for the leather industry itself, and this unused material increases the environmental impacts of tanneries and finished good factories. Leather manufacturing requires many operations to turn raw hide into a durable finished product (Figure 2) and wastes are generated throughout the leather production phase (Figure 3).

LCA calculations may use different allocation methods to calculate environmental impacts of food by-products (value-based, protein-based, 'value add', etc.). The current academic knowledge and practice usually considers a value-based allocation which calculates that 95% of the economic value is allocated to food.

From a value-based allocation point of view, leather is < 5% of the economic value of a cow.
Source: [lcafood2014.org]

The leather industry is about **$40 billion**
The value of the stakeholders is **> $1.2 trillion**

The apparel industry is **$1.7 trillion**
Source: [RLRT, 2018]

Textbox 1: Numbers at a glance

2.1 LEATHER LIFE CYCLE WASTE OVERVIEW

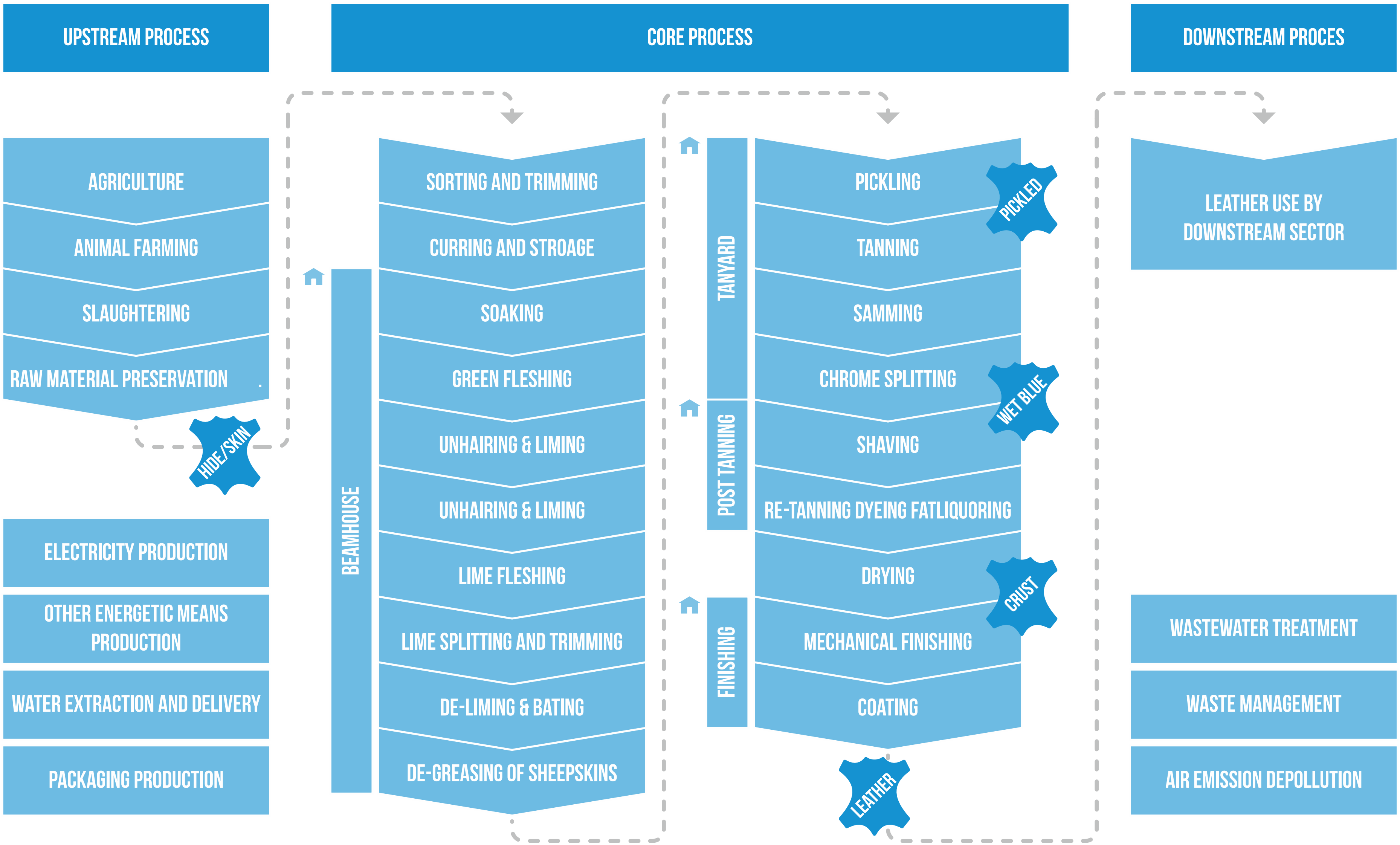


Figure 2: Representation of main processes of the virgin leather production value chain (Redrawn from [BRUGNOLI et al. 2012])

Lifecycle of leather

Increasingly diverse material mix and complexity of product

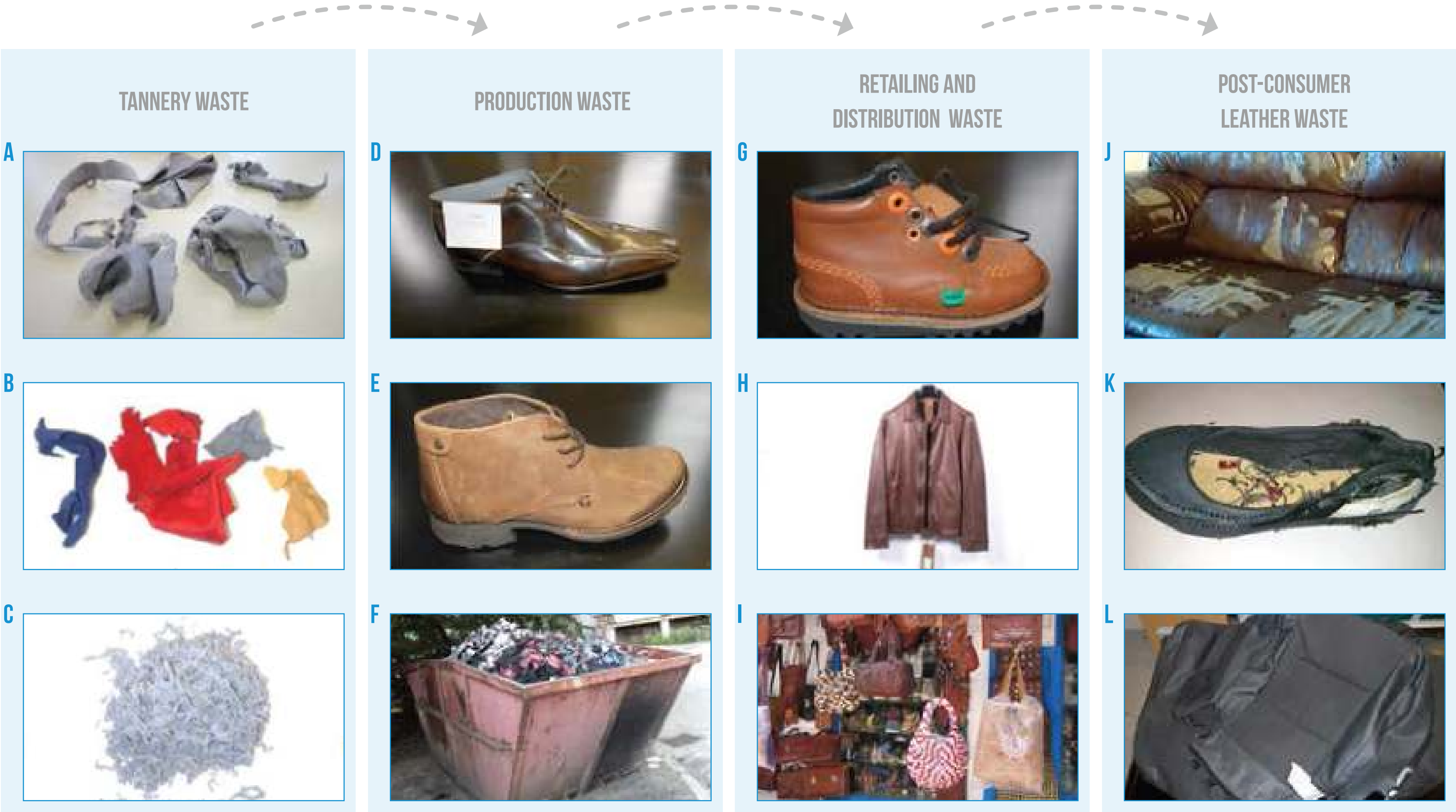


Figure 3: The lifecycle of leather and the waste associated with each stage [Pringle et al., 2016]

2.1.1. Core Processes

Leather wet processing

- 1000kg of raw hide gives only around 150kg of finished leather usable to make finished products
- A lot of waste is generated (see Figures 4, 5 and 6).

Tanning process

- Up to 47% of waste (chrome shaving, chrome splits, buffing dust and skin trimming) may be used to make recycled leather fibres materials.

Textbox 2: From raw hide to leather - numbers at a glance [Kanagaraj et al., 2006]

During the tanning process, solid wastes are generated as follows. Fleshing (50-60%); chrome shaving, chrome splits and buffing dust (35-40%); skin trimming (5-7%); hair (2-5%). These scraps and residues can be used to create new materials that may be of great interest (see Figure 4).

Study of beam house wastes and fleshing wastes is excluded from the present report as this material cannot be used to produce recycled leather fibres materials and other recycling processes already exist [Kanagaraj et al., 2006]. On the contrary, finishing waste (see Figure 3.b), chrome shaving (see Figure 3.a and 3.c), chrome splits, buffing dust and skin trimming wastes are interesting materials for the production of recycled leather fibres materials.

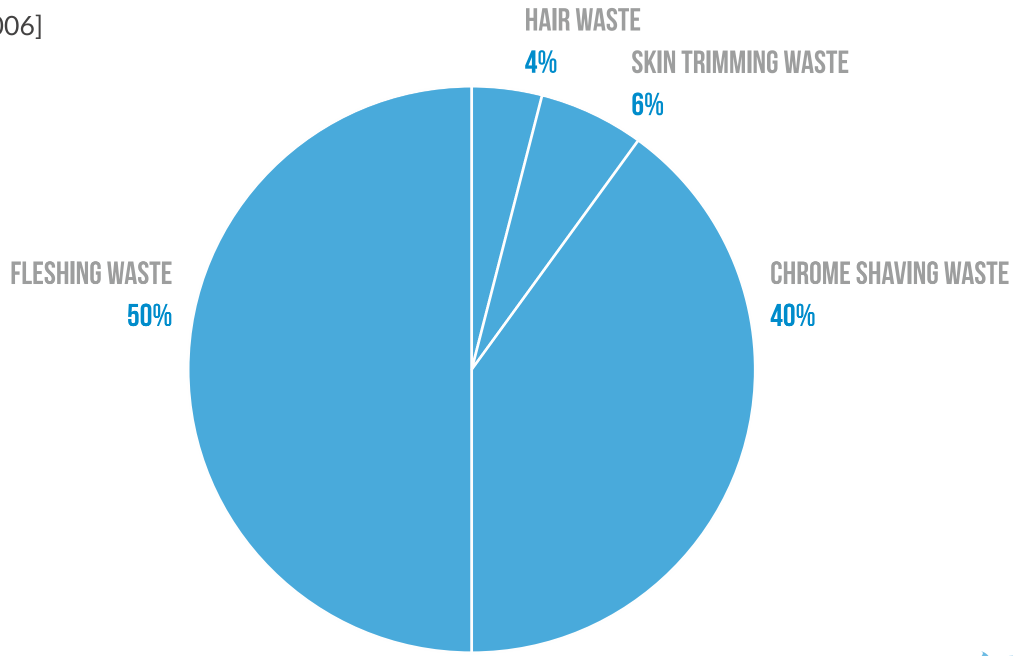


Figure 4: percentage of solid waste produced during the tanning process

2.1.2. Downstream processes

Leather is widely used for many consumer goods, such as footwear, garments, furniture, etc. [Kral et al., 2014] [EU Indus]. Waste is also generated at the cutting step of leather during the manufacture of finished products (see Figure 3.d, 3.e, 3.f). Depending on the leather quality, the cutting rate (the percentage of leather really used in a piece of leather) can range from 25-60% [CTC, 2000] which means up to 75% of leather is unused.

This waste is most of the time sent to landfill or incineration [Pringle et al., 2016]. According to He et al. (2018), landfill and incineration of leather waste is unacceptable from an environmental point of view because the incineration may produce toxic gases (nitrogen oxides and sulphur oxides) while the improper disposal of waste leather (Figure 5) is a risk for the environment and for human health: Release of chromium hexavalent which can easily access human cells and accumulates in the body causing damage to the internal organs (cancer and genetic mutations) (see chapter 2.2.2 for more details).

Alternative synthetic materials (i.e. coated polyamide fabric with polyurethane resin) can be used to replace leather in consumer goods with the intention of avoiding leather impacts. But these alternatives are made from non-renewable materials (polyamide and polyurethane) which can have also an important environmental impact.

Therefore, the use of leather which is a by-product of the meat and dairy industry [Kral, 2017] can be interesting with the condition to use leather waste and scraps instead of destroying them (and to consider them also as by-products and not waste anymore): The recycling of leather waste produced by the leather industry is expected to create a positive environmental, economic and social impact.

Figure 5: Piles of waste leather [HE et al. 2018]

The recycling of post-consumer products is also expected to reduce environmental impact of leather materials. Figure 3 illustrates different types of waste of finished leather products:

- Unsold stock, returned items from consumers including damaged items and seized counterfeit goods: (g), (h) and (i)
- Post-consumer leather waste: (j), (k) and (l).

Research is done to recycle end of life products with the objective to develop genuine closed loop recycling. But for now, there is significant room for improvement of the current waste management and recycling solutions for leather waste [Pringle, 2017]. And what about the recycling of recycled leather fibres materials? No scientific study dealing with this issue has been published yet. Leather can be recycled once into recycled leather fibres materials, but then what will happen to this material? Will it end up in landfill or incineration anyway, which means the problem has just been postponed but not removed? Further study and R&D work is needed in order to develop a real closed loop recycling process. Some of the recycled leather fibres materials manufacturers are already working on this subject and may propose solutions soon (see chapter 4). In any case, it is very important to verify that the environmental and social impacts of the recycling process do not exceed the ones due to the classical end of life processes such as landfill or incineration.

2.1.3. Waste synthesis

Figure 6 summarizes the production of material all along the production of leather: to produce 150kg of leather (from 1000kg of raw hide), 75kg of tanning waste, 9kg of finishing waste and up to 110kg of cutting waste could be used for the production of recycled leather fibres materials (total - almost 200kg of material).

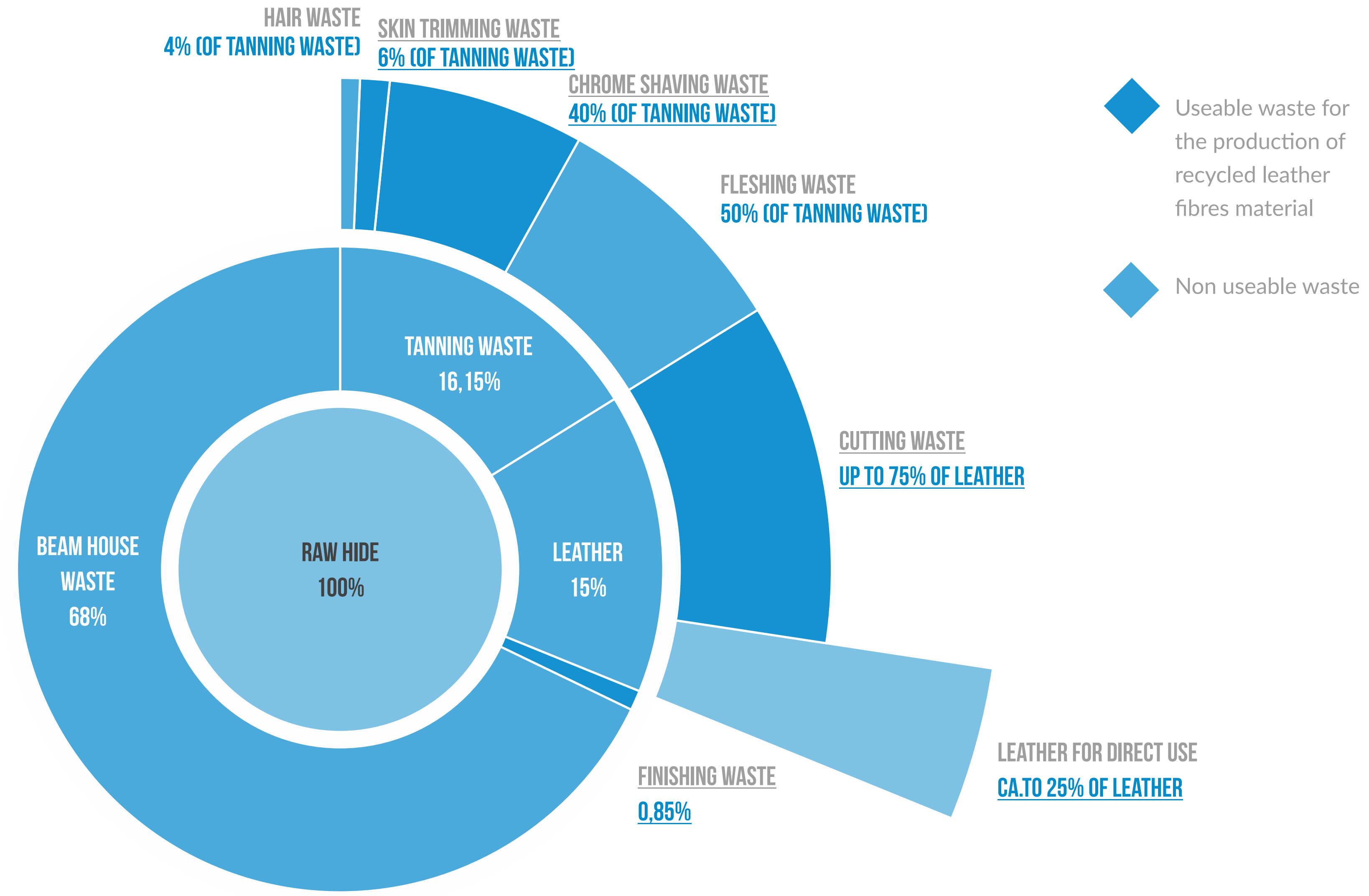


Figure 6: Production of material all along the production of leather (underlined - useful waste for the production of recycled leather fibres materials)

2.2. LEGAL CONTEXT

2.2.1. Leather waste

European Union

At the time of writing there is no specific EU legislation for the leather industry [EU Leather leg]. However, it is affected by legislation concerning the environment, the use of chemicals, and the marketing and use of certain dangerous substances, as well as the use of animal by-products:

- **Regulation (EC) No 1907/2006 on the Registration, Evaluation, Authorisation and restriction of Chemical substances (REACH)**, as the industry is an important downstream user of a wide variety of chemical preparations (see Textbox 4).
- **Directive 2010/75/EU on industrial emissions** according to which permit conditions, including emission limit values, must be based on the Best Available Techniques (BAT) [EU Emissions] [EU Leather leg]. The BAT reference document (BREF) for tanning of hides and skins was adopted in 2013 [JRC BREF TAN].
- **Regulation (EC) 1069/2009 and Commission Regulation (EU) 142/2011 on animal by-products and derived products not intended for human consumption** [EU By-products].

Note: there is no legislation concerning leather finish products, but specific legislation may exist, e.g. the legislation for footwear products [EU Footwear].

Regarding **waste legislation**, there are no specific waste streams for leather in the EU legislation [EU Env]. However, leather waste is covered by the Waste Framework Directive [EU Lex, 2018] which calls for a better waste management in the European Union in order to make the economy truly circular and to recognize waste as a resource (by-product). For now, leather waste is considered 'general' waste usually together with textiles waste, but it is important to foresee the future obligation to separate leather collection from other waste (for textile, EU member states must set up separate collection by 1 January 2025).

United Kingdom

Duty of care provisions in section 34 of the environmental protection act [UK, 1990] stipulate that if any

organisation such as a charity, local authority or business passes second-hand clothing waste to a textile recycling merchant, they must ensure that that merchant has the legal authority to take the waste. In effect, this means that the merchant is a member of the Textile Recycling Association, and holds compulsory employer's liability insurance [Osborn, 2012].

France

France is the only EU member state that has implemented a legal framework related to 'End Producer Responsibility' (EPR) of textile/leather producers [France CE], as well as regarding take back schemes of end-consumer products. [EcoTLC] lists all relevant legal provisions.

Italy

Since the beginning of 2017, post-production and post-consumer textiles/leather are considered 'special waste' ('rifiuti speciali'), and no longer 'urban waste' as before. Any such material must now comply with the new legislative framework on traceability and management. The consequence is that transport and handling of such 'waste' can only be done by companies with the required license, and that stringent documentation needs to be provided along the chain [Altalex, 2017].

United States

No specific regulation applies. Instead legal provisions are absorbed in the 'Resource Conservation and Recovery Act' [RCRA, 1976]. The act insists upon specific methods for the generation, storage, transport, treatment and disposal of hazardous waste produced during manufacturing of textiles and clothing [Osborn, 2012].

China

In summer 2017, the Chinese government decided to ban the imports of solid waste destined for recycling. The decision relates to 24 materials including plastic, paper and textiles, equivalent to 70% of all waste shipped to China [GOSC, 2018; WTO, 2017]. In April 2018, China's Ministry of Ecology and Environment announced import ban on an additional 32 scrap materials (16 materials to be banned by the end of 2018, another 16 at the end of 2019) [Redling & Toto, 2018].

2.2.2. Chemicals management and legal requirements

The use of recycled leather fibres materials raises the question of the chemicals used during the manufacture of leather that could end up in the primary material of recycled leather fibres materials. The whole process of leather production involves a sequence of complex mechanical processes but also chemical reactions (Figure 2). Amongst these, tanning is the fundamental stage, which gives leather its stability and essential character, and it is a consumer of a large quantity of chemicals (Textbox 3).

Issues related to general chemical management aspects such as wastewater management in tanneries are out of the scope of this report as it focuses on the leather by-products as the primary material for recycled leather fibres materials.

In this context, the lead questions to address are the following:

1. What are the main chemical risks associated with the tanning process that may have consequences on the primary material of recycled leather fibres materials?
2. What are the risks related to other manufacturing process?
3. What kind of primary materials can be used into the recycled leather fibres materials (post-production or post-consumer waste) and what are the risks and opportunities?

The tanning process itself is responsible for an important use of water and chemicals, some of which pose significant environmental management challenges [Stevens, 2018]: Chemical oxygen demand (COD), total dissolved solids (TDS), chlorides, sulfates and heavy metal pollution [Dixit et al., 2015] [Kanagaraj et al., 2006].

The chemicals discharged into water end up in highly polluted sediments and are (one of) the root cause(s) of salinisation of rivers. According to Dixit et al. (2015) the environmental impact on water and soil directly affect human health and biodiversity and must therefore be reduced to the extent possible.

Textbox 3: Pollution of tanning process

2.2.2.1. Chemical approach in tanning

About 80-90% of the leather is tanned using chromium oxide [Gombault et al., 2013]. Chromium oxides can exist under several degrees of oxidation from chromium (II) to chromium (VI). Chrome-tanning process uses trivalent chromium (III) salts in the form of basic sulfate (according to the REACH ANNEX XV REPORT, Chromium (VI) compounds are assumed not to be used for tanning anywhere in the world today [Chromium VI REACH] [REACH 47]).

Chromium (III) easily forms complexes with collagen, the main protein of the skin, to stabilize it. It gives very good properties such as mechanical and thermal resistance and softness for several industrial applications. Besides the use of chromium in the tanning process, chromium tanning salts may also be added by the retanning of the wet-blue leather.

Other non-chrome tanning agents can be used alone or in combination with the basic chromium sulphate [Gombault et al., 2013]:

- Vegetable tannins
- Syntans
- Aldehydes, and
- Oil.

According to the paper of Reich and Taeger (2009), the typical consumption of chemicals for the production of 1,000m² chrome tanned leather for shoe uppers and 430m2 split leather (in total 1430m² leather), produced from the same hides, is shown in Table 1.

In the European Union, REACH regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals) has been used since 1 June 2007 to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. It also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals […].

To comply with the regulation, companies must identify and manage the risks linked to the substances they manufacture and market in the EU. They have to demonstrate to the European Chemicals Agency (ECHA) how the substance can be safely used, and they must communicate the risk management measures to the users [ECHA REACH] [EU REACH].
REACH is a regulation used for all chemicals, not specific to leather.

Textbox 4: REACH

PRODUCT CATEGORY	CONSUMPTION KG
PROCESS CHEMICALS	
WATER	215 000
INORGANIC SALTS (MAINLY SODIUM CHLORIDE)	570
INORGANIC AND ORGANIC ACIDS	30
CALCIUM HYDROXIDE	285
SODIUM SULPHIDE	175
ENZYMES	20
TENSIDE	20
CHEMICALS OF WHICH 85-98 % STAYS PERMANENTLY IN THE LEATHER	
CHROMIUM TANNING AGENTS	175
VEGETABLE TANNINS	50
AROMATIC SYNTANS	50
POLYMER TANNING AGENTS	50
RESIN SYNTANS	10
FATLIQUORS	150
PIGMENT	35
POLYMER BINDER	30

Table 1: Chemicals used for the production of 1000 m² chrome tanned shoe leather and 430 m² split [Reich and Taeger, 2009]

While chromium (III) is safe, chromium (VI) is a serious biological threat to humans due to its high toxicity, the ability to penetrate the human cells and the fact that it can be responsible of pathogenic effects such as allergic reactions, dermatitis, skin ulcers, perforations of respiratory surface, lung cancer, liver and kidney damage, among others [Chromium VI REACH].

Chromium (VI) is not used intentionally in the production of leather but may be formed within the leather by oxidation of chromium (III) used during the tanning or the retanning processes.

Tanneries discard around 225kg of solid waste, which in most cases contain chromium, per ton of processed leather [Kolomaznik et al., 2008]. This represent an important quantity of waste, some of which may be considered as hazardous waste. Incorrect disposal or incineration of this waste can provide favourable conditions for the process of oxidation of chromium, changing it from chromium (III) to chromium (VI) which makes it extremely toxic [Gong et al., 2010]. As summarised by Santos et al. (2015), studies report that the presence of chromium VI within leather waste is a serious biological threat to humans due to its high toxicity.

Textbox 5: Risk of oxidation of chromium (III) in tanneries' solid waste

2.2.2.2. Chemical approach in dyeing

Chromium

Some pigments may also contain chromium (VI). Table 2 lists some of the pigments that might be used for leather (these pigments are on the candidate list of Substances of Very High Concern (SVHC) for authorisation in REACH regulation). This means that even if the leather is vegetable tanned without any use of chromium, the finishing step (dyeing process) may be responsible for the presence of chromium (VI) in the finished product. Therefore, it is important to take into account the entire life cycle of the leather production and not just a specific production stage to be sure not to have chromium in the finished product.

Azo compounds

Azo compounds are also a subject of concern under REACH restriction [REACH 43]. Indeed, under certain conditions, some azo dyestuffs can decompose in the organism and generate certain aryl amines that are considered carcinogenic [Frendrup, 2001, P.19].

PIGMENT	EC N°	COLOUR	REFERENCE COLOUR INDEX
LEAD CHROMATE	231-846-0	YELLOW	C.I. 77600 PIGMENT YELLOW 34
LEAD SULPHOCHROMATE YELLOW	215-693-7	GREEN YELLOW	C.I. 77603 PIGMENT YELLOW 34
LEAD CHROMATE MOLYBDATE SULPHATE RED	235-759-9	ORANGE	C.I. 77605 PIGMENT RED 104

Table 2: Chromium (VI) pigments that may be used for leather (based on [Chrom6less, 2005])

2.2.2.3. Chemical approach during other lifecycle stages of leather

According to the REACH ANNEX XV REPORT, chromium (VI) may as well be formed later during the processing of the leather for manufacturing of footwear and other products and it may be formed within the finished articles of leather. Leather goods that come into prolonged and close contact with the skin pose the greatest risk to consumers (shoes and gloves, clothes, hats, sports equipment, watch straps and straps for bags, furniture, etc.).

2.2.2.4. Post-production or post-consumer primary material for recycled leather fibres materials?

As seen previously in chapter 2.1, waste is produced throughout the life cycle of leather. Figure 3 gives a good idea of the state of the waste at each stage. Waste coming from distribution or post-consumer is usually more complex and in poorer condition than waste coming from tannery or manufacturing. Pringle (2017, p. 104) summarized qualitative characteristics of waste across the lifecycle of leather (see Table 3).

QUALITATIVE CHARACTERISTICS				
LEATHER LIFECYCLE STAGE	LEATHER PURITY/ MATERIAL MIX	GEOGRAPHICAL DISTRIBUTION OF WASTE	GEOMETRY OF WASTE	QUALITY OF WASTE
TANNERY	HIGH PURITY/LOW MIXING	CONFINED	SIMPLE GEOMETRY	GOOD CONDITION
MANUFACTURING	MEDIUM PURITY/SOME MIXING	MEDIUM DISTRIBUTION	MEDIUM COMPLEXITY	MEDIUM CONDITION
DISTRIBUTION AND RETAIL	LOW PURITY/ HIGH LEVEL OF MIXING	GLOBAL DISTRIBUTION	COMPLEX GEOMETRY	MEDIUM CONDITION
POST-CONSUMER	LOW PURITY/ HIGH LEVEL OF MIXING	GLOBAL DISTRIBUTION	COMPLEX GEOMETRY	POOR CONDITION

Table 3: Summary of all qualitative characteristics of waste across lifecycle of leather [Pringle, 2017]

Table 4 gives some points to better understand risks and opportunities to use post-production or post-consumer waste.

Based on this information, it is important for manufacturers using post-production and/or post-consumer primary material to be familiar with REACH or other regulation and to have good quality control at the reception of the material to be sure it is free of dangerous chemicals. Chapter 2.2.3 will give more details on third party standards used in the leather industry to improve material compliance (integrity and traceability).

	RISKS	OPPORTUNITY
POST-CONSUMER PRIMARY MATERIAL	• Lack of traceability on the raw material and chemicals • Degraded product • Mixture of different materials (leather, textile, rubber, polymers, metal) and difficulty to separate • Mixture of chrome-tanned and vegetable-tanned material • Low recycled rate of end-of-life finished products • Improper storage resulting in oxidation of chromium	• Studies and economical solutions are under development [Lee & Rahimifard, 2012] • Important quantity of material • Legislation to push the recycling of end-of-life products
POST-PRODUCTION PRIMARY MATERIAL	• In some countries, lack of traceability on the chemicals used for processing • Mixture of chrome-tanned and vegetable-tanned material • Improper storage resulting in oxidation of chromium	• Knowledge of the waste deposit • Consistency and homogeneity in materials • Fewer chemicals than post-consumer material (dye, coating, etc.) • Cost

Table 4: Post-production and post-consumer primary materials comparison

2.2.3. Compliance and traceability: Third party standards

As previously seen, the use of chemicals is a matter of concern in the leather industry (Textbox 6) and the question of the quality of the raw material is an important point to take into account. Leather products are manufactured using various processes, consuming many chemicals which will influence the finished product characteristics and quality. Consequently, leather by-products may have also different characteristics [Ozgunay et al. 2007].

These by-products can be used for different purpose: Recycled leather fibres materials are a good example of a solution to use them.

It is therefore important to first undertake a characterization of the by-products used as raw materials before, in order to design the target products to create, as well as the appropriate method to transform them. The finished product quality will depend on the quality and homogeneity of the raw material. Consequently, a leather by-product transformer needs to have a good knowledge of the upstream logistics chain to have a control on the quality of the raw materials. In this context third party labels have been created to standardize controls and to reassure industrials and consumers.

Note: the general picture of standards and labels of leather products is very complicated: There is a plethora of standards and labels in Europe. The remainder of the chapter will concentrate on the most commonly and widely used in the leather industry.

Leather industry faces many challenges:

- Environmental impacts (pesticides, chemical pollution, consumption of water and energy, waste)
- Social impacts (security, work rate, wages, child labour)
- Health risks, safety (product safety, professional environments, environment, ...)
- Traceability and transparency.

This coupled with consumer awareness leads the market to have more and more expectations and the leather industry has to:

- Know the regulations and fulfil the requirements of the market
- Secure products and manage risk for products and process
- Evaluate the supply chain performance (transparency, traceability, responsibility)
- Protect its image or stand out from the competition.

Textbox 6: Environmental and social challenges of the leather industry

2.2.3.1. Labels dealing with harmful substances: OEKO-TEX® Association

The International Association for Research and Testing in the Field of Textile and Leather Ecology (OEKO-TEX®) is a grouping of 18 independent textile research, leather research and test institutes in Europe and Japan and their representative offices in more than 60 countries around the world.

The member institutes are responsible for the joint development of test methods and limit values which form the basis of the product labels (see Figure 7) according to STANDARD 100 by OEKO-TEX®, MADE IN GREEN by OEKO-TEX® and LEATHER STANDARD by OEKO-TEX® as well as the production site certifications according to STeP by OEKO-TEX® (Sustainable Textile Production) and the chemical management tool DETOX TO ZERO by OEKO-TEX®. They are also entitled to carry out the corresponding laboratory tests and site audits [OEKO-TEX].

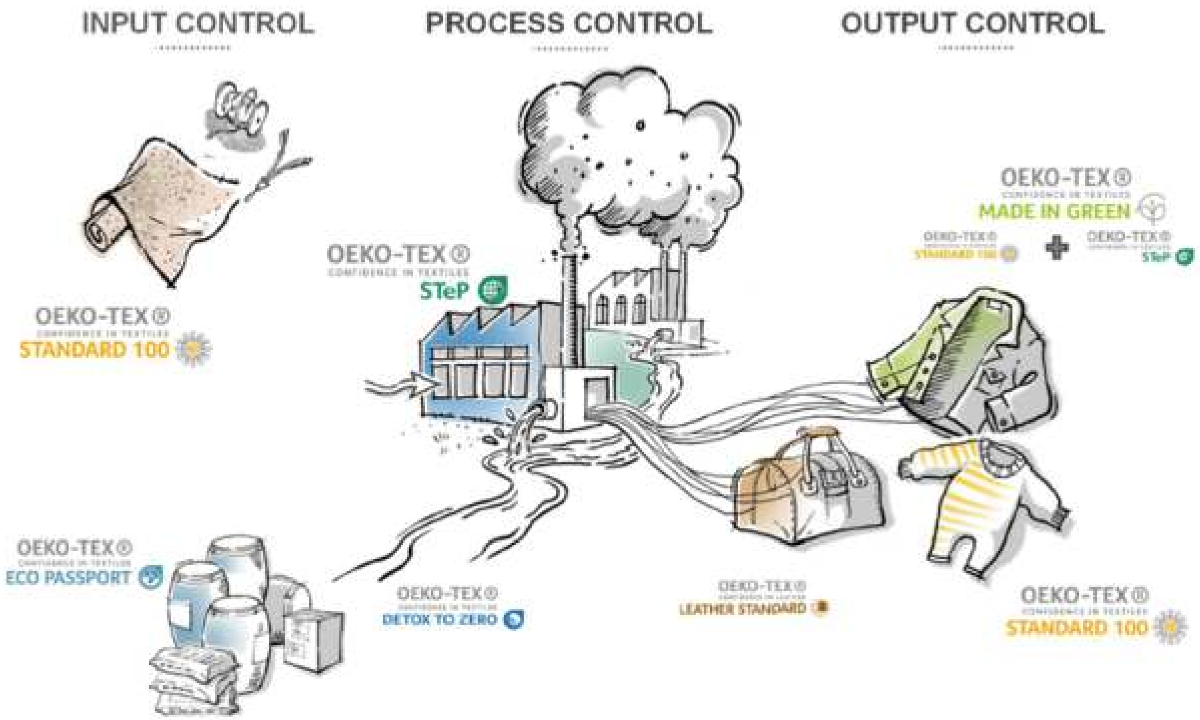


Figure 7: OEKO-TEX® labels (source [IFTH])

	OEKO-TEX® ASSOCIATION		
PRODUCT LABELS	**STANDARD 100 BY OEKO-TEX®**	**MADE IN GREEN BY OEKO-TEX®**	**LEATHER STANDARD BY OEKO-TEX®**
GEOGRAPHICAL AREA	Worldwide		
VALIDITY	Period of 1 year, must then be issued again		
WHAT KIND OF PRODUCT IS CONCERNED?	Textile products		Leather and leather articles
	Raw, semi-finished and finished products; accessory materials	Consumer products and semi-finished products	Semi-finished products (e.g. wet-blue, crust, etc.), finished leather, leather fibre material, ready made articles
WHERE IN THE SUPPLY CHAIN?	At all levels of the textile supply chain	At all levels of the textile supply chain	At all levels of the textile supply chain
WHAT DO THE LABEL VERIFY?	Materials tested for harmful substances	Materials tested for harmful substances AND that have been manufactured by using environmentally friendly processes and under safe and socially responsible working conditions	Materials tested for harmful substances (similar as the Standard 100 but with adjustment of the limit values for chromium)
EXAMPLE OF ARTICLE	Raw and dyed/finished yarns, raw and dyed finished fabrics and knits, consumer goods, accessories (buttons, zip fasteners, sewing threads or labels, etc.)	All kinds of items of clothing and furnishings	Wet-blue, wet-white, crust, leather, bonded leather fibres material, garments of all types, accessories, leather gloves, leather handbags, leather covers, etc.
OTHER INFORMATION	Textile products can only be certified according to the Standard 100 by Oeko-Tex if all components comply with the required criteria	The textile product must have undergone successful testing for compliance with the requirements of the Standard 100 by Oeko-Tex, and the product as well as the majority of its components and predecessors are produced by companies that have been audited and STeP certified by Oeko-Tex	The precondition for the certification of leather materials and leather articles/products is that all parts of an article meet the required criteria – in addition to the leather, for non-leather (e.g. textile or metallic) components, the requirements of the Leather Standard are combined with those of the Standard 100
BENEFITS	• REACH compliant • Highly credible and well-accepted label in the B2B and especially the B2C markets • Possibility to present the company and the product portfolio free of charge in OEKO-TEX website directory		
LOGO	OEKO-TEX® CONFIDENCE IN TEXTILES STANDARD 100 00000000 Institute Tested for harmful substances. www.oeko-tex.com/standard100	OEKO-TEX® CONFIDENCE IN TEXTILES MADE IN GREEN 000000000 Institute Tested for harmful substances and produced sustainably in accordance with OEKO-TEX® guidelines. www.madeingreen.com	OEKO-TEX® CONFIDENCE IN LEATHER LEATHER STANDARD 00000000 Institute Leather goods tested for harmful substances. www.oeko-tex.com/leatherstandard

Table 5: OEKO-TEX® product labels (source: [OEKO-TEX])

Table 5 gives more information on labels used for textile and leather products.

STANDARD 100 by OEKO-TEX® and LEATHER STANDARD by OEKO-TEX® make a distinction between four product classes:

- Product class I: Products for babies and toddlers up to 3 years of age (leather clothing, leather gloves, crawling sheepskin, fur etc.)
- Product class II: Products that are worn close to the skin (leather trousers/-jackets, leather underwear etc.)
- Product class III: Products used away from the skin (lined leather jackets/overcoats, leather handbags, leather belts etc.)
- Product class IV: Decoration/Furnishing materials (upholstery leather covers etc.).

2.2.3.2. Labels dealing with circular economy: RCS 100 (Recycled Claim Standard) and GRS (Global Recycle Standard)

Regarding the circular economy issue, there is a wide range of standards to certify generic recycled material. Table 6 summarises the two most often encountered product labels in the context of recycled leather fibres materials. These two labels are managed by Textile Exchange, a global non-profit organization founded in 2002 that works closely with all sectors of the textile supply network.

Textile Exchange identifies and shares best practices regarding farming, materials, processing, traceability, and product end-of-life in order to create positive impacts on water, soil, air, animals, and the human population created around the world by the textile industry [Textile Exchange].

	GLOBAL RECYCLED STANDARD (GRS) 4.0 [TE GRS]	RECYCLED CLAIM STANDARD (RCS) 2.0 [TE RCS]
ISO ECOLABEL TYPE [ISO 14024]	Type I	Type I
ISO ECOLABEL TYPE DESCRIPTION [GEN, 2018]	Voluntary, multiple-criteria based, third party programme that awards a license that authorises the use of environmental labels on products, indicating overall environmental preferability of a product within a particular product category, based on life cycle considerations	
TRACEABILITY / CHAIN-OF-CUSTODY	Content Claim Standard [TE CCS] Chain of custody system from the source to the final product, certified by an accredited third-party certification body	
ENVIRONMENTAL MANAGEMENT REQUIREMENTS	• Environmental management system • Chemical management system • Wastewater management requirement to measure: • Energy use • Water use • Wastewater/effluent • Emission to air [TE GRS], pp. 26	N/A
CHEMICAL MANAGEMENT REQUIREMENTS	• Substance exclusion list • ZDHC MRSL v.1.1 [ZDHC 2015; 2017] [TE GRS], pp. 32	N/A
SOCIAL & LABOUR REQUIREMENTS	• Code of conduct/policy • Specific requirements for: Forced, bonded, indentured and prison labour • Child labour • Freedom of association, collective bargaining • Discrimination, harassment, abuse • Health & safety • Wages, benefits, terms of employment, working hours	N/A
PRODUCT CLAIMS, LOGO USE	• GRS with % indication: 50% - 95% recycled content • GRS (no % indication): 95% to 100% recycled content. [GRS/RCS, 2017], pp. 29	• RCS blended: 5% - 95% recycled content • RCS 100: 95% - 100% recycled content [GRS/RCS, 2017], page 16
LABELS/ TRADEMARKS		

Table 6: Comparison: Global Recycled Standard (GRS), Recycled Claim Standard (RCS)

In addition to these standards, different working group are working on the sustainability of leather products and developing B2B certifications for tanneries and leather producers. Some of them are national initiatives while others are international.

The subject of the report is not to present all of these different groups though Textbox 7 gives a short description of working groups that may interest the reader.

LWG, the Leather Working Group, is based in Northampton (UK). The objective of this multi-stakeholder group is to develop and maintain a protocol that assesses the environmental compliance and performance capabilities of tanneries and leather producers, and promotes sustainable and appropriate environmental business practices within the leather industry.
The group seeks to improve the leather industry by creating alignment on environmental priorities, bringing visibility to best practices and providing suggested guidelines for continual improvement.
It is the group's objective to work transparently, involving suppliers, brands, retailers, leading technical experts within the leather industry, NGOs, academic institutions and other stakeholder organisations.
URL: https://www.leatherworkinggroup.com/ (accessed: 17 January 2019).

Responsible Leather Round Table (RLRT). This is an initiative started in 2017 by Textile Exchange to focus on leather in response to demand from brands to address the impacts of the full leather value chain.
URL: https://responsibleleather.org/ (accessed: 17 January 2019).

ZDHC, the Zero Discharge of Hazardous Chemicals Programme, is a foundation based in Amsterdam, Portland and Shanghai. Its mission is to advance towards zero discharge of hazardous chemicals in the textile, leather and footwear value chain to improve the environment and people's well-being.
URL: https://www.roadmaptozero.com/ (accessed: 17 January 2019).

WWF Leather Buyers Platform, created in 2016, is a group of businesses working together with WWF to reduce the environmental impact of leather tanning and drive positive change in the industry.
URL: https://www.wwf.org.uk/leatherbuyersplatform (accessed: 17 January 2019).

Textbox 7: Example of working groups to improve social and environmental impacts of textile and leather

3. LEATHER RECYCLING PROCESSES: AN OVERVIEW

Pringle et al. (2016) has described different technologies to recycle leather wastes. Figure 8 details these technologies throughout the leather lifecycle.

Only the fragmentation which is a mechanical treatment will be studied in the present document for the following wastes products:

- Leather waste from tannery waste
- Manufacturing production waste
- Post-consumer waste.

The other technologies are out of scope (thermal treatment, biological processing, chemical processing, direct re-use).

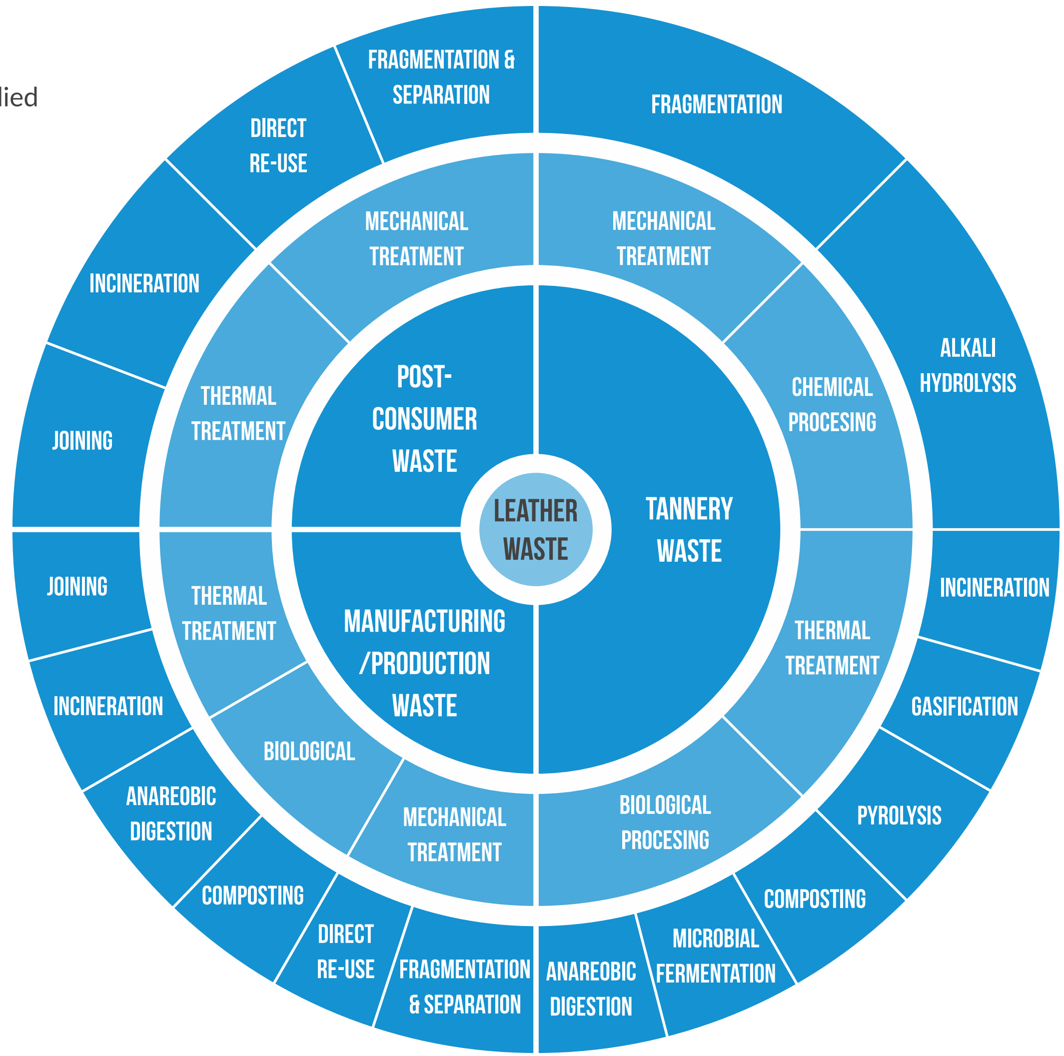


Figure 8: Avenues for recovery of leather waste throughout lifecycle [Pringle et al. 2016]

3.1. RECYCLED LEATHER FIBRES MATERIALS: AN INTRODUCTION

3.1.1. Terminology and public perception

As defined previously in the glossary, the terminology 'leather' is stringent: Standards like the European Standard EN 15987:2015 or the British standard BS 2780 are precise that if a product is made from reconstituted leather fibres or if the surface coating is too thick then it cannot be sold as 'leather'.

But these standards do not prevent the term being used in context where indeed there is no 'leather' as such being used but rather for the purpose of associating the leather image with a product in the head of the consumer. Consequently, recycled leather fibres materials compete on the market with 'synthetic leather' or 'artificial leather'. All these different products create confusion for the consumers, sometimes trying to make them believe that the products are made from virgin leather.

Furthermore, because brands and consumers increasingly focus on environmental concerns and sustainability, some products are called 'eco-leather' even if they are made from petroleum, which can be inappropriate [Fratini et al. 2016]. In fact, LCA comparison between leather and polyurethane 'synthetic leather' shows environmental advantages to the synthetic material [Higg MSI]. But this analysis usually does not take into account the recycling advantages of materials made from leather.

Manufacturers must be very careful when they communicate on their products. They need to be transparent to avoid green-washing and to avoid the provision of false information to consumers. Recycled leather fibres materials can't be named only 'leather' without specifying the use of 'reconstituted leather fibres' or 'recycled leather fibres'. This will avoid the manufacturer or the brands from being attacked for undertaking misleading commercial practices.

3.1.2. Material and process presentation

Recycled leather fibres materials are composite materials made from leather waste together with other materials which will bring specific properties (binder, reinforcement, colour, finishing, etc.). The percentage of leather fibres may vary between 10% and 90% of its content (the composition of the bonded leather fibres material depends on the manufacturer and its trade secret). In principle, the production of this material is similar to the production of paper:

1. Leather scraps are collected together
2. The scraps are made into a pulp and bonded together with polyurethane or latex binders
3. The material is dried
4. The surface is then embossed to give it the appearance of virgin leather.

The existing manufacturing technologies at this point are:

- Classical bonded leather (Figure 9)
- Advanced bonded leather using hydroentanglement technology (Figure 10)
- Innovative recycling technologies: Flash sintering technology (Figure 11).

Recycled leather fibres materials are usually manufactured in rolls or sheets. This format makes it possible to have less loss after the manufacture of finished products (no marks and straight cut like fabric).

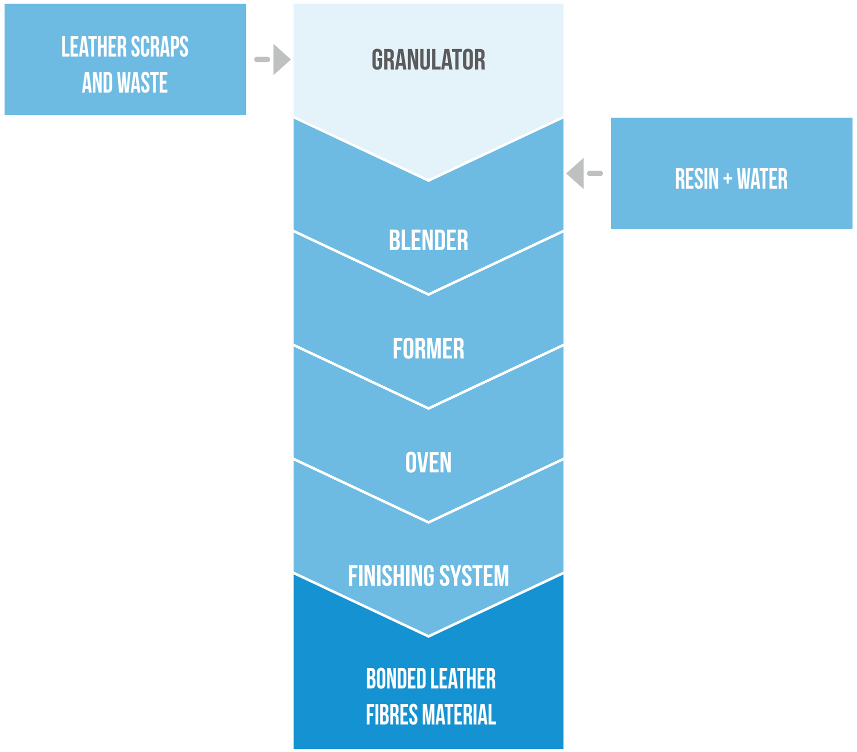
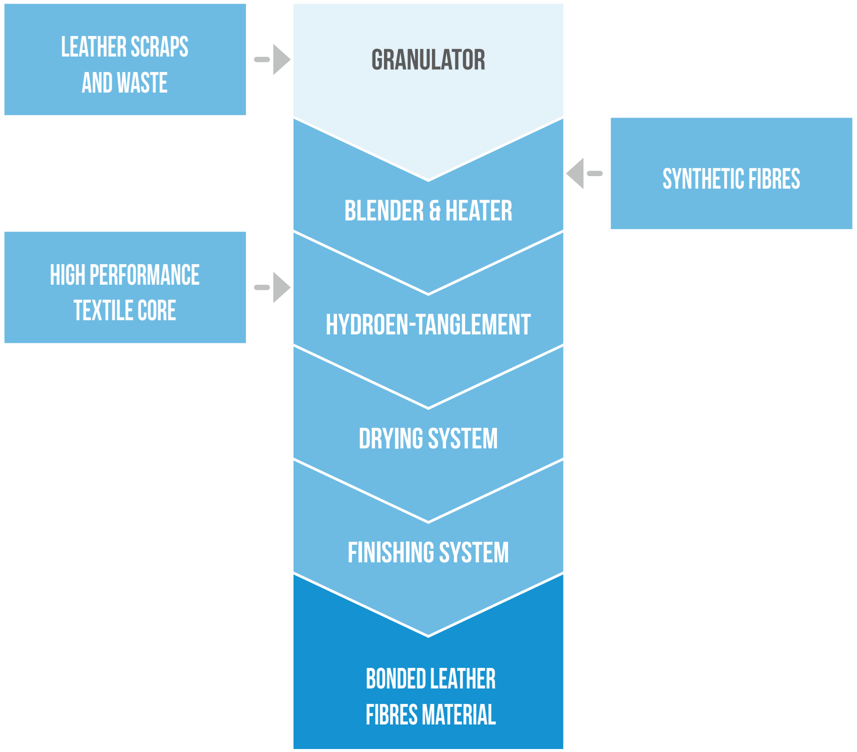


Figure 9: Classical bonded leather fibres material manufacturing process [Addie et al. 2001]



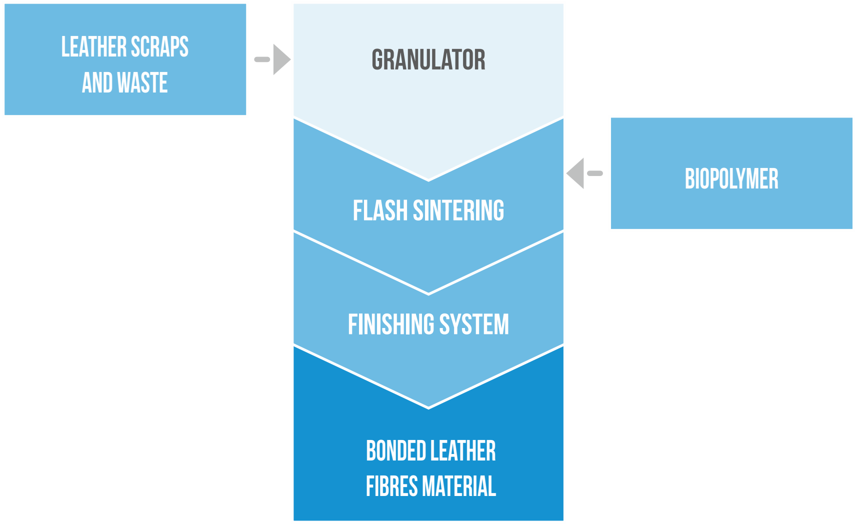


Figure 10: Hydroentanglement technology process [Bevan, 2005]

Figure 11: Flash sintering process [AUTHENTIC MATERIAL]

3.1.3. Performance and durability

The overall average use of a leather article is estimated by Kral (2017) at approximately 4 years (upholstery ~10 years, shoe ~1 year, leather goods and garments ~4 years). Shoes, bags, upholstery, etc. manufacturers may wonder what the characteristics of recycled leather fibres materials regarding microstructure, mechanical properties and rheological properties are when compared to virgin leather:

- If virgin leather is replaced by recycled leather fibres materials, will it have an impact on finish product quality?
- Is the interface between the binder (latex, resin, etc.) and leather fibres strong enough to guarantee enough mechanical properties?
- What about the durability of the recycled leather fibres materials during the use stage comparing to virgin leather?

Recycled leather fibres materials have many benefits for the industry and the consumers:

- Economic benefits: He et al. (2018) has showed that the recycling of manufacturing leather waste can increase the profit of the entire supply chain. Ding et al. (2017) also concluded this material can be a convenient, cost-efficient and environment-friendly technology to deal with the problem of recycling the chrome-containing leather shavings. The material is also less expensive than virgin leather (see manufacturer information in chapter 4).
- The material is lighter than virgin leather (see manufacturer information in chapter 4)
- The material can be as resistant as virgin leather (see Textbox 8 and chapter 4)
- With regards to durability some of them are said to be more durable than virgin leather (chapter 4). No scientific papers have been found to confirm that recycled leather fibres materials have a lower or higher shelf life than virgin leather (leather is a well-known material that can last for many years if it is properly cared with a moisturiser and other skin care products, but are there recycled leather fibres materials that can do the same?). Further studies would be needed to confirm this.

Alternative technology to improve material properties

Addie et al. (2001) say that the performance of the material will depend on the leather fibres size. Researchers have also studied the possibility to incorporate plant fibres into recycled leather fibres materials as reinforcement materials to enhances the mechanical and thermal properties [Senthil et al. 2015]. Plant fibres advantages are: Low cost; fairly good mechanical properties; high specific strength; non-abrasive; eco-friendly; and bio-degradability characteristics. Using these plants fibres may increase the ecological advantage of recycled leather fibres materials while reducing the cost and improving mechanical properties which are sometimes insufficient for certain uses requiring resistance. This could be an interesting technology to develop to create alternative technical products. But the end-of-life subject has to be considered to separate the components of this composite material.

3.1.4. Material availability

The global population is growing as well as the consumption of meat, especially in the developing countries. Consequently, the supply of leather raw material and the production of leather wastes and scraps are increasing together. But this trend is valid from a global point of view: If we look at it by region, in developed countries a declining consumption of red meat has reduced the supply of skins and leather hides, while in the developing world leather raw materials have increased [FAO 2016]. This means the supply of leather and leather scraps mainly comes from developing countries, with consequences on the environmental impacts of the supply chain due to long route transport, but also local environmental and social negative impacts in the developing countries (see chapter 2.2.2). ...

Santos et al. (2015) studied different recycled leather fibres materials composed of natural rubber and industrial leather waste varying the leather waste amount from 20 to 80phr (parts per hundred of resin, a unit of measurement used in formulation concerning the number of parts of a constituent per hundred parts of polymer, by mass). For each composition, they investigated the microstructure, the mechanical properties and the rheological properties of the material. The results of the study showed that the inclusion of leather waste in natural rubber is suitable for producing new raw materials with mechanical properties favourable to the manufacture of shoes, bags, upholstery, etc. These conclusions prove the feasibility of manufacturing recycled leather fibres materials as an interesting approach for recycling leather waste.

Textbox 8: Mechanical and rheological properties of the recycled leather fibres materials [Santos et al., 2015]

... Production of recycled leather fibres materials is dependent on the leather industry for the supply of raw material so close links of collaboration are necessary to ensure raw material availability and finished product is of the best quality, and also to guarantee that it is economically feasible [Pringle et al. 2016]. Waste must be consumed close to the place where it is produced to avoid transport over long distances and important impacts on the environment (this will also have a positive economic impact). Equally as seen in Chapter 2.1.2, the main leather consuming countries must develop local actions to recycle leather products at the end of their life. This will increase the sourcing of raw material for the production of recycled leather fibres materials while reducing transport over long distances.

3.1.5. Lead times

As a manufactured product, recycled leather fibres materials are industrially produced so the manufacturing lead time and the delivery lead time are well known and normally under control. The use of production by-products as raw material has the advantage that this material is currently quite easily available. Products on stock can usually be delivered in less than one week and finished products or special orders in less than one month.

Further information is presented in the Table 7 of Chapter 4 (some producers consider this information as confidential and will give more details directly to their customers).

3.1.6. Environmental and social impacts

Santos et al. (2015) quantified the presence of chromium III in the case of end of life of recycled leather fibres materials (presence in leachate extracts). Leaching tests showed that the amount of chromium released from this recycled leather fibres materials is lower than allowed as standard which shows that the material does not present a risk for humans and for the environment.

Except chemical impact studies, nowadays no scientific papers are available to communicate the environmental impact of recycled leather fibres materials throughout the life cycle. The lack of information on this subject has been confirmed by Quantis which is an expert company on product footprint (Life Cycle Assessment and other tools). LCAs are expected on recycled leather fibres materials. Similarly, comparison between virgin leather and recycled leather fibres materials are expected to quantify the environmental and social advantages of this product. The integration of these data into existing tools like the Higg Materials Sustainability Index (MSI) are expected to easily compare different types of material [Higg MSI].

The following chapters will give more information about existing companies which manufacture recycled leather fibres materials, usually called bonded leather fibres material.

4. COMPARISON OF THE RECYCLED LEATHER FIBRES MATERIALS PRODUCERS

	COUNTRY	PRODUCTION SITE	WEBSITE	TECHNOLOGY	INPUT MATERIALS	OUTPUT PRODUCTS
RELEA	New company and brand to be launched in spring 2019			Classical Bonded Leather fibres materials	• genuine leather fibres • natural or synthetic binders • waxes, fats and color pigments	sheets and rolls
LEDERTECH DEUTSCHLAND GMBH	Germany	Bopfingen	https://www.ledertech.de/	Classical Bonded Leather fibres materials	• leather scraps from tanning process • binder • water and synthetic (coating, pigment) (exact composition non available)	sheets and rolls
SALAMANDER BONDED LEATHER	Germany	Türkheim	https://www.salamanderbl.com/en/Welcome	Classical Bonded Leather fibres materials	• blend of vegetable tanned leather scraps and chrome shavings (Wet Blue) from tanning process • natural fat and latex • water and synthetic (coating, pigment) (exact composition non available)	sheets and rolls
GESTIONI INDUSTRIALI	Italy	Castello d'Agogna	http://www.gestioni-industriali.it/index.html	Classical Bonded Leather fibres materials	• vegetable tanned leather scraps • binder • water and synthetic (coating, pigment) (exact composition non available)	sheets and rolls
PRODOTTI ALPHA SRL	Italy	Tromello	https://prodottialfa.eu/en/	Classical Bonded Leather fibres materials	• scraps of chrome-tanned cow leather (wet blue) (55%) • natural latex (25%) • grease and natural tanning products (12%) • water and synthetic (coating, pigment) (9%)	sheets and rolls
RECYC LEATHER™	China	Shenzhen	http://www.recycleather.com/	Classical Bonded Leather fibres materials	• leather fibres from industrial glove off-cuts (60%) • latex/rubber (30%) • water and synthetic (coating, pigment) (10%)	sheets (140 x 110 cm)
SALPAX, S.A.	Spain	Cañada	https://www.salpax.es/eng/	Classical Bonded Leather fibres materials	• bovine-type fibers scraps from tanning process • natural Latex • water and pigment • polyurethane finish (exact composition non available)	rolls
ELEATHER ®	UK	Peterborough	https://www.eleathergroup.com/	Hydroentanglement technology [1]	• chrome-tanned leather scraps • high performance textile core • water and synthetic (coating, pigment) (exact composition non available)	rolls
AUTHENTIC MATERIAL	France	Toulouse	https://www.authentic-material.com/en/	Flash sintering technology [2]	• leather production wastes (wet-blue, wet-white, shavings, cutting) • post consumer waste (under development) • possibility to mix with a biopolymer	pieces

Table 7 (1/5): Comparison of the recycled leather fibres materials producers

[1] Hydroentanglement technology: bonding process for wet or dry fibres, the resulting bonded product being a similar to a nonwoven material (fabric or paper). It uses fine and high pressure jets of water which penetrate the fibres causing them to entangled with a high performance textile core [Bevan 2005] ; [EL technology].
[2] AUTHENTIC MATERIAL's technology is based on a patented process of fragmentation and recomposition of organic matter (horn, shells, leathers ...) resulting from the transfer of a flash sintering technology initially developed in powder metallurgy and plasturgy. This technology allows to develop tailor-made solutions in various forms [AUTHENTIC MATERIAL].

	APPLICATION		PRODUCT QUALITY
RELEA	- shoe industry - furniture & craft industries - architecture and design	- bag & fashion industry - high-tech	The used leather fibres are derived from high-quality genuine leather sections from the shoe, bag, fashion, upholstery, automotive industry and tanneries
LEDERTECH DEUTSCHLAND GMBH	- shoe industry (reinforcing edges, counters, insole linings, soles, heels) - other applications on demand	- leathergoods - belts	NA
SALAMANDER BONDED LEATHER	- shoe industry (counter, heeling, welt, insole, outsole material) - leathergoods (purses, bags etc.) - furniture	- bookbinding - packaging - belts - flooring	NA
GESTIONI INDUSTRIALI	- shoe industry - bookbinding - leathergoods - belts		NA
PRODOTTI ALPHA SRL	- bookbinding - belts - packaging	- leathergoods - furniture - labels	The company has registered the brand CORIUM which is the high end trend of the company (softer and easier to work)
RECYC LEATHER™	- shoe industry - belts - labels	- leathergoods - furniture - wall and flooring	- Certified as Recycled Leather: BS 2780. - Recyc LeatherTM product has been developped to be stronger and softer that usual bonded leather fibres material in order to be used as finished product (and not only as a reinforcing material)
SALPAX, S.A.	- shoe industry - belts - packaging, decoration	- leathergoods - furniture	NA
ELEATHER ®	- shoe industry (Nike Flyleather products) - seats in transport (aircrafts, buses, trains) - upholstery (airport lounges, restaurants, hotel, movie theatres)		Production plant has ISO certification: ISO 9001 and BS OHSAS 18001
AUTHENTIC MATERIAL	- luxury industry (watches, knives, pens, jewellery)		- all the natural material are selected in specific network, secured and traceable- test are regularly done, to check if there is no Chrome 6 transformation

Table 7 (2/5): Comparison of the recycled leather fibres materials producers

	PERFORMANCE AND DURABILITY	LIMITS OF APPLICATION
RELEA	- Technical properties adjustable / customizable according to specific requirements (dimensions, strength, ingredients for fire protection, extremely resistant coating, etc.) - Highest resistance to environmental influences (UV-resistance, chemicals, abrasion, water resistance, etc)	No constraints comparing to classic bonded leather fibres materials
LEDERTECH DEUTSCHLAND GMBH	NA	In shoe industry, limited to the rigid parts (stiffness limits)
SALAMANDER BONDED LEATHER	NA	In shoe industry, limited to the rigid parts (stiffness limits)
GESTIONI INDUSTRIALI	NA	In shoe industry, limited to the rigid parts (stiffness limits)
PRODOTTI ALPHA SRL	NA	No application in shoe industry
RECYC LEATHER™	- Lighter than virgin leather (about 80%) - Easy care (wet cotton) - In collaboration with the CTC group in Lyon (FR), it is possible to change the material according to specific specifications (stretchability, heat resistance, waterproof, flexibility, ...)	- The material is delivered in China only. - In Europe, they deliver only a range of small leather goods.
SALPAX, S.A.	NA	In shoe industry, limited to the rigid parts (stiffness limits)
ELEATHER ®	Nike informs Flyleather is 40% lighter and 5x more abrasion resistant than full grain leather	The company mainly works for transport and upholstery markets
AUTHENTIC MATERIAL	Properties equivalent to the original leather material, or with improved properties when combining leather and biopolymer	Expensive material

Table 7 (3/5): Comparison of the recycled leather fibres materials producers

	ENVIRONMENTAL AND SECURITY CERTIFICATIONS	ENVIRONMENTAL BENEFITS
RELEA	Products REACH compliance - LEATHER STANDARD by OEKO-TEX®	- Water-based surface coating - Less chemical smell (natural leather odor immanent)
LEDERTECH DEUTSCHLAND GMBH	Products REACH compliance - LEATHER STANDARD by OEKO-TEX®	A range of 'chrome-free' material has been developped under the name 'White Line'
SALAMANDER BONDED LEATHER	Production plant ISO 50001, ISO 14001 and EMAS Products REACH compliance - LEATHER STANDARD by OEKO-TEX®	The company guarantees that their bonded leather fibres material is made of over 90% of natural and re-growing raw materials
GESTIONI INDUSTRIALI	Products REACH compliance - LEATHER STANDARD by OEKO-TEX®	The production site has started to work on a special environmental program for water protection and a specific Environmental Management System in compliance with international standards.
PRODOTTI ALPHA SRL	Products REACH compliance - GRS certification	In 2015, the company introduced a division within its structure that is dedicated to supply natural rubber and latex
RECYC LEATHER™	Products REACH compliance - RoHS compliance - RCS 100 certification - SGS certification	'Chrome free' input material: traceable pre consumer leather waste
SALPAX, S.A.	Company member of the United Nations Global Compact initiative Products REACH compliance - LEATHER STANDARD by OEKO-TEX®	NA
ELEATHER ®	Production plant ISO 14001 No information on product certification is communicated	- No use of adhesives (fibre bonding using only water) - 95% of processed water is recycled - zero manufacturing waste is sent to landfill (91% of waste is recycled locally and wet waste is converted into fertilizer)- Nike says the material gives a reduction of -80% of the carbon footprint and -90% of water consumption [3]
AUTHENTIC MATERIAL	No certification is communicated	- Products can themselves be recycled up to 4 times to produce new materials - Tests are actually done to use post-consumer leather as a raw material

Table 7 (4/5): Comparison of the recycled leather fibres materials producers

[3] [Nike Flyleather]

	COST	PRODUCT LEADTIME	OTHER INFORMATION
RELEA	The price per square meter is in the range of 20% to 80% of high-quality European leather (the price will depend on the type of material, coating, format and purchase quantity).	On demand	- Aesthetic characteristics are very creative designable and customizable (individualization through free choice of color, diverse surface effects, unique textures, haptic branding, exclusive decors, etc.)
LEDERTECH DEUTSCHLAND GMBH	Price to be defined with suppliers according to the needs; each item has to be calculated separately (the cost is normally lower than virgin leather)	On demand	- Company with 80 years experience - Products available in different colours, different thicknesses, different grains
SALAMANDER BONDED LEATHER		raw material within the same week if it is not a special material finished goods 3-4 weeks	- Company created in 1917 - Product assortment: over 2,500 colours, 40 embossing grains and 9 different gloss levels - range of products from 0,35 – 7,5 mm thick - rolls can be split; several sheet sizes or cuttings are possible on demand
GESTIONI INDUSTRIALI		NA	Company created in 1962
PRODOTTI ALPHA SRL		NA	Company created in 1958
RECYC LEATHER™	Two time cheaper than virgin leather	3 weeks (delivery in China only)	- Company created in 2016 - The company has commercial offices in Hong Kong, France and Germany - 15 different embossing grain, colour reproduction from Pantone
SALPAX, S.A.	Price to be defined with suppliers according to the needs; each item has to be calculated separately (the cost is normally lower than virgin leather)	NA	Company with more than 40 years experience
ELEATHER ®		NA	Company created in 2007
AUTHENTIC MATERIAL	Price to be defined with suppliers according to the needs ; each item has to be calculated separately	NA	- Company created in 2016 - Project to expand at mid term (5 years) and offer higher volumes and low prices - Target to collect the luxury industry pre production materials (true close loop recycling)

Table 7 (5/5): Comparison of the recycled leather fibres materials producers

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

RELEA

Figure 12: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Ledertech Deutschland GmbH [4]

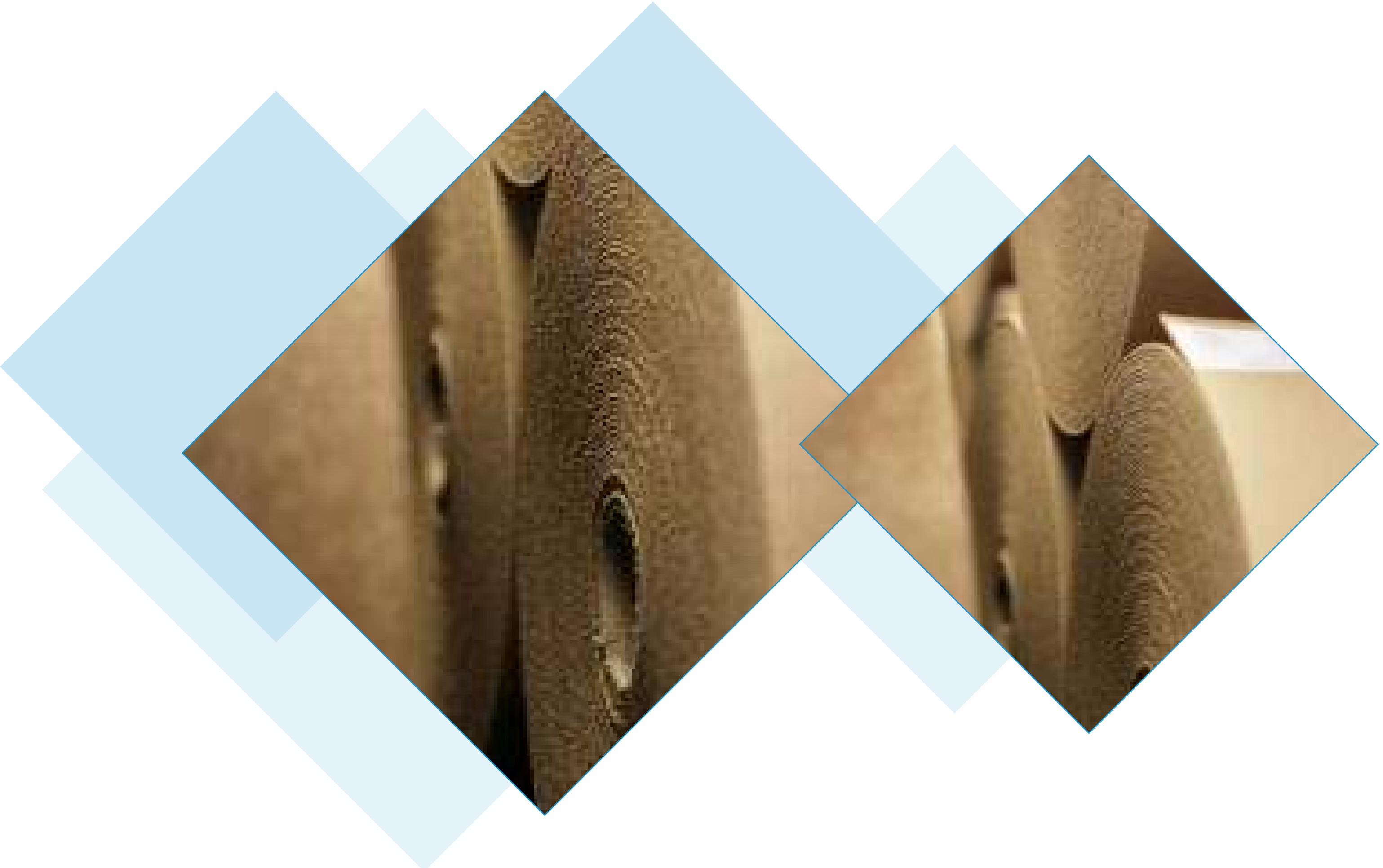


Figure 13: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[4] [Ledertech]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Salamander Bonded Leather [5]

Figure 14: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[5] [Salamander Bonded Leather]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Gestioni Industriali [6]

Figure 15: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[6] [Gestioni Industriali]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Prodotti Alpha Srl [7]

Figure 16: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[7] [Prodotti Alpha Srl]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Recyc LeatherTM [8]

Figure 17: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[8] [Recyc LeatherTM]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

ELeather® [10]

Figure 18: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[10] [ELeather]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Nike Flyleather (ELeather® technology) [11]

Figure 19: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[10] [Nike Flyleather]

5. RECYCLED LEATHER FIBRES MATERIALS PRODUCERS: PRODUCTS ILLUSTRATION

Authentic Material [12]

Figure 20: Example of the recycled leather fibres materials or finished products manufactured by the companies previously presented in Table 7

[11] [AUTHENTIC MATERIAL]

7. SUMMARY AND CONCLUSION

Leather transformation uses highly polluting processes (tanning is responsible for a large use of water and chemicals) and also produces many wastes that can be used to remanufacture other products.

Many initiatives and improvements are done to reduce the environmental impacts of the manufacturing phase. But work can also be done to improve the recycling of wastes like chrome shaving, chrome splits, buffing dust and skin trimming which are interesting materials for the production of recycled leather fibres materials.

Various industries already manufacture recycled leather fibres materials, usually called bonded leather fibres material. Classical bonded leather fibres materials have been manufactured for decades, but new material have been developed in recent years to improve quality, performance and sustainability. In parallel, standards and tools have been created and others are still in progress, to frame the production of these materials and to guarantee to the consumers a constant level of quality and no risk for their health.

As a conclusion to this study, if the production processes are under control and the raw materials used to produce recycled leather fibres materials are correctly traceable, this product can be a convenient, cost-efficient and environment-friendly technology to deal with the problem of recycling the production leather wastes. For brands seeking to diversify their sourcing and open to new materials and to innovation, looking at new recycled leather fibres materials can be an interesting way to improve product performance and sustainability impacts. But further studies are still expected to provide more concrete figures to communicate on the environmental impacts of these products.

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ANNEX

Annex 1: Recycled leather fibres materials producers: logo

RELEA	**LEDERTECH DEUTSCHLAND GMBH**	**SALAMANDER BONDED LEATHER**
GESTIONI INDUSTRIALI	**PRODOTTI ALPHA SRL**	**RECYC LEATHER™**
SALPAX, S.A.	**ELEATHER ®**	**AUTHENTIC MATERIAL**

Table 9: Brand logo of the recycled leather fibres materials companies

ANNEX

Annex 2: Leather alternatives of vegetable or other origin

Note: This part is not exactly within the scope of recycling of leather, but is nonetheless included in this report for the sake of completeness on the one hand, and also because there is some true innovation happening in this area.

Bio-fabricated alternatives

Bio-fabrication is a growing field of research that works on the production of complex biologically advanced material from raw biological materials or biochemical molecules. With the rise of 3D printing or additive manufacturing, many researchers are trying to develop the potential of this technology (bio-printing).

Modern Meadow (M.M.), a start-up company created in 2011 in New Jersey (USA), has created a bio-printed material inspired by leather, ZoaTM, which is the first generation of materials created with a designed collagen protein. With the ability to be any density, hold to any mould, create any shape, take on any texture, combine with any other material and be any size, Zoa™ is highly adaptable (source: [Modern Meadow]).

The production of ZoaTM follows the following steps:

1. Cells have been designed at the DNA level to create tailored micro-organisms which produce collagen proteins (the collagen is a protein found in the skin of animals)
2. Through fermentation, these newly designed cells are multiplied into billions of collagen-producing cell factories. These collagen proteins become the building blocks of the new material.
3. Depending on desired performance and design, the collagen proteins can be assembled into various structures that correspond to a range of material properties
4. The bio-fabricated collagen is tanned and finished through an ecological process.

From October 1, 2017 to January 28, 2018, M.M. has presented its ZoaTM creation at the Museum of Modern Art (MoMA) in Manhattan for the exhibition 'Items: Is Fashion Modern?'. On the occasion of the exhibition, the start-up has manufactured a t-shirt made of a blend of cotton and bio-fabricated leather. The product is not available on the market for the moment. The launch is planned for 2019. No more detailed information is available for the moment.

Figure 21: ZoaTM t-shirt exhibited at the MoMA (source: [Zoa])

ANNEX

Bio-based alternatives

Some alternatives to leather using vegetables have actually been commercialized or are under development. Here are some interesting examples (it is important to note that these products can't be called 'leather' [Fratini et al. 2016]):

- Piñatex®, an innovative natural textile made from pineapple leaf fibre [Piñatex]
- Muskin is a 100 % vegetable layer made from the Phellinus ellipsoideus, a type of large parasitic fungus that grows in the wild and attacks the trees in the subtropical forests [Muskin]
- MycoWorks, made from mycelium, a rapidly renewable natural resource [MycoWorks]
- VEGEA® whose technology is the valorization of grape marc, a 100% vegetal feedstock comprising the skins, the seeds and the stalks of the wine grape bunch, which are left over after winemaking [VEGEA®].

Annex 3: Other approach (The TAIMEE project)

TAIMEE: Thermal and Acoustic Insulating Material from Finished Leather Waste

The TAIMEE project was a European project co-funded by the Eco-Innovation Initiative of the European Union from 01/09/2012 to 31/08/2015. TAIMEE's budget was €1,251,332, including €625,666 from the European Union.

Figure 22: Image of the TAIMEE product

ANNEX

The project partners were:

- ACONDICIONAMIENTO TARRASENSE ASSOCIACION (LEITAT) (Terrassa, Spain)
- APLICACIONS DEL RECICLATGE AMETLLER 2010 SL (Sant Celoni, Spain)
- PLASFI SA (Santa Coloma de Queralt, Spain)
- FUNDACIO PRIVADA ASCAMM (Barcelona, Spain)
- NOBATEK (Anglet, France)
- ZICLA (Barcelona, Spain).

The project aimed at the production and market implementation of an innovative leather composite material with thermal insulation properties in addition to acoustical isolation properties for immediate application in the building sector. The material is elaborate with the waste generated in industries at the end of the tanning process and the companies that use leather to elaborate its products (the residues are currently sent to landfills).

The innovative eco-leather insulating panel is completely recyclable at the end its life as construction material. The project contributes to a better use of resources and raw materials for the insulation industry and to the reduction of the environmental impact in the tannery sector and in the production of leather goods (footwear, furniture, automotive), since 27,000tons of finished leather waste are sent to landfill sites in Europe every year.

This also contributes to the implementation of eco-friendly insulation material in the construction sector that improves the noise pollution and the energy efficiency of buildings and the reduction of CO2 emissions, according to the commitment of the European Directives 2002/91/EC and 2002/49/EC on energy performance of buildings and Environmental Noise. Unfortunately, the TAIMEE project has not been followed at the industrial level for economic reasons.

The price of the finished product on the market was not competitive [TAIMEE].

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