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**Life Cycle Assessment,
Carbon Footprint in Leather Processing**
(Review of methodologies and recommendations for harmonization)

Prepared by:

Federico Brugnoli
Leather consultant (LCA)

Project Manager
Ivan Král',
Industrial Development Officer

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EXPLANATORY NOTES

Glossary and Abbreviations Used In the Report

CF	Carbon Footprint
CF-PCR	Carbon footprint product category rules
CO_{2e}	Carbon dioxide equivalent
DIS	Draft International Standard
FAO	Food and Agriculture Organization
GHG	Green House Gasses
GWP	Global Warming Potential
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
IPP	INTEGRATED POLLUTION PREVENTION
IPP	Integrated Product Policy
ISO	International Standard Organisation
JMA	Japan Meteorological Agency
LCA	Life Cycle Analysis or Assessment
LCI	Life Cycle Inventory Analysis
LCIA	Life Cycle Impact Assessment
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
PCF	Product Carbon Footprint
PCR	Product Category Rules
TOE	Tonnes of Oil Equivalent
UK-Met Office	United Kingdom Meteorological Office
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organizations
WBCSD	World Business Council for Sustainable Development

Terms and Definition (FROM ISO DIS 14067)

For easy understanding, the most important are reported here. For additional terms and definitions, please refer to ISO DIS 14067 (1 & 2), from which the following definitions have been taken:

- **Carbon Footprint (CF):** weighted sum of greenhouse gas emissions and greenhouse gas removals of a process, a system of processes or a product system, expressed in CO₂equivalents.
- **Product Carbon Footprint (PCF):** carbon footprint of a product system
- **Product Category Rules (PCR):** set of specific rules, requirements and guidelines for developing environmental declarations for one or more product categories.
- **Carbon Footprint Product Category Rules (CF-PCR):** set of specific rules requirements and guidelines for developing carbon footprint declarations for one or more product categories.
- **Product System:** collection of unit processes with elementary and product flows, performing one or more defined functions and which models the life cycle of a product.
- **Life Cycle Assessment (LCA):** compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle
- **Life Cycle Inventory Analysis (LCI):** phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle
- **Functional Unit:** quantified performance of a product system for use as a reference unit.
- **Products:** any good and services
- **Primary Data:** quantified value originating from a direct measurement or a calculation based on direct measurements of a unit process of the product system at its original source
- **Secondary Data:** quantified value of an activity or life cycle process obtained from sources other than the direct measurement or calculation from direct measurements
- **Greenhouse Gas (GHG)¹:** gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the

¹ GHGs include among others carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆).

spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.

- **Global Warming Potential (GWP):** factor describing the radiative forcing impact of one mass- based unit of a given GHG relative to an equivalent unit of carbon dioxide over a given period of time
- **Carbon Dioxide Equivalent (CO₂e):** unit for comparing the radiative forcing of a GHG to carbon dioxide

EXECUTIVE SUMMARY

International concern has increased over the years on Climate Change. The ten hottest years on record have all occurred since 1998. 18 out of the last 21 years are among the 20 warmest years since 1880. Data and findings add weight to the common conclusion that the clear long-term trend is one of global warming. Most of the observed increase in global average temperature since the mid - 20th century is very likely due to the observed rise in anthropogenic greenhouse gas concentrations. Among these, particular attention is paid on CO₂ or Carbon Dioxide. Latest estimates show that global CO₂ emissions increased to 30,600 million tonnes in 2010. Industry and manufacturing contribute for 19% of all GHG emissions.

Interest has been developed in estimating the total amount of GHG produced during the various stages in the life cycle of products. The outcome of these calculations, are referred to as Product Carbon Footprints (PCFs).

Aim of the present technical report is to provide a robust overview of State of the Art publications, standards and papers references for the calculation of the Product Carbon Footprint of the product “Finished Leather” with recommendations for harmonization related to the main elements needed system boundaries.

The Carbon footprint of a product is defined as the “weighted sum of greenhouse gas emissions and greenhouse gas removals of a process, a system of processes or a product system, expressed in CO₂ equivalents” referred to a product system.

In case of finished leather, the carbon footprint, as it will be clearly explained in the document is expressed as:

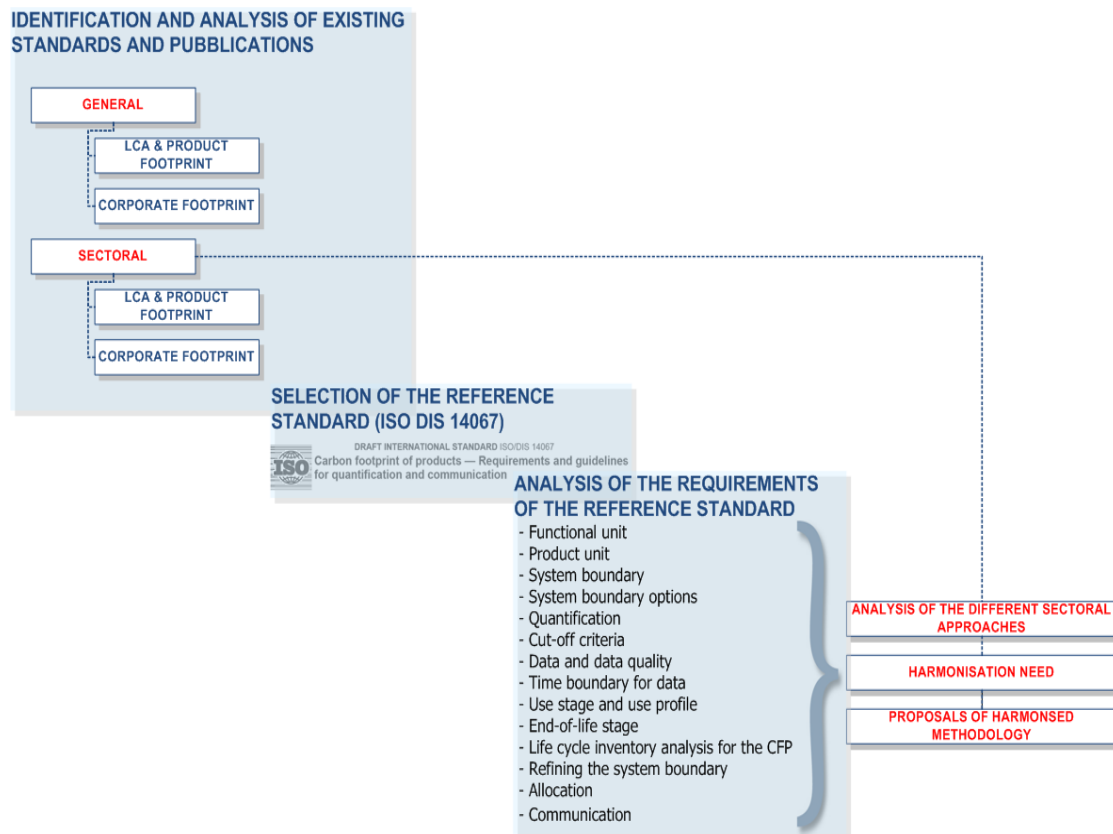
Kg of CO_{2e}/m² of finished leather

Currently, there is no single methodology and no agreement has been reached internationally on Leather PCF calculation methods.

The inherent complexity and lack of exactness of carbon footprint analyses contrasts with the need to communicate the results in a simple, clear and unambiguous way.

In order to identify possible harmonization among the methodologies currently in

place in the leather world, the methodological approach represented in the following figure has been implemented:



First of all, several among the different standards available today to footprint product and companies activities have been analysed, in order to identify a primary reference standard to be used for detailed evaluations. Ultimately ISO DIS 14067, being specific for the Carbon Footprint of products, referring largely on the existing ISO standards for life cycle assessments (ISO 14040/44) and environmental labels and declarations (ISO 14025) has been selected. ISO DIS 14067 has been selected also taking into consideration the fact that, being ISO the world’s largest developer of voluntary International Standards (that provides state of the art specifications for products, services and good practices, developed through global consensus), ISO 14067 will be used as reference also by other sectors developing knowledge on PCFs in the future. This will allow comparison.

Subsequently, sector specific papers, projects and standards published over the years on product and corporate footprint in the tanning industry have been analysed, in order to be able to propose a common approach to be followed in future activities.

It appears that the following aspects are of particular importance:

Functional unit: used in LCA and carbon foot printing to provide a reference to which environmental impacts are related. As a general principle, the functional unit shall be consistently measurable and it shall correspond to the basic unit that the tannery uses for trading the finished leather it produces, the recommendation is to use, as functional unit, 1 m² of finished leather, including an indication of the thickness of the material.

System boundaries: it is important to recognize the implications of the different conceptual approaches to raw hides and skins as raw materials for the tanning industry and in particular whether they are to be considered as a waste, as a by-product or as a co-product of the milk and meat industry. If the raw hides and skins are considered as waste of the milk and meat industry, the whole environmental impact (and therefore of the CO₂ equivalent content) has to be allocated to the main product of the economic value chain (milk and meat) whereas raw hides and skins considered in the basic LCA studies as “*recovered waste*”. This implies that agriculture and animal farming, as processes of the upstream module, shall be excluded from System Boundaries of LCA studies on leather.

More consistently with international legislation, it is also analysed the case in which raw hides are to be considered as a by-product or co-product of the milk and meat industry, some may argue that part of the environmental impacts (and therefore of the CO₂ equivalent content) have to be allocated to the co-product itself, on the basis of different allocation criteria. In this case, a relevant scientific LCA publication² of particular interest identifies a methodology for the renewable materials that involve the production of co products. According to that, for raw hides and skins coming from animals which have been raised mainly for human feeding purposes, such as milk and meat production (and therefore, bovines, sheep, goats and some other), the system boundaries are to be considered starting in the slaughterhouse, where activities and treatments are carried out in order to prepare the hides to be used for tanning.

Quantification: The different approaches reviewed show a certain similarity, basically converging in the subdivision of Leather production in single processes and quantifying the emissions from each process. The harmonised methodology proposed, in order to obtain Kg of CO_{2e}/m² of finished leather, lies in the quantification of CO_{2e}

² ³System expansions to handle co-products of renewable materials², published in the occasion of the 7th LCA Case Studies Symposium SETAC-Europe, 1999 by Bo P. Weidema

content of all the different products and material entering the tannery (UPSTREAM PROCESSES), adding CO_{2e} produced in the tannery itself (CORE PROCESSES), as well as CO_{2e} emanating from water and air purification and waste recycling/disposal (DOWNSTREAM PROCESSES).

Allocation: choosing an allocation rule conditions the environmental impact distribution between economic actors from a same value chain. Economic allocation seems to be much more imprecise in the specific case of leather. Factors contributing to the economic allocation (market price of raw hides, value of the animals during their lifespan) The consequent difficulty of a precise and consistent calculation of stable and reliable ratios lead to the conclusion that in the leather making process, allocation shall be avoided whenever possible and, if unavoidable, it should be made according to physical relationship within the single process under consideration.

Additional work should start with the set up of a specific working group, including different actors performing the processes included in system boundaries, among which the most important are: Slaughterhouses, Chemicals Producers, Energy and Water suppliers, Tanneries, Effluent treatment plants, Waste treatment plants.

Required knowledge to be produced includes:

- Harmonised Product Category Rules for LCA and PCF of Leather, including the conclusions of the present report
- Life Cycle Inventory (compilation and quantification of inputs and outputs for processes within the leather system boundaries) at pilot scale, including needed key actors
- Practical guidelines for LCA and PCF calculations, deriving from the Life Cycle inventory work
- Harmonised data quality and calculation requirements along the value chain

Finally, it is recognized that at the moment the LCA – Carbon Footprint topic is primarily of interest to tanners in industrialized, especially EU countries; however it is felt that also those in BRIC and even Least Developed Countries should be aware of the current environmental impact assessment and protection trends and be ready to apply them at appropriate time as needed. It is hoped that in the meantime better standardized methodologies and probably some blueprints will also be made available.

1. INTRODUCTION

International concern has increase over the years on Climate Change. The ten hottest years on record have all occurred since 1998³. 18 out of the last 21 years are among the 20 warmest years on record since 1880. These data and findings add weight to the common conclusion that the clear long-term trend is one of global warming (NOAA 2011, NASA 2011, UK-MetOffice 2011, JMA 2011).

Most of the observed increase in global average temperature since the mid- 20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations (IPCC 2007b). Among these, particular attention is paid on CO₂ or Carbon Dioxide.

CO₂ concentration in the Earth's atmosphere has been measured since 1958. It shows a steady mean increase from 357 ppmv (parts per million by volume) in 1992 to 389 ppmv in 2011. This increase is attributed to the combustion of fossil fuel, gas flaring, and cement production which has been accelerating in recent years (IPCC 2007).

1992 CO₂ emissions were around 22 000 million tonnes. Latest estimates show that global CO₂ emissions increased to 30 600 million tonnes in 2010 (IEA 2011).

80% of the global CO₂ emissions are generated by 19 countries - mainly those with high levels of economic development and/or large populations. The Energy Supply sector accounts for 26% of all GHG emissions, Forestry for almost 17% (mainly through worldwide deforestation), while Industry and Manufacturing contribute for 19%.

As a partial response to this situation, the scientific community, together with some industries has developed interest in estimating the total amount of GHG produced during the different stages in the life cycle of products — i.e. their production, processing, transportation, sale, use and disposal. The outcome of these calculations

³Information and data on environmental issues have been taken from the report “*Keeping Track of Our Changing Environment: From Rio to Rio+20 (1992-2012)*” published by UNEP in October 2011

based on the Life Cycle Assessment (LCA) of the products is referred to as Product Carbon Footprints (PCFs).

PCFs are becoming important in orientating choices both of companies and of consumers around the world. In particular, the fashion and leather sector has recently increased its activeness in this field.

The tanning process includes various chemical and mechanical processes aimed at turning putrescible organic matter (raw hides and skins) into high added value products, strategic for other industries like footwear, fashion, furniture, automotive.

Even if, among the different industries, tanning of hides and skins is not an energy and carbon intensive sector, there is an emerging need for a clear definition of the most important Life Cycle Assessment parameters of leather, to be used for Leather PCF calculations.

Since LCA calculations are, by definition, to be implemented on all the processes that concur to the realisation of the product, from raw material extraction, until the end of life of the product itself (the so called “cradle to grave” approach), one of the most important factors on which international agreement has to be reached is on the definition of the so called “System boundaries”. These define the process that has to be considered to be the initial phase of the product life (the cradle) and the one that determines its end (the grave). In the specific case of the leather industry, even if several works, papers and documents dealing with the LCA and carbon footprint have been produced over the years, at the moment there is no convergence on a universal methodology.

The present technical report aims at favouring the needed harmonisation process, analysing nature and typology of the raw material used by the tanning industry, producing methodological recommendations on the main elements needed for a correct Leather CF calculation and opening the way for a more detailed work, including different actors, in order to set up practical guidelines to obtain reliable Leather PCF data along the Leather Value Chain.

2. LEATHER RAW MATERIALS AND ANIMAL ORIGINS

Worldwide leather production derives from the processing of mainly three animal typologies:

- Bovine
- Sheep and Lambs
- Goats and Kids.

FAO publishes yearly “World statistical compendium for raw hides and skins leather and leather footwear” with estimates on worldwide raw hides and skins production. Data covering last 20years are represented in the following figure.

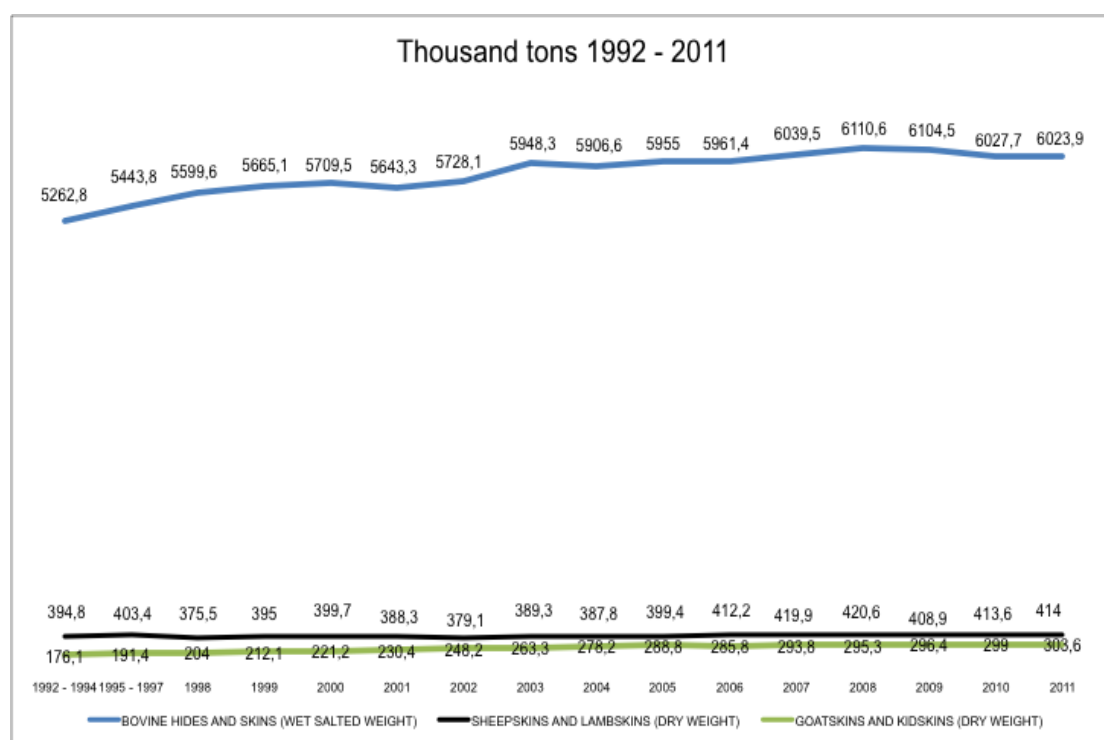


Fig. 1: World Production of Raw Hides and Skins (Bovine, Sheep, Goats)

In 2011, over 6.7 million tons of raw hides and skins of the above mentioned animal typologies have been produced. They cover more than 95%⁴ of the world finished leather production. Pig skins leather represent almost 4% of overall production, whilst other animal typologies (reptiles, deer, kangaroos, fishes, ostriches and other minor) cover the residual 1%.

On the basis of these estimates, it can be stated that more than 99% of the world leather production is coming from the processing of raw hides and skins deriving from animals which have been raised mainly for milk and/or meat production.

⁴Estimates of the Economic studies department of UNIC, Italian Tanners Association, based on FAO/UN/WTO data, integrated with information from tanning industrial associations.

3. LCA AND CARBON FOOTPRINT

Several different standards are available today, to footprint product and companies activities. This chapter briefly describes the main approaches and characteristics of each of them, in order to provide a general overview and to identify potential commonalities for harmonization purposes.

Life Cycle Analysis or Assessment (LCA) is the basic method used in carbon footprint. LCA “studies the environmental aspects and potential impacts throughout a product’s life cycle (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal” (ISO 14040, 2006).

A number of private schemes have emerged in the last years that offer methodology and expertise to footprint products and companies activities. In many cases these standards also provide guidance to reducing these footprints as well as procedures for certification and labelling against standards.

What follows is a general description of the main standards identified on environmental footprint of products and organization, with the aim of providing a general and informative description of the different experience a national and international level, present on the market today.

The information provided are not meant to be giving a detailed analysis on the standards, but rather general information on their key aspects that form the basis of the different approaches.⁵

3.1. Environmental Footprint

▪ ISO 14040:2006 Environmental management -- Life Cycle Assessment -- Principles and framework

ISO 14040:2006 describes the principles and framework for Life Cycle Assessment including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle

⁵ Analysis based on the EUROPEAN COMMISSION JOINT RESEARCH CENTRE Institute for Environment and Sustainability H08 Sustainability Assessment Unit. (Ispra, Italy, November 2011). *Analysis of Existing Environmental Footprint Methodologies for Products and Organizations: Recommendations, Rationale, and Alignment.*

interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA.

▪ **ISO 14044: Environmental management - Life Cycle assessment – Requirements**

ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies⁶.

▪ **ISO 14025: Environmental labels and declarations - Type III environmental declarations - Principles and procedures**

ISO 14025:2006 establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations. Type III environmental declarations as described in ISO 14025:2006 are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication under certain conditions is not precluded. It specifically establishes the use of the ISO 14040 series of standards in the development of Type III environmental declaration programmes and Type III environmental declarations.

▪ **Ecological Footprint**

The Ecological footprint (EF) standard is developed by Global Footprint Network. The EF provides measure of the extent to which human activities exceed biocapacity. Specifically, the EF integrates the area required for the production of crops, forest products and animal products, the area required to sequester atmospheric CO₂

⁶ISO 14044 was prepared by Technical Committee ISO/TC 207, Environmental management, Subcommittee SC 5, Life cycle assessment. The first edition of ISO 14044, together with ISO 14040:2006, cancels and replaces ISO 14040:1997, ISO 14041:1998, ISO 14042:2000 and ISO 14043:2000, which have been technically revised.

emissions dominantly caused by fossil fuel combustion, and the equivalent area estimated to be required by nuclear energy demand.

▪ **Product and Supply Chain Standards Greenhouse Gas Protocol (WRI/WBCSD)**

The World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD) started to develop their Product and Supply Value Chain GHG Accounting and Reporting Standard in September 2008. The GHG Protocol Corporate Standard provides standards and guidance for companies and other types of organizations preparing a GHG emissions inventory. It covers the accounting and reporting of the six greenhouse gases covered by the Kyoto Protocol—carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF₆). The Corporate Value Chain (Scope 3⁷) and Product Life Cycle Accounting and Reporting Standards were published in October of 2011. These new standards include requirements and guidelines on both product life cycle accounting and calculation and reporting of corporate. The Product Standard builds upon the ISO 14040 series of standards.

▪ **French Environmental Footprint (BPX 30-323)**

The repository of good practices, BPX30-323, was prepared under the French law called ‘Grenelle I’, which establishes the prospect of regulatory communication of environmental information relating to product. This document was developed with over 300 organisations representing all the various relevant stakeholders, sectors, and NGOs gathered in the ADEME (Agency for Environment and Energy Management) / AFNOR (French Association of Normalization) platform. BPX 30-323 gives general principles for the environmental communication of products. The carbon footprint is required whatever the category of product. The environmental communication includes indicators limited in number and specific to a category of product. These indicators take into account the main relevant impacts generated by the product. BPX 30-323 defines main principles for drawing up methodological guides specific to product categories (PCR). These methodological guides are developed by relevant stakeholders of different sectors and are validated by the ADEME / AFNOR platform.

⁷ Scope 1 encompasses a company's direct GHG emissions, whether from on-site energy production or other industrial activities. Scope 2 accounts for energy that is purchased from off-site (primarily electricity, but can also include energy like steam). Scope 3 is much broader and can include anything from employee travel, to "upstream" emissions embedded in products purchased or processed by the firm, to "downstream" emissions associated with transporting and disposing of products sold by the firm.

10 methodological guides (PCR) are already available, but not for leather. In parallel, ADEME has initiated the development of a public database to provide generic data that will enable the calculation of these indicators.

▪ **UK's Product Carbon Footprint (PAS 2050)**

The PAS 2050:2011 specifies requirements for the assessment of the life-cycle GHG emissions associated with the life cycle of goods and services (“products”), based on life cycle assessment techniques and principles (i.e. ISO14040/44). Requirements are specified for identifying the system boundary, the sources of GHG emissions that fall inside the system boundary, the data requirements for carrying out the analysis, and the calculation of the results. It includes the six GHGs identified under the Kyoto protocol and covers the whole life cycle of products, including the use phase and emissions from direct land-use changes that have taken place over the past 20 years.

▪ **ILCD: International Reference Life Cycle Data System**

In response to commitments in the IPP Communication of the European Commission, the International Reference Life Cycle Data System (ILCD) has been established for ensuring consistent and reproducible life cycle data and robust impact assessments. This system consists primarily of the ILCD Handbook and the ILCD Data Network. The Handbook is a series of technical guidance documents. It is developed through peer review and consultation and is in line with the ISO 14040 and 14044, while it provides further specified guidance for more quality-assurance than the broader ISO framework can offer. The ILCD Handbook provides detailed provisions for product (situation A⁸ and situation B) and corporate analysis (situation C). To facilitate this development, links have been established with National LCA Database projects in all parts of the world, and with the World Business Council for Sustainable Development (WBCSD) and the United Nations Environment Programme (UNEP).

▪ **ISO DIS 14067: Carbon Footprint of Product**

The International Standard addresses the single impact category of climate change and does not assess other potential social, economic and environmental impacts arising from the provision of products. Product carbon footprints assessed in

⁸Situation A relates to a life cycle based decision support on micro-level (e.g. for product-related questions)
Situation B refers to life cycle based decision support on a meso or macro-level, such as for strategies (e.g. raw materials strategies, technology scenarios, policy options, etc.)
Situation C relates to studies that require a entirely descriptive, accounting-type of life cycle model, typically referring to the past or present.

conformity with the International Standard do not provide an indicator of the overall environmental impact of products. The Standard was prepared by Technical Committee ISO/TC 207, *Environmental management*, Subcommittee SC 7, *Greenhouse gas management and related activities*.

3.2. Corporate Environmental Footprint

▪ ISO 14064: Greenhouse gases - Part 1, 2 and 3

ISO 14064-1:2006 specifies principles and requirements at the organization level for quantification and reporting of greenhouse gas (GHG) emissions and removals. It includes requirements for the design, development, management, reporting and verification of an organization's GHG inventory. ISO 14064-2:2006 specifies principles and requirements and provides guidance at the project level for quantification, monitoring and reporting of activities intended to cause GHG emission reductions or removal enhancements. It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario, monitoring, quantifying, documenting and reporting GHG project performance and managing data quality.

ISO 14064-3:2006 specifies principles and requirements and provides guidance for those conducting or managing the validation and/or verification GHG assertions. It can be applied to organizational or GHG project quantification, including GHG quantification, monitoring and reporting carried out in accordance with ISO 14064-1 or ISO 14064-2.

▪ Bilan Carbone

Bilan Carbone is an organizational GHG accounting guidance document and tool produced in France by ADEME (French Environment and Energy Management Agency). The guidance provided is more comprehensive than most other corporate GHG accounting methodologies. Emphasis is placed on physical realism in GHG accountancy. All greenhouse gases are considered, rather than the six Kyoto Protocol GHGs considered in most guides. Calculation templates that include emission factors and provide outputs relevant to reporting under several other schemes are provided.

▪ **Defra’s Guidance on how to measure and report your greenhouse gas emissions’**

The UK’s corporate GHG accounting guide is designed to support all organizations in reporting their greenhouse gas emissions, either voluntarily or to meet reporting requirements under the Companies Act 2006, where applicable. It is largely based on the GHG protocol and was developed following extensive consultation with businesses. The guidance sets minimum recommendations for what companies should report within the chosen organizational boundary, an intensity ratio, a base year. The guidance requires reporting of the six Kyoto GHG in terms of CO_{2e}. The guidance is accompanied by annually updated emissions conversion factors and calculation tool. As well as the recommendations of how to report, the guidance provides additional information to help companies report emissions reductions, set reduction targets and recalculate their base year. A separate version of the guidance is available for SMEs.

3.3. Methodological Considerations

There is no single methodology on Life Cycle Assessment of products and of company performances that is universally agreed upon and therefore no agreement is currently reached internationally on PCF calculation methods. The complexity and lack of exactness of some of the existing carbon footprint analyses contrasts with the need to communicate the results in a simple, clear and unambiguous way. The Carbon Footprint of a “functional leather unit” can be represented by the sum of the impacts of all the relevant phases of the upstream modules in the supply chain, those related to the production of leather in the tannery, and to the relevant downstream processes. In order to proceed with the correct identification of the requirements for a harmonized Leather PCF the main requirements of the ISO DIS 14067 are taken as reference.

The examples described above show that there is no single methodology on Life Cycle Assessment of products and of company performances that is universally agreed upon and therefore no agreement is currently reached internationally on PCF calculation methods.

Different definitions of the boundary of the LCA, in terms of which life cycle stages, emission sources and GHGs area considered, will produce very different results⁹ (Büsser et al., 2008).

There is a lack of comprehensive data for LCA, data reliability is questionable, and several databases with different data specifications (e.g. in terms of reference units) are often needed to perform an LCA. Carbon footprints are rarely accompanied by detailed methodological accounts. They are therefore difficult to assess by third parties or to compare with the footprints of like products. The inherent complexity and lack of exactness of carbon footprint analyses contrasts with the need to communicate the results in a simple, clear and unambiguous way to other businesses along the value chain and, ultimately, to consumers. The rapid proliferation of private PCF schemes raises two issues:

- The application of multiple schemes in the marketplace may lead to confusion about what information is relevant and useful and thereby diminish confidence in such information.
- As such schemes proliferate, one may become the *de facto* standard and thereby create a market access barrier for products using other carbon-foot printing schemes.

It is therefore clear the importance of harmonizing all the standards schemes and practical experience on the market today get a unique and direct methodology recognizable by the consumers

Within the scope of the present technical report, therefore, in order to proceed with the correct identification of the recommendations for harmonisation in Leather PCF calculation, the methodology chosen included:

- The identification of ISO DIS 14067 as reference standard
- A detailed analysis of the existing sectoral background knowledge
- A “leather specific” review of the ISO DIS 14067 requirements
- The definition of recommendations for harmonisation on each requirement analysed

⁹ See Simon Bolwig and Peter Gibbon Risø-R-1719-(EN) December 2009). *Emerging product carbon footprint standards and schemes and their possible trade impacts.*

Despite the fact that ISO DIS 14067 is a standard still in its draft version and needs to be finalised, it has been used as a reference for the present work based on the following considerations:

- ISO is a worldwide federation of national standards bodies, impartial and with the best potential impact for standards recognition and accreditation of certification bodies, since standards are based on international consensus
- ISO DIS 14067 is based on ISO LCA and Environmental Labels and Declarations existing standards, widely internationally recognised
- ISO DIS 14067 is specific for Product Carbon Footprint and therefore, the future standard will most likely be used also by other industrial sectors in the future.

From a methodological point of view, the Leather PCFs calculations will be based on a modular framework¹⁰, allowing to quantify the:

- impacts of all the relevant phases of the upstream modules in the supply chain
- impacts related to the tanning process
- impacts related to the relevant downstream processes (i.e. water purification).

4. SECTORAL BACKGROUND KNOWLEDGE

This chapter gives a comparison of different approaches which have been identified for the purposes of the present work, concentrating on the most relevant requirements on which agreement has to be reached, such as, for example: functional unit, system boundaries and allocation rules. Seven relevant papers have been identified on leather Life Cycle Assessment (environmental footprinting), and one standard has been defined for a calculation and auditing model for Corporate Carbon Footprint (CCF) for tanneries.

As said, there seems to be no clear definition of “Carbon Footprint” and there is still some confusion on what it actually means, on how to measure it and on what unit is to be used. While the term itself is rooted in the language of Ecological Footprinting (Wackernagel, 1996), the common baseline is that the carbon footprint stands for a certain amount of gaseous emissions that are relevant to climate change and

¹⁰ See Carlo Brondi, Rosanna Fornasiero, Manfredi Vale, Ludovico Vidali and Federico Brugnoli. *Modular framework for reliable LCA-based indicators supporting supplier selection within complex supply chains.* (APMS-2012)

associated with human production or consumption activities¹¹. But this is almost where the commonality ends. There is no consensus on how to measure or quantify a carbon footprint. The spectrum of definitions ranges from direct CO₂ emissions to full life-cycle greenhouse gas emissions and, in the leather world, sometimes not even the units of measurement are clear.

Depending on methodologies and standard adopted, results can be significantly different. The most relevant requirements on which agreement has to be reached are:

1. Functional Unit
2. System Boundaries
3. Quantification
4. Allocation Rules

The sector specific background knowledge represent an heterogenic scenario of LCA and PCF approaches, which have been collected in order to have a comprehensive analysis on how the same requirements have been dealt with in the past. What follows is a short abstract summary of the different standards and papers considered.

4.1. Leather Specific Product Environmental Footprint

- **THE INTERNATIONAL EPD® SYSTEM PRODUCT CATEGORY RULES. CPC Class 2912. FINISHED BOVINE LEATHER VERSION 1.0 DATED 2011-09-28.** Product category rules (PCR) are specified for specified information modules “gate-to-gate”, so called core modules. The structure and aggregation level of the core modules is the defined by the United Nation Statistic Division. The PCR provides rules for which methodology and data to use in the full LCA, i.e. life cycle parts up-stream and down-stream in core module. The PCR also have requirements on the information given in the EPD. The product group under study in the analysed PCR documents is “finished bovine leather” which is part of the product group “Tanned or dressed leather; composition leather” and the product class “Other leather, of bovine or equine animals, without hair on”.

- **B. RIVELA, M. T. MOREIRA, C. BORNHARDT, R. MEÄ NDEZ, AND G. FEIJOO.** *Life Cycle Assessment as a Tool for the Environmental Improvement of the Tannery Industry in Developing Countries.* (Environ. Sci. Technol. 2004). A

¹¹ ISAUK Research Report 07-01.A Definition of “Carbon Footprint”.

representative leather tannery industry in a Latin American developing country has been studied from an environmental point of view, including both technical and economic analysis. Life Cycle Analysis (LCA) methodology has been used for the quantification and evaluation of the impacts of the chromium tanning process as a basis to propose further improvement actions. Four main subsystems were considered: beamhouse, tanyard, retanning, and wood furnace.

- **Kurian Joseph, N. Nithya. *Material flows in the life cycle of leather.* (Journal of Cleaner Production 17 (2009) 676–682).** This paper presents a study on the resource and environmental profile of leather for communicating to the consumers about the environmental burdens of leather products. The results indicate that environmental impacts were caused during the tanning and finishing of leather as well as the electricity production and transportation required in the life cycle.

- **Notarnicola Bruno, Puig Rita, Raggi Andrea, TarabellaAngela, PettiLuigia, RiusAntoni, Tassielli Giuseppe, De CamillisCamillo, MongelliIgnazio. *LCA OF ITALIAN AND SPANISH BOVINE LEATHER PRODUCTION SYSTEMS IN AN INDUSTRIAL ECOLOGY PERSPECTIVE.*** The paper presents the LCA-based results of a research program called *Cicle Pell: Industrial ecology in the animal-to-leather chain* funded by the EU, aiming at identifying the economic and environmental improvements, which can be achieved by companies in the leather supply chain by applying the industrial ecology principles. In this paper the results of the LCA of bovine leather manufactured in Italy and Spain are described in order to put in evidence the eco-profile of the two systems and to find out if the difference in the adopted technologies and cooperative management solutions have led to significant environmental differences.

- **Final Report-Gruppo DANI S.p.A. *LCA and Carbon footprint of finished bovine leather.* (June 2011).** In the publication was quantified the Carbon footprint of 1 m² of finished leather produced in “Gruppo Dani” SpA and a consequently communication of the results using a CFP claim under a business to business approach, publically available. The publication represents the first step of an Italian industry in the tannery sector for the environmental evaluation of their product applying LCA methodology and according to the International standard ISO DIS 14067.

- ***ECOLABEL, STUDY FOR THE FOOTWEAR CRITERIA REVISION. Produced for the European Commission by Life Cycle Engineering. (Oct. 2008).***

The document reports on the results of a project, which aim was to assess the need for updating/developing new Ecological criteria for the Footwear product group. The project, leading to the document has been analysing the market, the state of art of technology, laws and ongoing legislative initiatives related to this sector and environmental life-cycle considerations to make recommendations on the revision of the existing criteria, as well as to provide a robust basis for a wide consultation of the interested parties in order to collect comments and, later, consensus.

- **Lloren; Mil., Xavier Domnech, Joan Rieradevall, Pere Fullana, Rita Puig.** *Application of Life Cycle Assessment to Footwear [Int. J. LCA 3 (4) 203 - 208 (1998)].* Life Cycle Assessment (LCA) has been applied in the leather footwear industry. Due to the fact that the goal of the study is to point those steps in the footwear cycle which contribute most to the total environmental impact, only a simplified semi-quantitative methodology is used. Background data of all the inputs and outputs from the system have been inventoried. Impact assessment has been restricted to classification and characterization. and this phase is also important for its non-renewable resource consumption.

4.2. Leather Specific Corporate Environmental Footprint

- **ECO2L, ENERGY CONTROLLED LEATHER.** *Calculation of a Corporate Carbon Footprint (CCF) for a leather factory with evaluation of internal energy consumption in comparison to the BEET energy benchmark (Best Energy Efficiency for Tanning) (Oct. 2011).*

As an active contribution to climate protection, the ECO2L (energy-controlled leather) label encompasses a calculation and auditing model for determining the energy efficiency and CO₂ emissions of leather production on site. For the audited tannery, it confirms the energy-efficient production of leather and the systematic determination of the corporate carbon footprint by means of a defined calculation model within specified system boundaries.

5. LEATHER SPECIFIC REVIEW OF ISO DIS 14067 REQUIREMENTS

The different leather specific approaches have been analysed in the context of each relevant ISO DIS 14067 requirement, in order to identify and propose a harmonised approach / methodology for the definition of the base elements for Leather PCF quantification and calculation. At the current state of the art of the leather world, among others, four requirements need more attention:

- Functional unit*
- System boundaries*
- Quantification*
- Allocation rules*

Therefore these topics have been analysed in more detail.

In ISO DIS 14067, the methodology for CFP quantification is based on specific requirements:

- Functional Unit
- System Boundary
- System Boundary Options
- Quantification
- Product Unit
- Cut-Off Criteria
- Data And Data Quality
- Time Boundary For Data
- Use Stage And Use Profile
- End-Of-Life Stage
- Life Cycle Inventory Analysis For The CFP
- Refining The System Boundary
- Allocation
- Communication

The aim of the analysis is therefore to compare the different approaches (when relevant) proposed in our research based on the methodology of ISO DIS 14067,

providing an analysis of needs for harmonisation and recommendations on how to interpret its requirements for the methods to be adopted in assessing the CFP.

5.1.Functional Unit

The functional unit is used to provide a reference to which environmental impacts are related. In the different approaches analysed, some refer to the finished products realised, others to the raw materials processed. As a general principle, the functional unit shall be consistently measurable and it shall correspond to the basic unit that the tannery uses for trading the finished leather it produces, the proposal is to use, as functional unit, 1 m² of finished leather (kg in case of sole leather), providing an indication of the thickness.

5.1.1. ISO DIS 14067 Requirements

“A CFP study shall clearly specify the functions of the product system being studied. The functional unit shall be consistent with the goal and scope of the CFP study. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. Therefore the functional unit shall be clearly defined and measurable”.

5.1.2. Review of Background Knowledge: Functional Unit

Tab. 1 Review of Background Knowledge: Functional Unit

REFERENCE DOCUMENTS	APPROACH
Best Available Techniques (BAT) Reference Document for the Tanning of Hides and Skins, final draft - June 2012.	In Chapter 3 “Current consumption and emission levels” the document refers to both the 1 m ² of finished product (i.e solvent consumption) and to the weight of raw material entering the factory (i.e water consumption, expressed in m ³ /t)
PCR leather (EPD)	The declared unit is the production of 1 m² of "finished bovine leather" according to ISO 11646 . The product class of reference is “Other leather, of bovine or equine animals, without hair on” with the CPC code 2912. The environmental impact shall be given per declared unit

REFERENCE DOCUMENTS	APPROACH
ART. RIVELA-Environ. Sci. Technol. 2004, 38, 1901-1909	The functional unit chosen was 1 twsh input (preserved hides) . The tannery under study has a process capacity of 330 ton of preserved hides per year for shoe production using a chrome-tanning process.
LCA leather- Material flows in the life cycle of leather Kurian Joseph*, N. Nithya	The study was performed using a F.U. of 100 m² of finished leather
LCA of Italian and Spanish bovine leather - production systems in an industrial ecology	The functional unit used in the study is 200 kg of chrome-tanned bovine leather, with a thickness of 1.3 mm , to be used for the manufacture of women shoes. Stating a width of 1.3 mm means that 200 kg of finished leather is equivalent to 1000 kg of salted raw hide and also equivalent to 2000 square feet. Any of these quantities could be the reference flow
ECO2L-Handbook-complete-9-9-2011_GB- Calculation of a Corporate Carbon Footprint (CCF) for a leather factory with evaluation of internal energy consumption in comparison to the BEET energy benchmark (Best Energy Efficiency for Tanning)	The corporate carbon footprint describes the emission of CO ₂ equivalents from production as well as the upstream and downstream processes for the location within defined system limits. It is expressed in “ kg CO₂/m² of product and / or product mix ”
Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA	The functional unit used in this application is 1 m² of finished leather . Since the tannery produces a very wide range of article based on skins from different backgrounds and minor changes in the overall process of manufacture of leather, are taken into account the data related to a product with average characteristics, then after evaluating the possible variability of emissions GHG within a range of 5%. Given that the initial stages of processing are nearly constant evaluation of the variability of the result will be made taking into account the final stages of dyeing and finishing. It is then, possible to extend the study results to a single type of leather.

5.1.3. Harmonization Need

Among the different methodologies analysed, there is a convergence in the use of specific functional units. Carbon footprint methodologies were mainly built using LCA principles and, as so, recognize the interest in defining a functional unit. Establish a commonly agreed definition will allow to evaluate a service provided by the product. It enables to ensure that products will be compared on a similar basis.

5.1.4. Recommendations

In general terms, the functional unit shall correspond to the basic unit that the tannery

uses for trading the finished leather it produces. For a wider application, due to the fact that worldwide finished leather trade is mostly done on the basis of the surface, the proposal is to use, as functional unit, **1 m² of finished leather**. A reference should be added on standards used for measuring the surface of leather (i.e. “ISO 11646 Leather -- Measurement of area”, UNI 11380:2010 “Guidelines for surface measurement of leather through electronic devices”).

The particular case of Sole Leather production shall be considered, due to the fact that the products are sold by weight. In this case, even with limited applications, the functional unit proposed is **1 kg of sole leather**.

5.2. System Boundary and System Boundary Options

The system boundary determines which unit processes shall be included in the calculation of the Leather PCF. System boundaries represent one of the most important requirements on which an agreement has to be reached and a harmonised approach has to be adopted.

For leather realised with raw hides and skins coming from animals that have been raised mainly for milk and/or meat system boundaries, start at the slaughterhouse and end at the exit gate of the tannery.

It has to be specified that environmental impact of leather production (and therefore Carbon Footprint) might be strictly dependent on thickness of the leather itself. This is particularly true when dealing, for example, with water dosage (and therefore energy consumption) and chemical dosage in some process phases, which are done on the basis of the weight of the lot of material (i.e. hides, pelts, wet blue) that is going to be processed. Thicker materials require more water, more energy and more chemicals. In this context, for the definition of the functional unit, an indication of the thickness of the products is suggested to be included. When needed, thickness categories or (weighted) average values might be used.

5.2.1. ISO DIS 14067 Requirements

System Boundary: *“The system boundary determines which unit processes shall be included within the CFP study. The selection of the system boundary shall be*

consistent with the goal of the CFP study. The criteria used in establishing the system boundary shall be identified and explained”.

System Boundary Options: “The setting of the system boundary can be different depending on the intended use of the CFP study. Where the assessment of the CFP is intended to be communicated to consumers, the quantification of the CFP shall comprise all stages of the life cycle”.

5.2.2. Methodological Approach To System Boundaries

In order to better analyse the different approaches included in the publications identified, a brief introduction shall be made to clarify some key points, as the harmonised definition of system boundaries represents one of the most important factor determining carbon footprint contribution.

In order to proceed with a clear methodology that allows an agreement on system boundaries, it has been decided to implement a “step by step” approach, starting from the identification of all Life Cycle Processes involved in leather production and ending up with a proposed identification of System boundaries, based on the review of background knowledge currently adopted, integrated with some harmonisation considerations.

Main reference standard for the implementation of the methodological approach on System Boundaries is the Pcr Basic Module - Cpc Division 29 - Leather and Leather Products; Footwear Version 1.0, dated 2010-11-30. In the document, the identification of general system boundaries are logically divided as shown in the following figure:

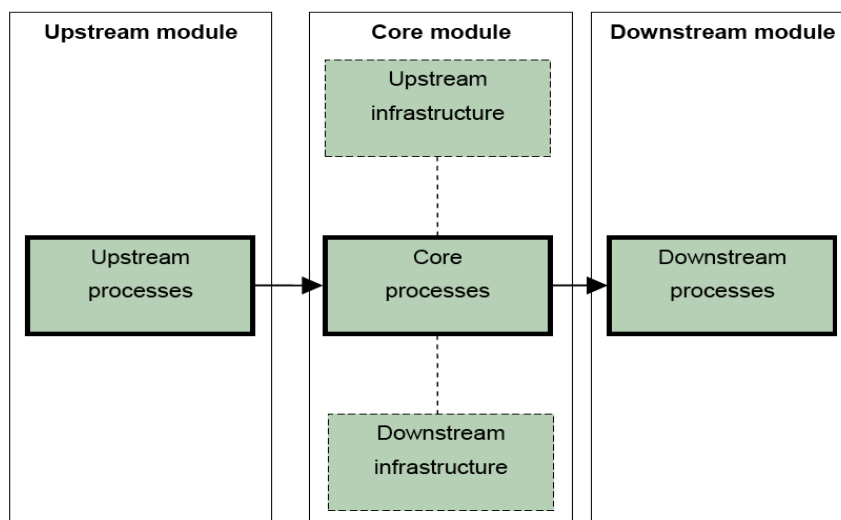


Fig.2: Representation of Unit Processes

Figure 2 illustrates that all relevant unit processes taking place in leather production, can be divided into **upstream, core and downstream processes**. According to this representation, the overall approach that will be followed in the present report consist in the identification of all processes to be included in the representation of the leather value chain, evaluating their relevance and need for inclusion in the system boundaries.

The **upstream processes** include the inflow of raw materials and energy needed for leather production:

- raw material extraction
- generation of energy wares used in production
- chemical and ancillary production
- production of auxiliary products used such as detergents for cleaning etc
- agriculture, if relevant
- animal breeding, if relevant
- slaughterhouse

The **core processes** include:

- production of finished leather
- production of leather based products
- production of packaging
- external and internal transportation of raw materials and energy wares to the core process

The **downstream processes** include transportation from final production to an average distribution platform. It is voluntary to include:

- the customer or consumer use of the product
- recycling or handling of packaging waste/materials after use.

A graphical representation of the different processes included in the leather value chain is included in the following figure for illustration.

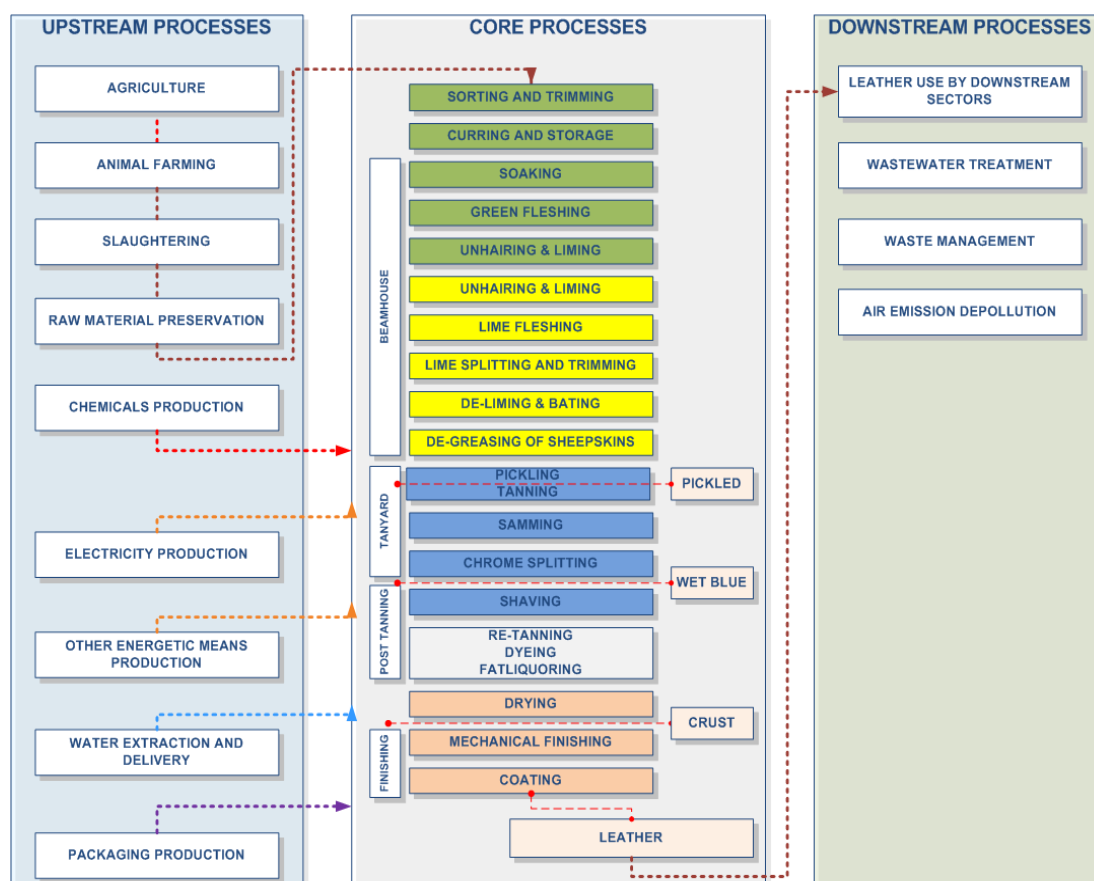


Fig. 3: Representation of Main Processes of the Leather Production Value Chain

5.2.3. Review of Background Knowledge

Tab. 2 Review Of Background Knowledge: System Boundaries

REFERENCE DOCUMENTS	APPROACH
Best Available Techniques (BAT) Reference Document for the Tanning of Hides and Skins, final draft - June 2012.	The production of raw hides and skins depends on animal population and the slaughter rate and is related mainly to meat consumption.
Final report footwear (ECOLABEL)	Cattle raising is included, estimating that about 6% of a cow is destined to produce leather, that means that 6% of the environmental impacts can be considered for leather production; Slaughterhouse , the allocation value used has been 7,69%; Tanning , the density of the finished leather has been considered equal to 1,5 kg/m ²

REFERENCE DOCUMENTS	APPROACH
PCR leather (EPD)	<p>UPSTREAM MODULE:</p> <ul style="list-style-type: none"> ◆ <i>Agriculture;</i> ◆ <i>Cattle raising;</i> ◆ <i>Slaughtering.</i> <p>Production of all raw materials shall be included, if not otherwise excluded by the cut-off rules. CH₄ and N₂O are the particularly important GHG. This PCR follows a conservative approach, interpreting a raw hide as a by-product of cattle raising, instead of a waste output of the slaughtering stage interpreting the manufacturing processes carried out in the tannery as a recovery of waste.</p> <p>CORE MODULE:</p> <ul style="list-style-type: none"> ◆ <i>From raw hide to wet blue</i> – Preservation/storage of raw hides; soaking/unhairing/liming; fleshing/pelt splitting and trimming; deliming/bating/pikling/tanning/sammying. ◆ <i>From wet blue to crust</i> – Soaking; Wet blue splitting and shaving; Neutralization/retanning/dyeing/fatliquoring;Drying ◆ <i>From crust to finished leather</i> – Spraying/coating; finishing/embossing/ironing/milling/buffing/measuring. <p>DOWNSTREAM MODULE: The distribution scenario shall always be included. The transport to the average distribution platform shall be considered, taking into account also the return path. It is possible to use average transport means and load factors.</p>
ART. RIVELA-Environ. Sci. Technol. 2004, 38, 1901-1909	<p>The tanning process in this study comprises all the steps from the raw hide to the “crust for finishing” leather using chromium as the core tanning compound. Three main subsystems were considered for the evaluation of the process:</p> <ul style="list-style-type: none"> ◆ Beamhouse; ◆ Tanyard; ◆ Retanning; ◆ Energy and chemicals supply. <p>Dressing and finishing were not included because they strongly depend on the article produced, so it is rather difficult to obtain representative data and eventually would make a comparison of the whole life cycle impossible.</p>
LCA leather- Material flows in the life cycle of leather Kurian Joseph*, N. Nithya	<ul style="list-style-type: none"> ◆ Slaughtering ◆ Transportation ◆ Preservation ◆ Tanning and finishing ◆ Waste management ◆ Disposal <p>Evaluated for both material and energy demands, along with by-products and waste generation. The upstream boundary for fuel cycle was included, while other upstream and downstream activities like post-manufacturing processes and consumer use were not included.</p>

REFERENCE DOCUMENTS	APPROACH
LCA OF ITALIAN AND SPANISH BOVINE LEATHER - PRODUCTION SYSTEMS IN AN INDUSTRIAL ECOLOGY	The agricultural phase and the cattle-breeding have been kept out of the system, as it is defined by the Cicle Pell research project, which mainly focuses on the environmental implications of the slaughtering and tanning processes. The further steps of leather processing and women's shoes production, as well as the phase of use of the shoes and their disposal, are outside the system boundaries.
Application of Life Cycle Assessment to Footwear (LCA Case Studies)1998	<i>"If we considered that Hides are an unavoidable waste in the production of meat for which a use has been found, and so they are free of environmental burdens up to the slaughterhouse waste production, then the Slaughterhouse waste would be our system boundary, but as we opted for an economic allocation, there is no reason not to bring the boundary to the top, at the Grass production, and this is the boundary we have finally worked with."</i>
Simple Shoes Final Report - Analysing the Environmental Impacts of Simple Shoes	The inputs and outputs of this system range from the production of raw materials to the disposal of the shoes to landfill. Within this system, the process of shoe assembly includes only energy information and there are no processes for the use phase due to lack of data availability. Further, this LCA does not include the disposal of process wastes or the manufacturing of ancillary materials. In addition, the inputs and outputs from production lifecycles associated with the building of the machines, the manufacturing facilities and transportation vehicles, as well as additional operations (lighting, heating of building and production of fuels and electricity) are not being considered due the lack of available raw data to support a credible assessment.
ECO2L-Handbook-complete-9-9-2011_GB - Calculation of a Corporate Carbon Footprint (CCF) for a leather factory with evaluation of internal energy consumption in comparison to the BEET energy benchmark (Best Energy Efficiency for Tanning)	This practical model, trying to keep existing standards and norms, includes the production itself as well as upstream and downstream processes. In The system boundaries are not included: <ul style="list-style-type: none"> ◆ Production of chemicals ◆ Employee travel ◆ Delivery of leather ◆ Delivery by products ◆ Costumer use phase + disposal ◆ Customer The cattle farming/fattening were not included in the calculation for the following reason: cattle are primarily produced for milk or meat production but not specifically for leather production. Therefore, hide is considered a by-product.

REFERENCE DOCUMENTS	APPROACH
Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA	In this application model, the model “cradle to gate” was used, considering all phases of the life cycle from the agricultural phase and the cattle-breeding going trough: <ul style="list-style-type: none"> ◆ Slaughterhouse; ◆ Split in liming Tanning; ◆ Split wet blue dye; ◆ Finishing; ◆ Preparation for transportation; The following elementary flow was considered: <ul style="list-style-type: none"> ◆ Extracting raw materials ◆ Production of electricity and thermal energy ◆ Production of main and auxiliary chemicals ◆ Fresh Water Supply ◆ Transport And the following boundaries were considered the end part of the system: <ul style="list-style-type: none"> ◆ Waste production, Recovery of fleshings, Production crusts, Air emission, Emissions into water.

5.2.4. Harmonization Need

It is evident that, depending on the methodology chosen, the system boundary changes. The most important difference, both in terms of approach and of quantitative implications is that it is represented by the inclusion/exclusion of some processes of the Upstream Module, with particular reference to agriculture and animal farming. There is therefore a specific need for defining a harmonised approach, which can ultimately be used for future follow up actions.

The first consideration that shall be applied refers to the nature of raw hides and skins, as starting material for the leather making process.

It is important to determine whether raw hides and skins are to be considered as:

- co-product
- by-product
- waste

of the milk and/or meat industry.

Apart from the documents which have been presented in paragraph 5.2.3, some other background knowledge may lead to the conclusion that raw hides and skins have to be considered as a waste of the milk/meat industry:

- The PCR "Meat of Mammals", referring to allocation rules, explicitly states that: [...] “products that are not compliant to the quality requirements and are destined to other chains must be considered waste and reported as indicated

in the specific section”.

- The specific PCR on “Finished Bovine Leather” explicitly confirms that “A raw hide could be considered as a waste output of the slaughtering stage, interpreting the manufacturing processes carried out in the tannery as a recovery of waste”.
- The Basic Module PCR for leather and leather products states that agriculture and animal breeding should be included in the system boundaries only “if relevant”, and we interpret this as clearly indicating those cases in which animals are fed and breed with the specific aim of producing leather (i.e.: what happens with some niche markets, such as for example some specific species of reptiles.)
- The European “Reference Document on Best Available Techniques in the Slaughterhouses and Animal by-products Industries” refers to hides and skins as a sub-product (and not as a co-product), and reports the phases in which these are treated to be prepared for tanning, e.g.: cooling during storage or salting.
- The EU Ecolabel criteria on Footwear (including leather shoes), derived from the application of an LCA, do not include any parameter concerning the upstream processes of agriculture, animal breeding or even slaughtering.

In this sense, the case of raw hides and skins are considered as waste of the milk and meat industry, the whole environmental impact (and therefore of the CO₂ equivalent content) has to be allocated on the main product of the economic value chain (milk and meat) being raw hides and skins considered in the basic LCA studies as “*recovered waste*”. **This implies that agriculture and animal farming, as processes of the upstream module, shall be excluded from System Boundaries of LCA studies on leather.**

In order to carry out a complete analysis, it should be also considered the case in which raw hides are considered as a by-product or co-product of the milk and meat industry, with the implication that part of the environmental impacts (and therefore of the CO₂ equivalent content) have to be allocated to the co-product itself, on the basis of different allocation criteria (economic, mass, and system expansion). In this sense, a scientific publication of particular interest is represented by “System expansions to

handle co-products of renewable materials”, published in the occasion of the 7th LCA Case Studies Symposium SETAC-Europe, 1999 by Bo P. Weidema.

The document specifies that: *“The production of most renewable materials involves co-products. Traditionally, the environmental impacts have been allocated between the different co-products according to a more or less arbitrary allocation ratio. Following the ISO requirements, and based on SETAC recommendations, allocation shall be avoided whenever possible. The general belief has been that avoiding allocation through system expansion was not always possible for co-products from renewable material production, since the substitutions involved were considered to be too complex, difficult to determine, and sometimes involving endless regressions. However, these perceived problems can be solved by applying a stringent procedure for identifying the affected processes. The paper shows a number of case studies on renewable materials where allocations have been avoided through system expansion.*

Moreover, it specifies that:

“The co-producing process has one determining product, i.e. the product that determines the production volume of that process. This is not necessarily the product used in the specific lifecycle study. There may be any number of co-products, while at any given moment there can be only one determining product”.

And:

“That a product determining the production volume of a process is the same as saying that this process will be affected by a change in demand for this product”.
To say that there can be only one determining product at any given moment, is not the same as saying that the other co-products are not of importance. That the co-products can obtain a certain price on the market may well be a precondition for the process to expand its production volume. But when this precondition is fulfilled, it is still only a change in demand for the determining product that will be able to affect the production volume of the process. A graphical representation of the different processes involved is shown in the following figure.

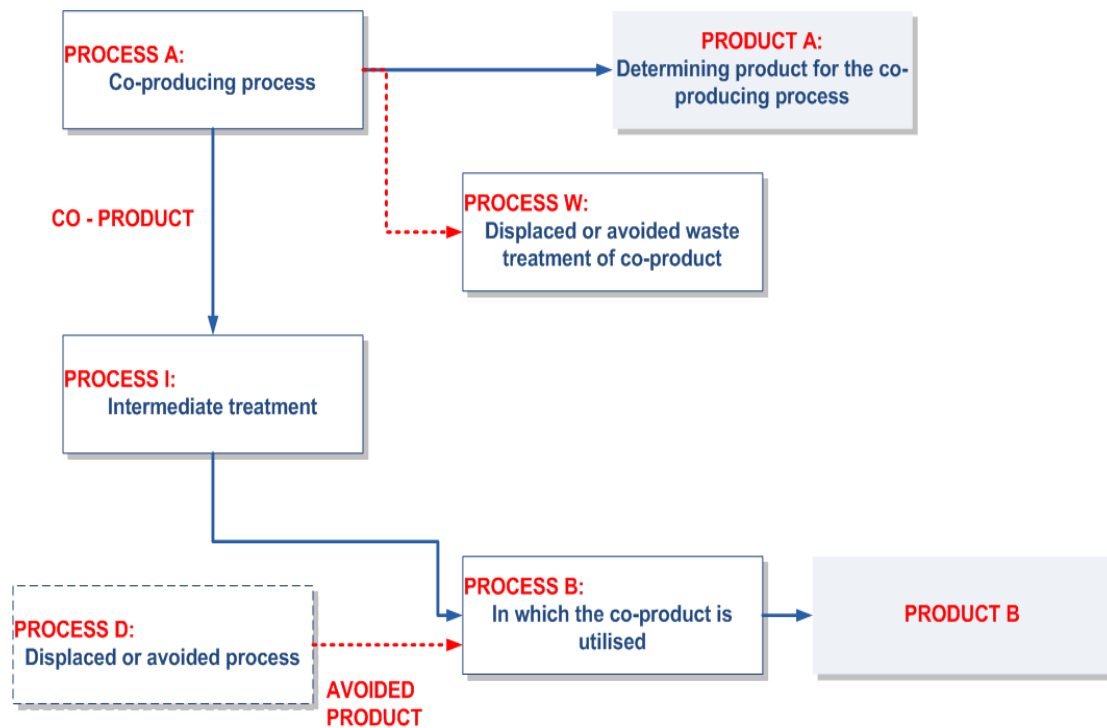


Fig. 4: Model for Describing System Expansion and Delimitation In Relation To Co-Production.

Performing a system expansion in relation to co-products is to identify exactly how the production volume of the processes in figure 4 will be affected by a change in demand for the product that is used by the life cycle study in question (both when this is the determining product for the co-producing process (A) and when it is the product in which the co-product is utilised (B)). The answer to this question can be summarised in four simple rules:

- 1) The co-producing process shall be ascribed fully (100%) to determine the product for this process.
- 2) Under the conditions that the non-determining co-products are fully utilised in other processes and actually displaces other products there, product A shall be credited for the processes, which are displaced by the other co-products, while the intermediate treatment (and other possible changes in the further life cycles in which the co-products are used, which are a consequence of differences in the co-products and the displaced products) shall be ascribed to product A.

If the two conditions stated in rule no. 2 are not fulfilled, rule no. 3 and 4 apply, respectively:

- 3) When a non-determining co-product is not utilised fully (i.e. when part of it must be regarded as a waste), but at least partly displaces another product, the intermediate treatment shall be ascribed to product B, while product B is credited for the avoided waste treatment of the co-product.
- 4) When a non-determining co-product is not displacing other products, all processes in the entire life cycle of the co-product shall be fully ascribed to product A.

When analysing the particular situation of raw hides and skins, in relation to the requirements for the application of the system expansion, it can be clearly affirmed that:

- a) **Raw Hides and Skins should be considered co-products of renewable materials:** A renewable resource is “a natural resource with the ability to reproduce through biological or natural processes and replenished with the passage of time. Renewable resources are part of our natural environment and form the eco-system”. For bovines, ovines and goats, this definition applies perfectly to the meat production (determining product), which is a renewable material, that has co-products as raw hides and skins.
- b) **Raw hides and skins, non-determining co-products are not utilised fully, but at least partly displace other products.** As widely known in sectoral literature, a small portion of the raw material input (around 20–25%) is transformed into finished leather. The remaining portion consists of other by-products and waste of animal origin. At the same time, leather displaces other materials (mostly synthetic) in the realization of footwear, leather goods, garment, car interiors, and furniture.

Under these circumstances, applying in a conservative manner the 4 rules explained before, for the product **Finished Leather realised with raw hides and skins coming from animals which have been farmed both for their milk production and for their meat**, the rule applicable is n° 3. Slaughtering is the intermediate processes “T”. Finished leather, moreover, could be credited for the avoided waste treatment of raw hides and skins entering the tannery.

Conclusion: The system boundaries are to be considered starting in the slaughterhouse, where activities and treatments are carried out in order to prepare the hides to be used for tanning (e.g.: conservation of the hides and skins by way of cooling systems or salting) and ending at the exit gate of the tannery.

5.2.5. Recommendations

Based on the conclusion that the system boundaries are starting in the Slaughterhouse, where activities and treatments are carried out in order to prepare the hides to be used for tanning (e.g.: conservation of the hides and skins by way of cooling systems or salting) and ending at the exit gate of the tannery.

The proposed, system boundaries are shown in the following figure.

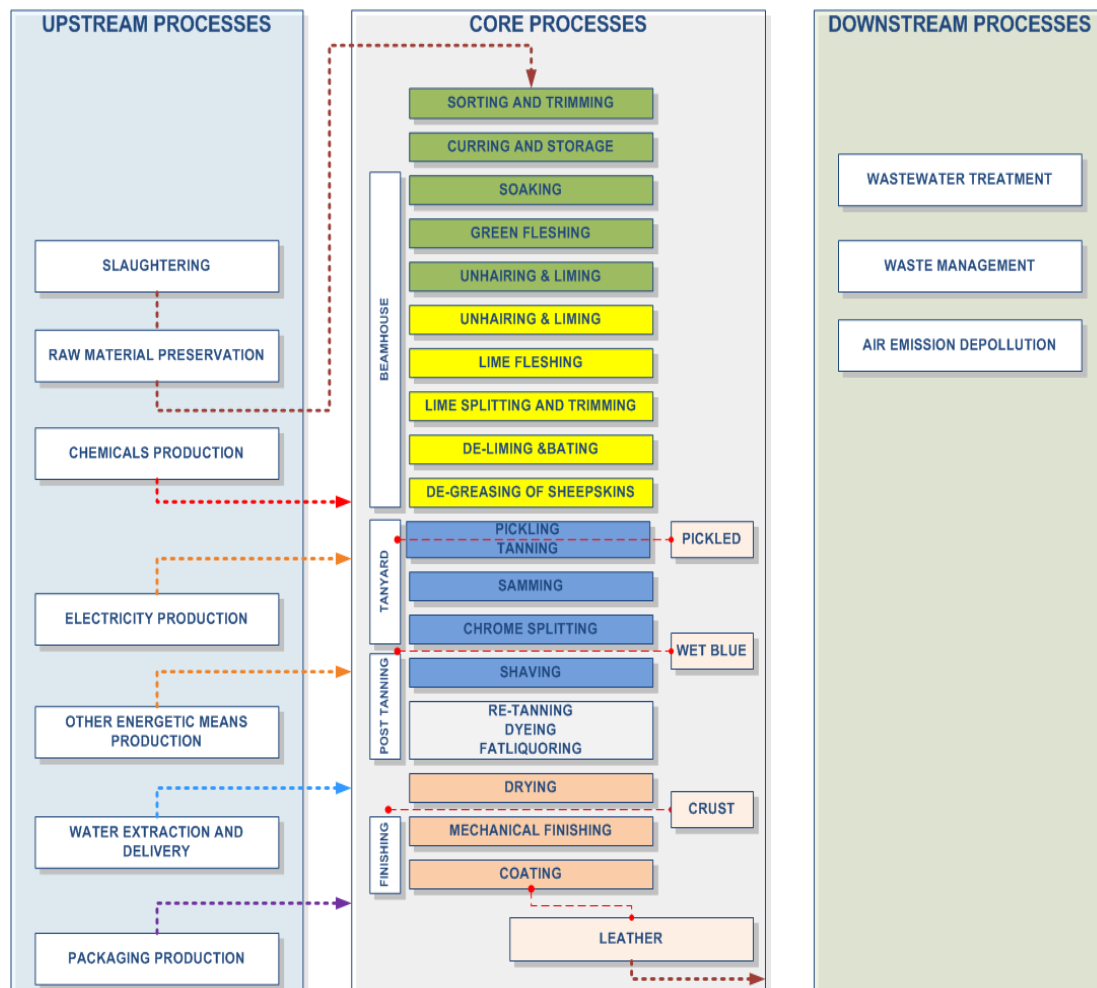


Fig. 5: System Boundaries

As seen in Figure 5, agriculture, animal farming, and leather use by downstream sectors have been excluded from system boundaries, which now start from the

“Cradle” (slaughterhouse), to “Gate” (that can be considered as the finished product warehouse exit gate of the tannery). In this context, downstream processes, with particular reference to waste management, air emission depollution, wastewater purification, as well as all kind of transportation (represented in the figure by the arrows) are to be always included in System Boundaries.

5.3. Quantification

Final aim of Leather PCF quantification for finished leather is to obtain the following indicator:

Kg of CO_{2e}/m² of finished leather

The different approaches identified in the reference documents show a certain similarity, basically converging in the subdivision of leather production in single processes and quantifying the emissions from each process. The harmonised methodology proposed, in order to obtain Kg of CO_{2e}/m² of finished leather, lies in the quantification of CO_{2e} content of all the different products and material entering the tannery (UPSTREAM PROCESSES), summing them to the CO_{2e} produced in the tannery itself (CORE PROCESSES), and the CO_{2e} produced for water purification, waste recycling/disposal and air depollution (DOWNSTREAM PROCESSES). The present chapter presents therefore examples of indicators to be calculated for obtaining precise quantitative information on different tanning processes.

5.3.1. ISO DIS 14067 Requirements

Quantification carried out in accordance with this International Standard shall include all GHG emissions and removals of those unit processes within the defined system boundary that have the potential to make a significant contribution to the CFP.

5.3.2. Review of Background Knowledge

Tab. 3: Review of Background Knowledge: Quantification

REFERENCE DOCUMENTS	APPROACH
PCR leather (EPD)	<p>The quantification approach utilized in this standard, following a conservative approach, considering in calculation the emission produced from the cattle raising phase, quantifies the carbon footprint of product in the three principal steps of the production of finished leather: UPSTREAM, CORE and DOWNSTREAM. For what concern the core module, all tanning processes have to be included in the study, including primary and secondary packaging. However, the production of the raw materials used for production of all product parts shall be included according to the cut off rules. Manufacturing processes covered by third parties and inputs and outputs of semi-finished leather have to be considered. The downstream process doesn't take into account the "use phase scenario", since no specific function has been defined.</p>
<p>ECO2L-Handbook-complete-9-9-2011_GB - Calculation of a Corporate Carbon Footprint (CCF) for a leather factory with evaluation of internal energy consumption in comparison to the BEET energy benchmark (Best Energy Efficiency for Tanning)</p>	<p>Energy consumption in production: The total energy consumption for all external and internal energy sources is recorded as an annual consumption volume, and is converted and evaluated in MJ/m² for comparison to the BEET benchmark. The CO₂ emissions and / or emission equivalents resulting from the production and / or combustion of fossil fuels (e.g. oil, natural gas, coal) are calculated and evaluated.</p> <p>If, for example, biological diesel fuel replacement (oil) from machine glue stock is produced on the premises and used directly as an energy source within the company, the energy needed for the preparation process (electricity / steam) is included, but no emission data are calculated for the combustion of this diesel replacement fuel (CO₂-neutral). Producing and directly consuming this replacement fuel means the operation purchases less fossil diesel and / or gas, therefore improving the emission balance.</p> <p>UPSTREAM PROCESS: Processes that precede leather production at the location but belong to the production chain as a whole can be viewed and defined as upstream processes. For the product "upholstery leather from cowhide", these can generally include hide harvesting and handling, subsequent transportation of the hide and the production and transportation of semi-finished goods to the leather factory. The production and transportation of the required chemicals, the transportation of other goods (machines, replacement parts, office supplies etc.) as well as energy generation can also be included in this upstream chain. If the production process as well as all upstream and downstream processes "from the cradle to the grave" were taken into account, the product carbon footprint (PCF) would be calculated.</p> <p>Cattle farming / Fattening and Production of Split, Wet-Blue or Crust as Raw Material: The CO₂ emissions from cattle farming / fattening were not included in the calculation.</p> <p>Raw hide winning and Preservation: Hide harvesting and preservation for trading in hides are not included in the ECO2L model.</p>

	<p>Transportation of Rawhide from assembly centre to Leather Factory: The transportation of rawhide from the assembly centre of a hide dealer or from the slaughterhouse to the leather factory is included in the corporate carbon footprint, since the company being evaluated can usually influence it (e.g. regional procurement of raw material, means of transport optimisation and selection).</p> <p>Transportation of Preliminary Products as Raw Material (Split, Wet-Blue, Wet-White, Crust) to the Leather Factory: The transportation of all preliminary products from the supplier's distribution warehouse to the tannery is included in the model calculation for the corporate carbon footprint. In the current version, the transportation of economic goods such as machines, replacement parts and office supplies is not included.</p> <p>CO₂ emissions from the production of chemicals are not included in the current ECO2L calculation. Insofar as a leather factory wants to report product-specific CO₂ emissions for its leather, the data from the CTC study (10) for energy consumption in the production of chemicals for chrome-tanned leather can be used for allocation. The energy consumption calculated there is 21 kWh/m² of leather and, when the European CO₂emission factor of 0.310 kg CO₂/kWh is taken into account, corresponds to CO₂ emissions of 6.51 kg CO₂/m².</p> <p>The CO₂ emissions for the transportation of chemicals from the production site to the distribution warehouse are not included in the calculation of the CO₂ footprint.</p> <p>The transportation of chemicals from the central warehouse to the leather factory is included. The CO₂ emissions for the generation of externally procured electrical energy are included in the calculation. For the CO₂ emissions from the generation of electricity, the energy mix of the energy sources that are used is crucial. This means there are significant differences between the specific emission factors of various countries / providers.</p> <p>DOWNSTREAM PROCESSES: The subsequent transportation to the customer of semi-finished goods produced in the leather factory, e.g. split, wet-blue or crust as well as finished leather, is not included in the corporate carbon footprint calculation. CO₂ emissions in the usage phase are not included in the ECO2L model. The disposal of leather and therefore the possible CO₂ emissions of leather after the end of the usage phase varies widely, depending on the disposal method. This is not included in the ECO2L label. The CO₂ emissions associated with the transportation of all wastes are included.</p>
<p>Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA</p>	<p>In the practical approach of the ISO DIS 14067 standard, the quantification was done based on the system boundaries described in previous chapter.</p> <p>For the UPSTREAM phases, the slaughterhouse distance from the production site was considered negligible. The processes considered are: water consumption, energy consumption. Transportation of raw hides and chemicals were considered.</p> <p>The CORE module was divided in the following phases: raw hides flow; energy consumption; liming; tanning; dyeing; finishing; water consumption and waste water; waste and by-product; emission;</p> <p>In the core module, the allocation methodology for the splitting phase gives 50% of environmental impact to the split and 50 % to the grain.</p>

5.3.3. Harmonization Need

The quantification in the three approaches have very similar methodologies,

subdividing the process in different steps and quantifying emission from each process.

5.3.4. Recommendation

The final aim of the process is to quantify the CPF of the product leather, which is defined in ISO DIS 14067 as the “*sum of greenhouse gas emissions and removals in a product system, expressed as CO₂ equivalent and based on a life cycle assessment*”. The CO₂ equivalent of a specific amount of a greenhouse gas is calculated as the mass of a given greenhouse gas multiplied by its global warming potential¹².

According to this definition and to the previous definition of the functional unit, a CF of leather shall be expressed as:

Kg of CO_{2e}/m² of finished leather

In order to be able to quantify the CF defined above, the ISO DIS 14067, in chapter 6.1 specifies that: “*A CFP study assesses the GHG emissions and removals in the life cycle of a product. The unit processes comprising the product system shall be grouped into life cycle stages; e.g., raw material acquisition, production, distribution, use and end-of-life. GHG emissions and removals from the product’s life cycle shall be assigned to the life cycle stage in which the GHG emissions and removals occur. Partial CFPs may be added together to quantify the CFP, provided that they are performed according to the same methodology*”¹³. According to the described “Modular approach”, the methodology is based on the quantification of CO_{2e} content of all the different products and material entering the tannery (upstream processes), summing them to the CO_{2e} produced in the tannery itself (core processes), and the CO_{2e} produced for water purification, waste recycling/disposal and air purification (downstream processes).

Precise calculations methodologies and guidelines are beyond the scope of the present paper. It has in any case been considered useful to provide general indications and a first technical definition of a possible methodology, through an exemplificative definition of PCF indicators. In order to do this, some assumptions have to be made:

¹²ISO DIS 14067, Paragraph 3.1.1 and explanatory notes

¹³ISO DIS 14067, Paragraph 6.1

- 1) *Considerations are to be intended on tanneries producing finished leather, starting from preserved raw hides and skins (therefore carrying out in their production facilities the full production cycle).*
- 2) *Time boundary is one calendar year.*
- 3) *No outsourced production processes are foreseen¹⁴.*
- 4) *For the sake of simplicity, splitting is foreseen only on pelts (lime splitting) Splits are calculated to account for 50% of the weight of the pelt. Splits exit the system as co-products, while grain leather continues until the end of the process and it is then sold as a finished product. All environmental impacts before splitting are then allocated 50% on the grain leather and 50% on the split.*
- 5) *Raw hides and skins are bought on the basis of their weight (expressed in kilograms)*
- 6) *Slaughtering and raw material preservation (salting) are carried out in the same production facilities.*
- 7) *Quantification methodologies of core processes are to be made on yearly production of the whole tannery.*
- 8) *The tannery is selling finished leather on the basis of the surface (expressed in m²).*
- 9) *Range of thickness of finished leather does not vary substantially from one article to the other.*
- 10) *Transport of hides and skins, of chemicals and all other auxiliaries shall be included, but no specific calculation criteria have been identified*
- 11) *Waste water treatment is carried out within the same production site of the tannery, but is treated as an independent facility.*
- 12) *Air emissions cleaning impact, being mostly linked to electric energy consumption and to waste production, even if considered as downstream processes, is to be included in the core processes consumption and emission indicators.*

The following table summarises the kind of information and quantitative indicators that shall be obtained in all different processes of the system boundaries, allowing a quantification of the Carbon footprint of leather.

¹⁴ If presents, contribution to Leather PCF of outsourced processes shall be taken into account. The assumption is made for simplicity reasons.

Tab. 4: CF information from upstream processes: SLAUGHTERING AND RAW MATERIAL PRESERVATION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN UPSTREAM FACILITIES	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	Supplier Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals.	GHG content per unit of raw hides and skins produced from supplier “i”
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals	RAW _i : kg CO _{2e} /kg of preserved raw hides and skins

Tab. 5: CF information from upstream processes: CHEMICALS PRODUCTION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN UPSTREAM FACILITIES	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
UPSTREAM PROCESSES	CHEMICALS PRODUCTION	For each chemical used in production, product and supplier specific data shall be obtained from the different producers, in order to quantify the CO _{2e} produced for each kg of the same chemical which is going to be traded. These shall be calculated from the producers on the basis of all different contribution of energy and raw materials consumptions.	GHG content per unit of chemicals produced for product “i” and supplier “j”
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw wides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals	CHEM _{ij} : kg CO _{2e} /kg chemical product

Tab. 6: CF information from upstream processes: ELECTRICITY PRODUCTION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN UPSTREAM FACILITIES	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
UPSTREAM PROCESSES	ELECTRICITY PRODUCTION	<p><u>Supplier specific</u> data shall be obtained from the producers of electric energy, in order to quantify the CO_{2e} produced for each kWh that the tannery is going to purchase. Same methodology applies in case the electric energy is produced within the tannery itself, also through renewable resources. In this latter case, the production carried out in the tannery shall be considered as a distinct supplier.</p>	GHG content per unit of electric energy produced by supplier “i”
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	<p><u>Site specific</u> data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO_{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals.</p>	<p>POWER 1_i: kg CO_{2e}/kWh of electric energy produced.</p>

Tab. 7: CF information from upstream processes: OTHER ENERGETIC MEANS PRODUCTION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN UPSTREAM FACILITIES	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
UPSTREAM PROCESSES	OTHER ENERGETIC MEANS PRODUCTION	A part from electric power, energy consumption in tanneries is mainly linked to the thermal need of different process phases and to the fuel need of internal transport equipment in the tanneries (i.e. forklifts). Many different energy sources are used for heat production, among these, natural gas, heavy fuel oil, Diesel, Oil, Solar Heat etc. For the aim of the present work, we consider only Methane, as other energy source, purchased by the tannery in m ³ . Supplier specific data shall be obtained.	GHG content per unit of methane gas produced by supplier “i”
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	<p><u>Site specific</u> data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO_{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals.</p>	POWER 2i: kg CO _{2e} /m ³ of methane gas produced

Tab. 8: CF information from upstream processes: WATER EXTRACTION AND DELIVERY

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN UPSTREAM FACILITIES	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
UPSTREAM PROCESSES	WATER EXTRACTION AND DELIVERY	Water is used in the tannery mainly as a means to achieve the chemical transformation of the skins through the use of products carried in solution. In fact, processing the skin is developed via a series of phases performed in an aqueous environment. Therefore, water consumption and water treatment represent the most important environmental aspects in tanning. Tanneries adopt various water supply systems. These include artesian wells and connections to industrial and civil plants. GHG quantification shall be explicated only in this latter case, being the energy consumption linked with wells included in the overall energy consumption of the tannery.	GHG content per unit of water extracted and distributed by supplier “i”
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	<p><u>Site specific</u> data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO_{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals</p>	WATER 1 _i : kg CO _{2e} /m ³ water supplied

Tab. 9: CF information from upstream processes: PACKAGING PRODUCTION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN UPSTREAM FACILITIES	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
UPSTREAM PROCESSES	PACKAGING PRODUCTION	Different kinds of packaging are used in tanneries for the delivery of finished leather. In GHG quantification we suggest not to consider packaging of inputs products, which shall be quantified in the other upstream processes indicators. Product and supplier specific data shall be obtained.	GHG content per unit of packaging material for finished leather “i” produced by supplier “j”
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals.	PACK 1 _{ij} : kg CO _{2e} /kg of packaging material supplied

Tab. 10: CF Information From Core Processes: BEAMHOUSE

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN THE TANNERY	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
CORE PROCESSES	BEAMHOUSE	As described above, the production of the tannery is assumed to be fully carried out in the same production facility, having lime splitting carried out at the end of the beamhouse process with splits accounting for 50% in weight of the pelt, carrying with them 50% of the environmental impacts generated in the previous phases. In the overall calculation of CF, production process shall therefore be divided in the different phases leading to beamhouse (including splitting) and in the others, leading to the final product. In order to proceed with a possible allocation (see the following chapter) of CO _{2e} per m ² of finished leather, it is in fact important to be able to identify the specific impacts that are linked with process phases up to splitting. In case the informative system of the tannery may allow a precise quantification of the mass of splits exiting the system and the one destined to grain production, site specific data shall be used.	Amount of processed pelts following the different process directions.
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	<u>Site specific</u> data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals.	<p>PROD 1: splits exiting the system (kg/year)</p> <p>PROD 2: grain leather entering the tanyard (kg/year)</p>

Tab. 11: CF Information From Core Processes: FINISHED LEATHER PRODUCTION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN THE TANNERY	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
CORE PROCESSES	FINISHED LEATHER PRODUCTION	<p>In order to quantify the amount of CO_{2e}, to be assessed in comparison with the identified functional unit, very important information that shall be obtained in the tannery is the quantity of finished leather produced in the calendar year, expressed in m². A tannery possessing a state of the art informative system may easily calculate the figure, by applying the following formula:</p> $ \begin{aligned} \text{PROD 3} = & \\ & \text{finished leather in storage at the beginning of the period} \\ & + \\ & \text{finished leather sold} \\ & - \\ & \text{finished leather in storage at the end of the period} \end{aligned} $	Amount of finished leather produced
		UOM	
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	<p>Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO_{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals.</p>	PROD 3: m ² of finished leather produced

Tab. 12: CF Information From Core Processes: PROCESS CONSUMPTIONS AND EMISSIONS

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN THE TANNERY	
CORE PROCESSES	PROCESS CONSUMPTIONS AND EMISSIONS	<p>At this stage it is important to be able to quantify all physical indicators that can characterise leather production in the core processes. The suggested way of proceeding is to identify all key performance indicators that may result useful for the calculation of CO₂ calculations during the production process. In order to do this, following a step by step approach all process consumptions and emissions shall be identified both for phases up to beamhouse, and for the following. Processes, leading to finished leather.</p> <p style="text-align: center;">A TABLE SUMMARISING THE DIFFERENT INDICATORS THAT CAN BE OBTAINED AND THAT CAN CONTRIBUTE TO CALCULATION OF CF OF LEATHER WILL BE PROVIDED AFTER THE DESCRIPTION OF THE DOWNSTREAM PROCESSES</p>	

Tab. 13: CF Information From Downstream Processes: WASTEWATER PURIFICATION

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN THE TANNERY	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
DOWNSTREAM PROCESSES	WASTEWATER PURIFICATION	<p>Tanneries set up different methodologies for purifying the water they discharge. In general, these systems include several steps of water purification (primary, secondary, sometimes even tertiary treatments) that use chemicals and consume energy (primarily electricity). The amount of chemicals and electricity deployed in the purification process strictly depend upon the quality of the water which is discharged and the emission limits that are to be reached. In this context, indicators used internationally to evaluate the performance of purification plants are calculated on the quantity of water being treated (m³) or, in more evolved situations, on the quantity of COD removed from water (kg). We choose to use the first one, for the sake of simplicity, but point out the need also for reconsidering more in detail the issue. Moreover, wastewater treatment produces sludge as waste, the impact of which shall be accounted for entirely in the downstream process. Its contribution is therefore considered to be accounted for in the indicator WATER 2.</p>	<p>GHG content per unit of purified wastewater</p> <hr/> <p>UOM</p>

UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw wids and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals	WATER2: kg CO _{2e} /m ³ water purified
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Tab. 14: CF Information From Downstream Processes: WASTE RECYCLING And Disposal

SYSTEM BOUNDARIES	PROCESSES	INFORMATION TO BE OBTAINED IN THE TANNERY	SPECIFIC INDICATORS TO BE OBTAINED FROM UPSTREAM PROCESSES
DOWNSTREAM PROCESSES	WASTE RECYCLING	As precisely described in the PCR basic module CPC Division 29 at point 7.1.5 <u>Boundaries to other product life cycles</u> states that: “If there is an inflow of recycled material to the production system in the production/manufacturing phase, the recycling process and the transportation from the recycling process to where the material is used shall be included. <u>If there is an outflow of material to recycling, the transportation of the material to the recycling process shall be included.</u> The material going to recycling is then an outflow from the production system”. It means that, for all the kind of waste produced by the different phases of the leather production process, the contribution of these kind of material can be <u>conservatively</u> considered zero, <u>provided that the tannery can guarantee that the material is actually sent for recycling.</u> Specific cases apply when the material is used for energy production.	GHG content per unit of recycled waste
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	Site specific data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw wids and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals	WASTE 1: kg CO _{2e} /kg of recycled waste: ZERO

DOWNSTREAM PROCESSES	WASTE DISPOSAL	In case waste produced by tannery is not sent to recycling, the CO ₂ emissions resulting from its disposal shall be considered in the CF calculations. Although this general principle is widely accepted, the lack of specific data which need to be consistent per material type and per disposal facility make it not possible to get to precise indicators.	GHG content per unit of <u>non recycled waste</u>
			UOM
UPSTREAM PROCESSES	SLAUGHTERING AND RAW MATERIAL PRESERVATION	<u>Site specific</u> data shall be obtained from the different slaughterhouses from where raw hides and skins come from, where both slaughtering and preservation processes are carried out, in order to quantify the CO _{2e} produced for each kg of preserved raw hides and skins. These shall be calculated on the basis of all different contribution of energy and chemical products consumptions only in the slaughtering process. Allocation shall be made on the basis of the mass of raw hides and skins, in comparison with the whole mass of the animals	WASTE 2: kg CO _{2e} / kg of non recycled waste

As said before, having identified all specific indicators from Upstream and Downstream processes, it is important to be able to quantify all physical KPIs that can characterise site specific leather production in the core processes.

The suggested way of proceeding is to identify all key performance indicators that may result useful for the calculation of CO₂ calculations during the production process. In order to do this, following a step by step approach all process consumptions and emissions shall be identified both for phases up to beamhouse, and for the following (up to finished leather).

The following Table 15 describes the calculation methodology that can be adopted at the tannery level.

Tab. 15: TANNERY SPECIFIC CONSUPTION/EMISSION INDICATORS

PROCESS PHASE	ENVIRONMENTAL ASPECT	UPSTREAM/DOWNSTREAM PROCESSES INDICATORS	TANNERY SPECIFIC CONSUPTION/EMISSION INDICATORS	TANNERY SPECIFIC CF INDICATORS
BEAMHOUSE	RAW HIDES CONSUMPTION	RAW_i : kg CO _{2e} /kg of preserved raw hides and skins	Total raw hides/skins consumption in the considered period, per supplier (kg/year)	CF BEAM 1 : kg CO _{2e} /year coming from of preserved raw hides and skins consumed
BEAMHOUSE	CHEMICALS CONSUMPTION	CHEM_{ij} : kg CO _{2e} /kg chemical product	Total <u>beamhouse</u> consumption of Chemical i from Supplier j in the considered period (kg/year)	CF BEAM 2 : kg CO _{2e} /year coming from consumed chemical products
BEAMHOUSE	ELECTRICITY CONSUMPTION	POWER 1_i : kg CO _{2e} /kWh of electric energy produced	Total <u>beamhouse</u> electricity consumption from Supplier i in the considered period (kwh/year)	CF BEAM 3 : kg CO _{2e} /year coming from electricity used in Beamhouse
BEAMHOUSE	THERMAL ENERGY CONSUMPTION	POWER 2_i : kg CO _{2e} /m ³ of methane gas produced	Total <u>beamhouse</u> methane gas consumption from Supplier i in the considered period (m ³ /year)	CF BEAM 4 : kg CO _{2e} /year coming from methane gas used in Beamhouse
BEAMHOUSE	THERMAL ENERGY CONSUMPTION	NONE	Total <u>GHG emissions from the process of combustion of the methane gas</u> used in beamhouse(kg/year)	CF BEAM 5 : kg CO _{2e} /year coming from the combustion of methane gas used in Beamhouse ¹⁵
BEAMHOUSE	WATER CONSUMPTION	WATER 1_i : kg CO _{2e} /m ³ water supplied	Total water consumed in beamhouse in the considered period (m ³ /year)	CF BEAM 6 : kg CO _{2e} /year coming from water consumed
BEAMHOUSE	PACKAGING CONSUMPTION	PACK 1_{ij} : kg CO _{2e} /kg of packaging material supplied	NONE	NONE

¹⁵The potential climate change impact of each GHG emitted shall be calculated by multiplying the mass of the gas released by the 100 year GWP given by the IPCC in units of “kg CO₂ per kg emission”

PROCESS PHASE	ENVIRONMENTAL ASPECT	UPSTREAM/DOWNSTREAM PROCESSES INDICATORS	TANNERY SPECIFIC CONSUMPTION/EMISSION INDICATORS	TANNERY SPECIFIC CF INDICATORS
BEAMHOUSE	WASTEWATER DISCHARGED AND PURIFIED	WATER 2: kg CO _{2e} /m ³ water purified	Total water discharged from beamhouse in the considered period (m ³ /year)	CF BEAM 7: kg CO _{2e} /year coming from water discharged and purified
BEAMHOUSE	WASTE SENT FOR RECYCLING	WASTE 1: kg CO _{2e} /kg of recycled waste: ZERO	Kg of waste sent to recycling, produced in the beamhouse	ZERO
BEAMHOUSE	WASTE NOT SENT FOR RECYCLING	WASTE 2: kg CO _{2e} / kg of non recycled waste	Kg of waste <u>not</u> sent to recycling, produced in the beamhouse(kg/year)	CF BEAM 8: kg CO _{2e} /year coming from waste not sent to recycling
BEAMHOUSE	DIRECT AIR EMISSIONS	NONE	Total <u>GHG direct emissions from the beamhouse processes</u> (kg/year)	CF BEAM 9: kg CO _{2e} /year coming from the direct emissions of GHG from the Beamhouse processes ¹⁶

BEAMHOUSE	TOTAL CF BEAM (kg CO_{2e}/year) = CF BEAM 1 + CF BEAM 2 + CF BEAM 3 + CF BEAM 4 + + CF BEAM 9
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BEAMHOUSE	TOTAL CF BEAM to be allocated on finished leather (kg CO_{2e}/year) = CF BEAM (kg CO_{2e}/year) * PROD 2/PROD 1 (%)
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¹⁶The potential climate change impact of each GHG emitted shall be calculated by multiplying the mass of the gas released by the 100 year GWP given by the IPCC in units of "kg CO₂ per kg emission"

The process described in the previous tables can be applied to all the following phases exactly with the same methodology.

Once calculations are performed for the processes that follow the beamhouse (where we have assumed that splitting occurs), the following indicators will be obtained:

TOTAL CF BEAM to be allocated on finished leather (kg CO_{2e}/year)

TOTAL CF OTHER PROCESSES (kg CO_{2e}/year)

Carbon footprint of finished leather is therefore calculated as follows:

Leather CF = (TOTAL CF BEAM + TOTAL CF OTHER PROCESSES)/ PROD 3

Confronting the Units of Measure:

$$(\text{Kg of CO}_{2e}/\text{m}^2) = (\text{kg CO}_{2e}/\text{year})/\text{m}^2/\text{year}$$

5.4. Cut-Off Criteria

The analysis shows how consistent cut-off criteria shall be defined during the goal and scope definition phase of the carbon footprint calculation. The total omitted emission shall not exceed 0,1% compared to the total emission from all processes within defined system boundary.

5.4.1. ISO DIS 14067 Requirements

“Consistent cut-off criteria that allow the omission of certain processes of minor importance shall be defined within the goal and scope definition phase. The effect of the selected cut-off criteria on the outcome of the study shall also be assessed and described in the CFP study report”.

5.4.2. Review of Background Knowledge

Tab. 16: Review Of Background Knowledge: Cut – Off Criteria	
REFERENCE DOCUMENTS	APPROACH
PCR leather (EPD)	<p>Life Cycle Inventory data that fulfil the following cut-off criteria shall be included in the Core Module:</p> <ul style="list-style-type: none"> • All chemical materials, not containing components subject to labelling or legal requirements (non hazardous materials), $\geq 1,5$ weight % referred to the total weight of the material (weight of the commercial presentation) consumed in all production processes in the time of reference, considered with the mean percentage of the chemical active substance present in the commercial presentation; all chemical materials which contain components that are subject to labelling (e.g. the European Directives on substances and preparations) or submitted to legal requirements (hazardous materials) shall be listed until a total weight of the commercial presentation of $\geq 0,01\%$ for materials containing components that as marked with the following hazard symbols and risk phrases: <ul style="list-style-type: none"> ○ Environmental Hazard -N and/or R52, R53, R59 ○ Carcinogenic - Category 1 and 2: T or T+ and R45 or R49; Category 3: Xn and R40 ○ Mutagenic - Category 1 and 2: T or T+ and R46; Category 3: Xn and R68 • All chemical materials which contain components that are subject to labelling (e.g. the European Directives on substances and preparations) or submitted to legal requirements (hazardous materials) shall be listed until a total weight of the mixture of $\geq 0,05\%$ for materials containing components that are marked with all other hazard symbols and risk phrases excluded for the 0,01% cut off definition. The weight of reference is always the commercial presentation where the hazardous component is contained in. The mass to be considered is the mean value of the percentage of the hazardous component contained resulting from the international risk schedule; • In order to guarantee a conservative approach all chemical products excluded from the previous cut off rules shall be considered by aggregating the masses consumed of their commercial presentations. For every manufacturing phase the non hazardous products excluded shall be aggregated and shall be considered like the most consumed non hazardous chemical product in that phase. Likewise for every manufacturing phase the hazardous products excluded shall be aggregated and shall be considered like the most consumed hazardous chemical product in that phase; • For all chemical materials, the calculation approach shall be the multiplication of the weight of the commercial presentation by the respective percentage of the active chemical substance; • The water and the inert material contained in the commercial presentation don't have to be considered. <p>Processes that contribute less than 0.1% to the total impact can be omitted from the impact assessment.</p>
Final report-GRUPPO DANI S.P.A.LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA	Activities and processes that together contribute less than 0.1% to the climate impact are omitted from the total inventory. For the other criteria of the cut off reference is made to what defined in the PCR.

5.4.3. Harmonization Need

The cut-off criterion allows having a clear framework for deciding of the inclusion or exclusion of processes in the analysis. Consistent cut-off criteria shall be defined during the goal and scope definition phase. The studies don't seem to need a real harmonization need since activities and processes that together contribute less than 0.1% to the climate impact are omitted.

5.4.4. Recommendation

The total omitted emission shall not exceed 0.1% compared to the total emission from all processes within defined system boundary.

5.5. Data And Data Quality

Carbon footprint studies should use data that reduce uncertainty; the analysis shows the importance of this parameter to ensure the reliability of the results. Determination of the best data quality could be supported by a data scoring framework that allows the different attributes of data quality to be combined.

5.5.1. ISO DIS 14067 Requirements

“Site-specific data shall be collected for all individual processes under the financial or operational control of the organization undertaking the CFP study, and shall be representative of the processes for which they are collected. Site-specific data should be used for those unit processes that contribute considerably to the CFP, as determined in the sensitivity analysis”.

5.5.2. Review of Background Knowledge

Tab. 17: Review Of Background Knowledge: Data And Data Quality	
REFERENCE DOCUMENTS	APPROACH
Final report footwear (ECOLABEL)	<p>One of the most time consuming elements in LCA work is acquiring the data needed for the inventory calculations and to justify their quality and reliability. Data used in this LCA come from both direct information (throughout ad hoc questionnaires) and from sources that are available on public domain.</p>
PCR leather (EPD)	<p>UPSTREAM MODULE: Selected generic data shall be used if specific data are unavailable, e.g. data from commonly available data sources such as commercial databases and free databases, describing specific raw materials or processes usually referring to the system under study or to other systems equivalent from a technical point of view. Rules for generic data: If these data sources do not supply the necessary data, other generic data may be used and documented. The environmental impact of the processes where the other generic data are used must not exceed 10% of the overall environmental impact from the product system.</p> <p>CORE MODULE: Specific data (often called site specific data) shall be used for the Core Module, except for the chemical and auxiliary materials for which generic data can be used. Specific data are gathered from the sites where specific processes are carried out.</p> <p>The requirements for specific data also include actual product weights, amounts of raw materials used and amounts of waste etc.</p> <p>Specific data for the generation of electricity bought shall be used if possible. The data should be verifiable by invoice or similar. If specific data are not available or if the electricity bought is not specified for parts of the Core Module, the electricity mix used in those parts shall be approximated as the official electricity mix in the country of manufacture. The mix of energy shall be documented.</p>
Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA	<p>For this LCA were collected specific data ex novo (primary data or site specific) for most of the processes of the life cycle, especially for processes that affect the internal stages of processing at the tannery. For the upstream processes, because of the difficulty in obtaining reliable primary data it has been used data of the specific database LCA food, in accordance with the provisions of PCR. The database used is specific to the Danish LCA food data.</p> <p>The method chosen in the used software for the conversion of all GHG in CO₂ equivalent, were values of the GWP of all greenhouse gases in the most recent IPCC report of 2007. The process for electrical energy is created specifically with the emission factor of the electricity supplier.</p> <p>The lack of data in the literature for certain chemicals used in tanning process had obliged, during the processing of data, to identify in the database substances as similar as possible to that actually used, introducing an approximation error. It was not possible to estimate the quantification of this error.</p>

5.5.3. Harmonization Need

Data quality is an important parameter to ensure the reliability of results, given the important amount of information to be collected. According to the studies considered, data and data quality should be obtained from direct or indirect information. The EPD standard quantifies the percentage of generic data that can be considered.

5.5.4. Recommendation

Carbon footprint studies should use data that reduce uncertainty. Determination of the best data quality could be supported by a data scoring framework that allows different attributes of data quality to be combined. Although it is recognised by the author that at the current stage there is an evident lack of site/supplier specific data, there is an incoming need of spreading the good practice among the whole leather value chain of providing CF reliable information together with the goods which are sold on the market, in order to allow tanneries to make a comparison among different suppliers and implement concrete CF reduction strategies.

5.6. Time Boundary For Data

In the two studies considered in this chapter the data are representative within a temporal boundary of 1 year, which is considered also by the author the most appropriate time boundary, for data completeness, reliability and accessibility to primary information both in the tannery and along the value chain, which are necessary for a complete quantification of the emission considered.

5.6.1. ISO DIS 14067 Requirements

“The time boundary for data is the time period for which the quantified figure for the CFP is representative”.

5.6.2. Review of Background Knowledge

REFERENCE DOCUMENTS	APPROACH
PCR leather (EPD)	The data shall be representative for the year/time frame for which the EPD is valid (maximum 3 years)
Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA	The study was developed with temporal boundary as a 1 year. It makes possible to highlight the changes in the CFP and the distribution of impact over time. The study referenced in year 2010. Therefore the primary data, also called "site-specific" in ISO DIS 14067 CD.2 are from that period, with the exception of a few primary data at the time of writing the study were not yet available for 2010 and that were then replaced with 2009 data. Secondary data come from databases contained in the LCA software, SimaPro 7.1, and other LCA studies related to raw materials considered.

5.6.3. Harmonization Need

In both cases, the data are representative within a temporal boundary of 1 year.

5.6.4. Recommendation

One year should be the time boundary necessary for a complete quantification of the emission considered.

5.7. Use Stage And Use Profile

5.7.1. ISO DIS 14067 Requirements

“When the use stage is included within the scope of the CFP study, GHG emissions and removals arising from the use stage of the product during the product’s service life shall be included”.

As described in the previous chapter, leather use by downstream sectors have been excluded from system boundaries, which now start from “Cradle” (the slaughterhouse), to “Gate” (that can be considered as the finished product warehouse of the tannery).

5.8. End-Of-Life Stage

5.8.1. ISO DIS 14067 Requirements

“The end-of-life stage begins when the used product is ready for disposal, recycling,

reuse, etc. All the GHG emissions and removals arising from the end-of-life stage of a product shall be included in a CFP study, if this stage is included in the scope”.

Again, as described in the previous chapter, leather use by downstream sectors have been excluded from system boundaries, which now start from “Cradle” (the slaughterhouse), to “Gate” (that can be considered as the finished product warehouse of the tannery).

5.9. Life Cycle Inventory Analysis For The CFP

Data sources are the main aspect to consider dealing with this issue. It is generally required to use known sources (process data) or recognized sources (default value) to overall to trace the data origin.

5.9.1. ISO DIS 14067 Requirements

“LCI is the phase of LCA involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. After the goal and scope definition phase, the LCI of a CFP study shall be performed, which consists of the following steps, for which the following pertinent provisions, adapted from ISO 14044:2006, listed below shall apply. If CFP-PCR are adopted for the CFP study, the LCI shall be conducted following the requirements in the CFP-PCR.

- ***Data collection;***
- ***Validation of data;***

Relating data to unit process and functional unit.

5.9.2. Review of Background Knowledge

REFERENCE DOCUMENTS	APPROACH
PCR leather (EPD)	<p>The consumption of natural resources per declared unit shall be reported in the EPD, divided into core, upstream and downstream module.</p> <p>The input parameters for the extracted resources are:</p> <ul style="list-style-type: none"> • Non-renewable resources: <ul style="list-style-type: none"> ○ Material resources; ○ Energy resources. • Renewable resources: <ul style="list-style-type: none"> ○ Material resources

REFERENCE DOCUMENTS	APPROACH
	<ul style="list-style-type: none"> ○ Energy resources • Water use • Electricity (electricity consumption during manufacturing) <p>The environmental impact per declared unit for the following environmental impact categories shall be reported in the EPD, divided into core, upstream and, if relevant, downstream module.</p> <ul style="list-style-type: none"> • The emission of greenhouse gasses (expressed in global warming potential, GWP, kg CO₂-equivalents, in 100 years perspective). • Emission of ozone-depleting gases (expressed as the sum of ozone-depleting potential in kg CFC 11-equivalents, 20 years) • Emission of acidification gases (expressed as the sum of acidification potential expressed in kg SO₂-equivalents) • Emission of gasses that contribute to the creation of ground level ozone • Emission of substances to water contributing to oxygen depletion.
<p>LCA leather- Material flows in the life cycle of leather Kurian Joseph*, N. Nithya</p>	<p>The inventory of the inputs and outputs for 100 m² of leather during the life cycle stages such as slaughtering, hide preservation, tanning and finishing, waste management, transportation and electricity production was done. The inventory was done to quantify the material and energy use and the waste produced by the system investigated. The inventory of hide preservation, waste management, transportation and electricity production systems was based on secondary data from published literature and personal communication with related institutions. Primary data were collected by discussions with selected industries in south India and related institutions. Measurements and observations were made wherever secondary data were not available. A typical medium-sized (processing an average of 150 bovine animals per day) slaughterhouse operation was studied for assessment of the slaughtering stage. Four medium-sized tanneries (processing an average of 1000 kg rawhides per day), of which, two processing rawhides to wet blue and two processing wet blue to finished leather typifying tanning and finishing stages of leather were chosen for the study. Primary data were collected by personal discussions and through questionnaire survey of industries. Estimates of the amount of emissions during transportation of materials were made using emission factors and the distance it was transported. The inventory data were averaged and normalised to the functional unit to obtain the total water, energy, chemicals and fossil fuel consumption and emissions generated for 100 m² of finished leather and to assess the impacts on resource use, global warming and acidification.</p>
<p>LCA OF ITALIAN AND SPANISH BOVINE LEATHER - PRODUCTION SYSTEMS IN AN INDUSTRIAL ECOLOGY</p>	<p>In the publication the inventory was made up by the following macro phases of the life cycle:</p> <ul style="list-style-type: none"> • Slaughterhouse; • Storage; • Tannery; • Solid waste management; • Tannery waste water treatment. <p>As a common assumption, depending on the geographical background of the study, the electric energy mix of the Catalan and the Italian system will be considered.</p>
<p>Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA</p>	<p>A good example of the application of the standard ISO DIS 14067 for the inventory analysis, results from this application. The inventory has been divided for the different phases of the product lifecycle:</p> <ul style="list-style-type: none"> • Rawhide: <ul style="list-style-type: none"> ○ Agriculture and breeding; ○ Slaughterhouse; ○ Transport of chemicals and auxiliaries

REFERENCE DOCUMENTS	APPROACH
	<ul style="list-style-type: none"> • Production processes in the tannery: <ul style="list-style-type: none"> ○ Hides flows; ○ Energy consumption; ○ Liming; ○ Tanning; ○ Dyeing; ○ Finishing; ○ Water consumption and discharge; ○ Waste and by products of production; ○ Emission; ○ Preparation for shipment. <p>For each single phase the inventory was done developing the following methodologies:</p> <ul style="list-style-type: none"> ✓ System boundaries; ✓ Data quality; ✓ Assumptions; ✓ Allocation methodology and reference flows; ✓ Input and output for each reference flow.

5.9.3. Harmonization Need

Data sources are the main aspect to consider dealing with issue. It is generally required to use known sources (process data) or recognized sources (default value) overall to trace the data origin.

5.9.4. Recommendation

The approach used for inventory in the present document is described, together with quantification proposals, at chapter 5.3 (Quantification). Detailed Inventory work shall be carried out in future by a homogeneous working group, represented by companies involved in processes included in the leather system boundaries.

5.10. Allocation

In this analysis it's evident how the different approaches are all based on LCA studies and several examples led to an economic criteria used for allocating CF on leather in different processes of the System Boundaries. In the proposal, though, allocation should be avoided whenever possible, and, if unavoidable, it should be made according to physical values linked with single processes.

5.10.1. ISO DIS 14067 Requirements

“The inputs and outputs shall be allocated to the different products according to the clearly stated and justified allocation procedure. The sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process

before allocation. Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach. The interest of this topic is generally recognized and methodologies keep an open approach on this subject, in order to remain flexible.”

5.10.2. Review of Background Knowledge

REFERENCE DOCUMENTS	APPROACH
<p>PCR leather (EPD)</p>	<p>UPSTREAM MODULE: Raw hides used for leather production have to be classified in three different categories, calf, bull and cow, different for living weight and allocation percentage of the raw hide, in order to calculate the weighted weight ex slaughterhouse (X) of a representative raw hide for the tannery. The mass allocation of the impact of agriculture, cattle raising and slaughterhouse has to consider percentages, distinguished by the three categories calf, bull and cow.</p> <p>CORE MUDULE: Allocation between different products and co-products shall be based on physical relationships. If physical relationships cannot be established or used, allocation can be based on other relationships, for example economic allocation. Any other allocation procedures must be justified. The process of slaughtering shall be treated by physical allocation (mass). Related to the splitting activities, it is used a surface criteria, so the environmental impact, until this cycle phase, is equally allocated between split hide (50%) and grain leather (50%). It should be differentiated between the splitting in the beam house and splitting WB. Furthermore calculations shall consider the correct mass of raw hides necessary for the production of the declared product unit, having particular care of the weight variations in the manufacturing phases. The weight variations that have to be applied are specified. (Y)is the weight of the representative raw hide ready for soaking/liming of the tannery. <i>"All tanning processes have to be included in the study. Manufacturing processes not listed may be included. However, the production of the raw materials used for production of all product parts shall be included according to the cut off rules"</i>.</p> <p>The weight X of the raw hide ex slaughterhouse necessary for obtaining Y kg of raw hide ready for soaking/liming is: $Y=X*((a8(1-b))+c*(1-d))$ Y: weight of the representative raw hide ready for soaking/liming X: weight of the representative raw hide ex slaughterhouse a: percentage of salted raw hides used in the tannery b: percentage of weight reduction of salted raw hides between slaughtering and soaking/liming (fixed at 15% for all categories)² c: percentage of fresh raw hides used in the tannery d: percentage of weight reduction of fresh raw hides between slaughtering and soaking/liming (fixed at 3% for all categories)</p> <p>DOWNSTREAM MODULE: distribution scenario use phase is omitted from the LCA since no specific function has been defined for production of finished bovine leather and the LCA boundaries have been chosen from "cradle to gate"; The waste treatment phase is omitted from the LCA since no specific function has been defined for production of finished bovine leather and the LCA boundaries have been chosen "cradle to gate"</p>

REFERENCE DOCUMENTS	APPROACH
<p>LCA leather- Material flows in the life cycle of leather Kurian Joseph*, N. Nithya</p>	<p>Meat is the main product of slaughtering; the allocation of environmental burdens to leather was based on total market value share of rawhide (14%) amongst the slaughterhouse products. In the splitting phase, splits with an economic value are obtained. They represent about 5.5% of the economic value. Burdens of wastewater system were calculated using the energy consumption needed to reduce COD below regulatory levels. Transport distances for the main input materials (hide, water, salt, chromium salt, fuel) were calculated from typical places of origin.</p>
<p>LCA OF ITALIAN AND SPANISH BOVINE LEATHER - PRODUCTION SYSTEMS IN AN INDUSTRIAL ECOLOGY</p>	<p>Slaughterhouse: The allocation of the slaughtering co-products has been managed by following the causality principle on the basis of economic and mass criteria with the following percentage rates: Italy: 7.9% leather, 92.1% meat and others edible parts; Spain: 7.7% leather, 92.3% meat and others edible parts. Whereas economic criteria have been used, the trend of prices variability between the related prices has been taken into account.</p> <p>Tanning: The allocation between crusts and leather is the same for both systems with the following percentage: 5.5% crusts, 94.5% leather. Whereas economic criteria have been used, the trend of prices variability between the related prices has been taken into account. By analysing the tanning flowcharts of the Spanish and Italian systems, we can see that the two processes are very similar.</p>
<p>art. Mil† - Application of Life Cycle Assessment to Footwear (LCA Case Studies)1998</p>	<p>Allocate burdens using economic criteria. The reason of this election is that the relative economic value of one co-product could be considered as the part of cause this co-product has had in the occurrence of the process. It has been used a typical value of 7.69% as the relative economic value of hides. This datum has been taken from the Catalan industry, as it is a critical value which will greatly determine the overall impact of the phases upstream the slaughterhouse, and so it must be a foreground datum.</p>
<p>Final report-GRUPPO DANI S.P.A. LCA E CARBON FOOTPRINT PER IL PRODOTTO PELLE BOVINA FINITA</p>	<p>The allocation attributes the amount of product, defined functional unit, the proper amount of a specific input or output and consequently the relative impact linked to it. For each phase it has been calculated different allocation coefficients, generally based on physical criteria, committed to the mass ratio or the surface of single activities /processes. Every time is needed to distribute the system inputs and output, it has been used the mass criteria for allocation in kg, while from the output of the phase of dyes on, the surface in m². Regarding the impact of cattle breeding and agriculture, there is no allocation. There are no other co-products (e.g. milk) to allocate. For the slaughterhouse it has been used an economic allocation between meat and other edible products, skin and waste. The allocation of energy and materials flows and the consequent release of substances in the environment are directly connected to the unit's declared finished leather.</p>

5.10.3. Harmonization Need

The allocation procedure usually described in the carbon footprint methodologies is based on LCA principles. This shows that a consensus has been established on the

importance of this subject. A different allocation setting could change the conclusion of a comparative LCA. The ISO 14040 gives some general indication to establish the allocation rules. However, they allow some freedom of interpretation. In the publications analysed, several examples led to an economic criteria used for allocating CF on leather in different processes of the System Boundaries.

5.10.4. Recommendations

It's important that allocation rules are fixed through a transparent and participative process to ensure results, acceptance and comparability. Choosing an allocation rule conditions the environmental impact distribution between economic actors from the same value chain. Economic allocation seems to be much more imprecise in the specific case of the leather value chain. Factors contributing to the economic allocation, in fact, are subject to variations that can significantly influence the results, and no methodology analysed seems to have taken them into account. Taking the case of the slaughterhouse as an example, the factors used in background knowledge publications, for an economic allocation are the value on the market of raw hides and skins and those of meat and other edible parts of the animals. The ratio between these factors lead to percentages used to allocate the environmental impact of specific process. Taking into consideration the value of the animal, sales price of the meat at the slaughter is often not the only economic contribution of the animal throughout its lifespan. The most obvious example is represented by a milk cow, which has been producing milk for some years before entering the abattoir. At the same time, the economic value of raw hides and skins depend on their market price. Looking at data referring to price historical evolutions of raw hides and skins, significant variations are observed in less than one year period. The consequent difficulty of a precise and consistent calculation of stable and reliable ratios lead to the conclusion that in the leather making process, allocation shall be avoided whenever possible and, if unavoidable, it should be made according to the physical relationship within the single process under consideration.

6. Conclusions

Analyzing generic and leather specific background knowledge on Life Cycle Assessment and Product Carbon Footprint, the present report has produced consistent proposals for convergence and harmonization, on the most important elements related to finished leather LCA and PCF studies:

- **Functional Unit:** as a general principle, the functional unit shall be consistently measurable and it shall correspond to the basic unit that the tannery uses for trading the finished leather it produces, the proposal is to use, as functional unit, 1 m² of finished leather (1 kg in the case of Sole Leather), including an indication of the thickness of the material.
- **System Boundaries:** for LCA and PCF of finished leather deriving from hides and skins which have been raised mainly for milk and/or meat production, start in the Slaughterhouse, where activities and treatments are carried out in order to prepare the hides to be used for tanning and end at the exit gate of the tannery.
- **Quantification:** the harmonised methodology proposed in order to obtain Kg of CO_{2e}/m² of finished leather, lies in the quantification of CO_{2e} content of all the different products and material entering the tannery (UPSTREAM PROCESSES), adding CO_{2e} produced in the tannery itself (CORE PROCESSES), as well as CO_{2e} emanating from water and air purification and waste recycling/disposal (DOWNSTREAM PROCESSES).
- **Allocation:** in the leather making process, allocation shall be avoided whenever possible and, if unavoidable, it should be made according to physical relationship within the single process under consideration.

The present technical report aims moreover at opening the way for a more detailed work, including different actors of the leather value chain, in order to set up practical guidelines to obtain reliable Leather PCF data.

Additional work should start with the set up of a specific working group, including different actors performing the processes included in system boundaries, among which the most important are: Slaughterhouses, Chemicals Producers, Energy and Water suppliers, Tanneries, Effluent treatment plants, Waste treatment plants.

Required knowledge to be produced includes:

- Harmonised Product Category Rules for LCA and PCF of Leather, including the conclusions of the present report.
- Life Cycle Inventory (compilation and quantification of inputs and outputs for processes within the leather system boundaries) at pilot scale, including needed key actors.
- Practical guidelines for LCA and PCF calculations, deriving from the Life Cycle inventory work.
- Harmonised data quality and calculation requirements along the value chain.

Finally, it is recognized that at the moment, the LCA – Carbon Footprint topic is primarily of interest to tanners in industrialized, especially EU countries; however, it is felt that those in BRIC and even Least Developed Countries should be aware of the current environmental impact assessment and protection trends and to be ready to apply them at an appropriate time as needed. It is hoped that in the meantime better standardized methodologies and probably some blueprints will also be made available.

7. References

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