Environmental Impact
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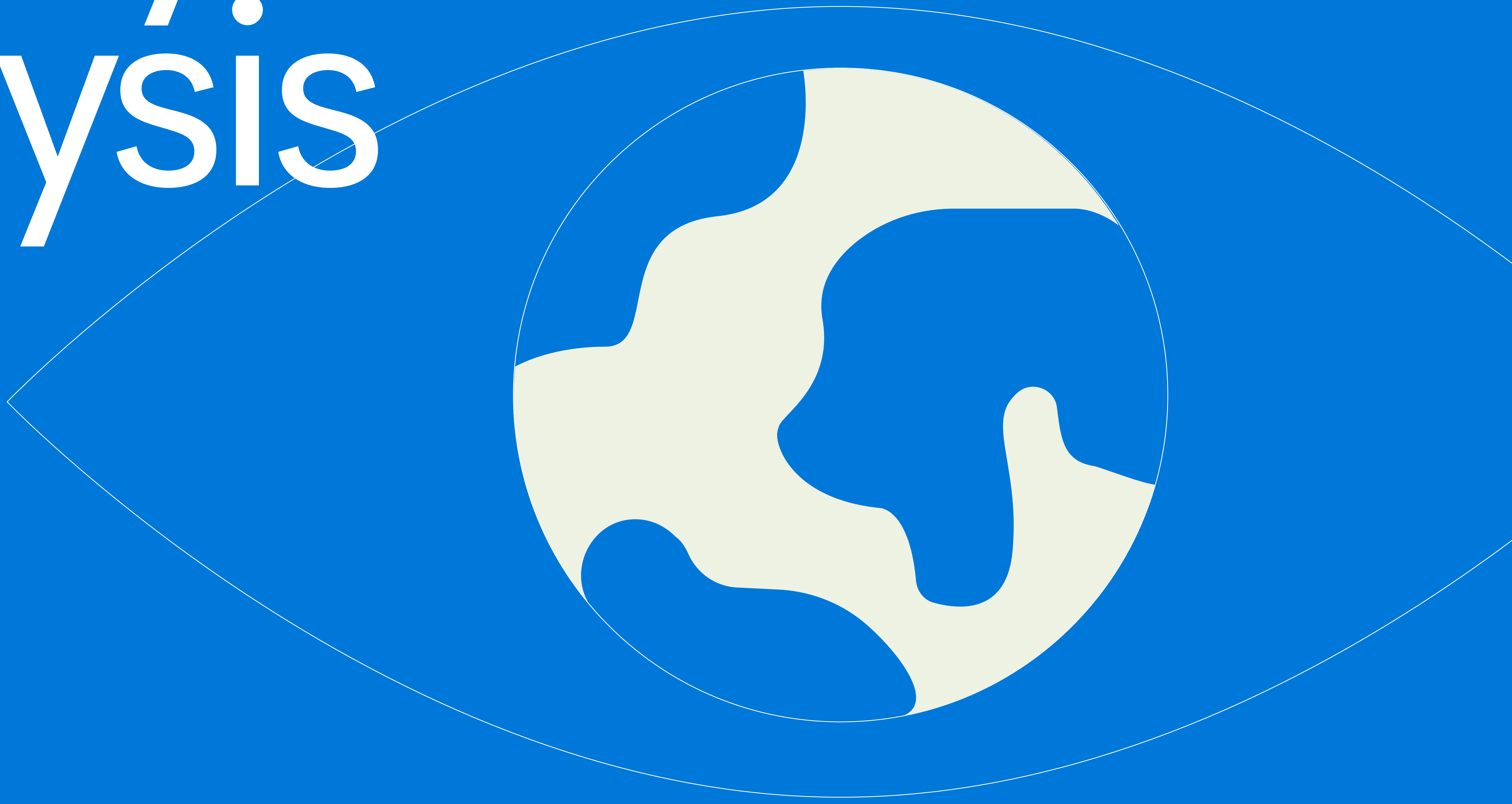
Responsibility Reports

ace & tate

02

Life Cycle Analysis

Based on the life cycle of frames Neil and Pierce



2019

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Definitions

In the report, terminology is used to specify a process or a material.
An explanation of these terms is stated in the definitions table below.

Frame	Frame	The material holding the lenses in front of a person's eyes.
	Glasses	Also known as eyeglasses or spectacles, devices consisting of glass or hard plastic lenses mounted in a frame that holds them in front of a person's eyes, typically using a bridge over the nose, and arms that rest over the ears. In this document the term glasses is used to indicate the frame and the lenses.
	Hardware	The metal components of a frame such as a core wire, hinges and screws.
Lenses	Lenses	Transparent curved material for concentrating or dispersing light. Lenses are used to improve vision (prescription lenses) and/or for UV protection (sun lenses). In this document the term lenses is used to indicate the material mounted in the frame and relates to demo lenses, sun lenses, prescription lenses and plano lenses.
	Demo lenses	Lenses made out of Polymethyl methacrylate (PMMA). These lenses are mounted in the frame after production and are used to maintain the shape of the frame during transport and on stock. These lenses are eventually replaced with prescription glasses.
	Plano lenses	Lenses made out of CR39 with UV filter and anti-reflection coating, without prescription. These lenses are used by customers that don't have a prescription. Plano lenses are also used for show models in stores.
	Sun lenses	Coloured lenses made out of CR39 with UV filter and anti-reflection coating, with or without prescription.
	Prescription lenses	Lenses made out of CR39 with UV filter and anti-reflection coating, with prescription.
	Edging	The shaping of a lens into the frame in the right position and in accordance with the prescription required by the customer.
	Mounting	The assembly of the lenses into a frame.
Packaging	Consumer-packaging	Materials used to protect the glasses when shipped to the end-consumer. Also, materials to clean the glasses, which include a case, a cleaning cloth and a tote bag.
	Packaging	The materials used to transport the components of the glasses without damaging them.

01

Summary

This document contains the method used and the results of Ace & Tate's second life cycle analysis (LCA). The LCA is a follow-up of last year's report. The goal of this analysis is to understand if, and to what extent, improvements in the supply chain have positively impacted the overall environmental impact of the product. Ace & Tate wants to transparently communicate on this process to all of their stakeholders.

For this LCA, Pierce • **fig. 1** (material variants; acetate, bio-acetate and recycled acetate), the Pierce clip-on and Neil were selected out of 122 frames styles. These frame types and materials represent top selling frames and include all major components that run through the core of Ace & Tate's manufacturing process: metal, acetate variants and titanium. To calculate the environmental impact of Pierce and Neil, Ace & Tate and Sustainalize have developed an LCA tool. The goal of this tool is to gain an understanding of where and what the major impacts of Pierce and Neil are and to incrementally decrease the impact accordingly.

For Pierce, the use phase, which accounts for almost 20% of the greenhouse gas (GHG) emissions, has the biggest environmental impact when it comes to CO2 -eq. The production of the frame, edging & mounting, and (transport of) consumer packaging contributes another 48%, which implies that these four life cycle stages equal 68% of the impact on CO2 -eq.

For Neil • **fig. 2**, relatively the highest impact also comes from the use phase with about 22%. Production of the frame, edging & mounting and (transport of) consumer packaging of the final product contributes another 45%, which implies that these four stages in the life cycle equal approximately 67% of the impact on CO2 -eq. This detailed information will enable Ace & Tate to put carbon labels on the different frames: virgin acetate versus bio acetate and recycled acetate and metal versus titanium. Ace & Tate aims to be able to give customers the full scope and be transparent about their impact. In 2019 Ace & Tate was not yet selling recycled acetate frames.

Read the full LCA and Co2 report summary here.

The following environmental indicators have been included in the LCA: agricultural land occupation; climate change; fossil depletion; freshwater ecotoxicity; freshwater eutrophication; human toxicity; ionising radiation; marine ecotoxicity; marine eutrophication; metal depletion; natural land transformation; ozone depletion; particulate matter formation; photochemical oxidant formation; terrestrial acidification; terrestrial ecotoxicity; urban land occupation and; water depletion.

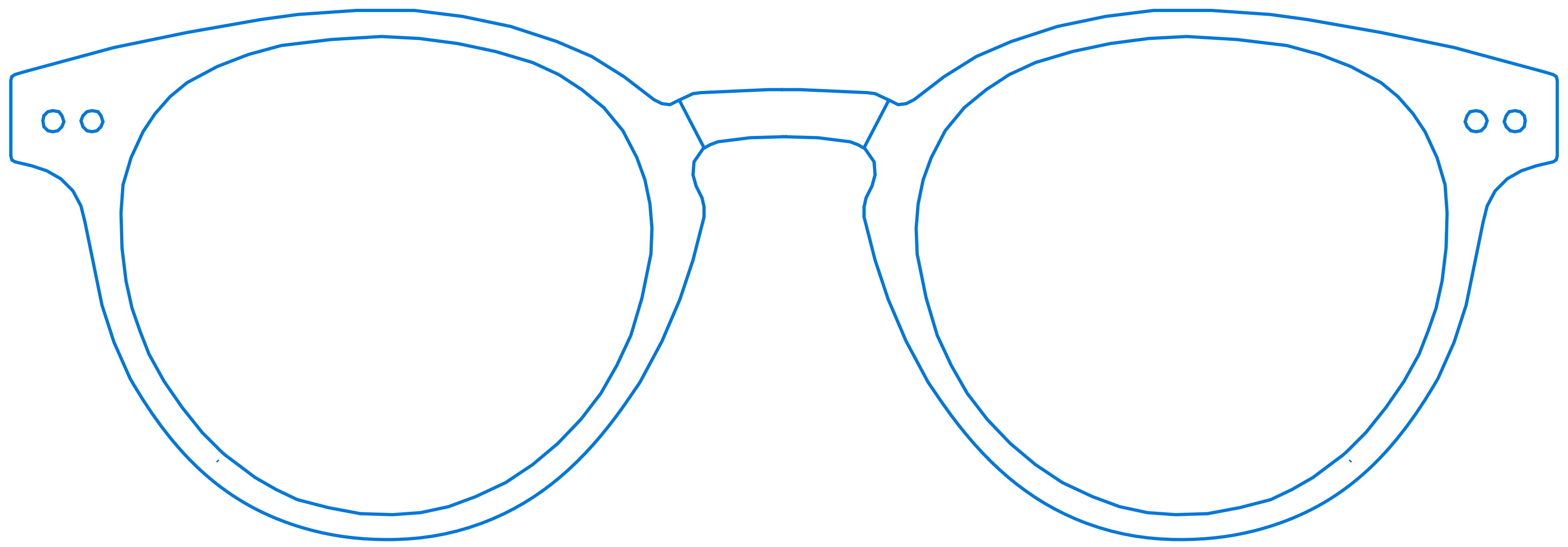


fig. 1

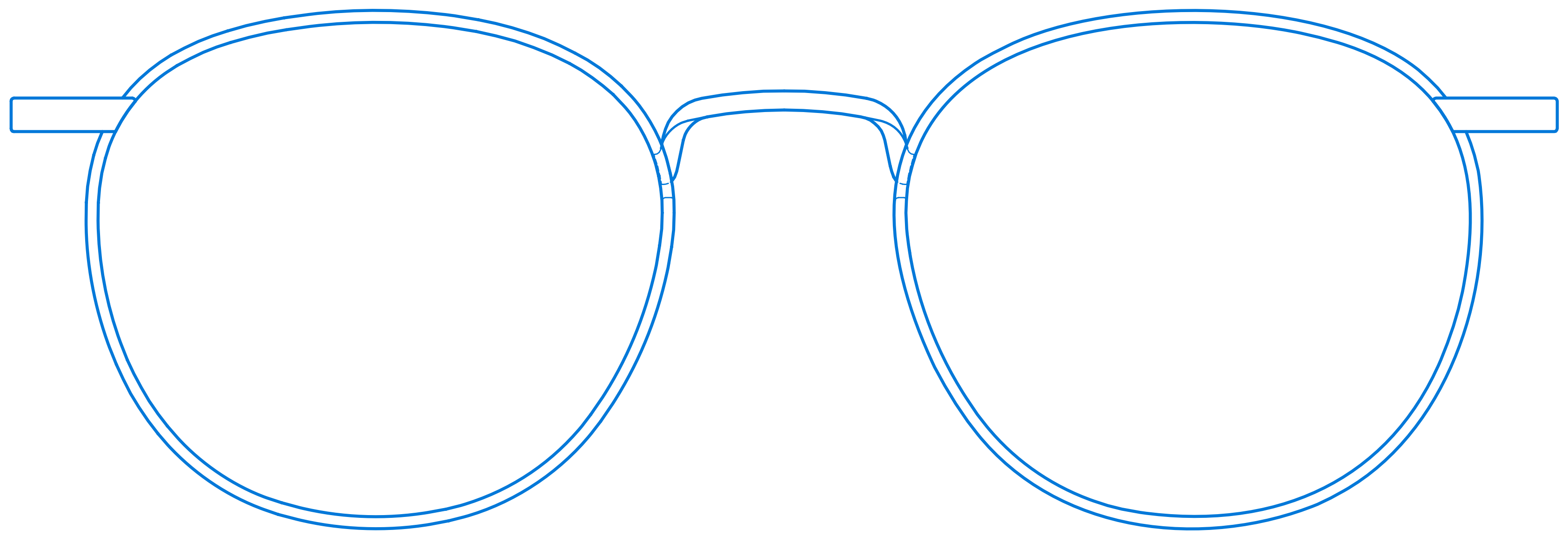


fig. 2

fig. 1 Pierce
fig. 2 Neil

02

General statement

2.1 LCA Practitioner and commissioner

This LCA has been commissioned by Ace & Tate and performed by Sustainalize.

Ace & Tate, a direct-to-consumer, omnichannel eyewear brand, based and founded in Amsterdam in 2013 by Mark de Lange with the ambition that eyewear is not only a medical device but also a tool for self-expression. The Dutch brand changes the way people buy and think about eyewear, turning a medical device into a tool for self-expression and making the shopping experience seamless and fun. Ace & Tate celebrates bold views by collaborating with creative individuals, while acting responsibly. The brand offers nice eyewear, at transparent prices, too: from €98, including prescription. The brand now offers quality eyewear for everyone with physical stores in different countries across Europe (the Netherlands, Belgium, Denmark, United Kingdom, Ireland, Austria, Sweden, Spain, Switzerland and Germany) and available online in a growing number of countries.

Ace & Tate's sustainability approach is based on the principles of Measure Impact, Set Goals, Collaborate & Engage, Transparent communication. The first baseline was conducted in 2017. The first LCA is based on the year 2018 and published in 2019.

2.2 Time period covered and standards used

The study commenced in January 2020 and was finished in October 2020. It covers the sales and production data from the 2019 calendar year. This LCA report is in accordance with ISO 14040 and ISO 14044.

2.3 Verification

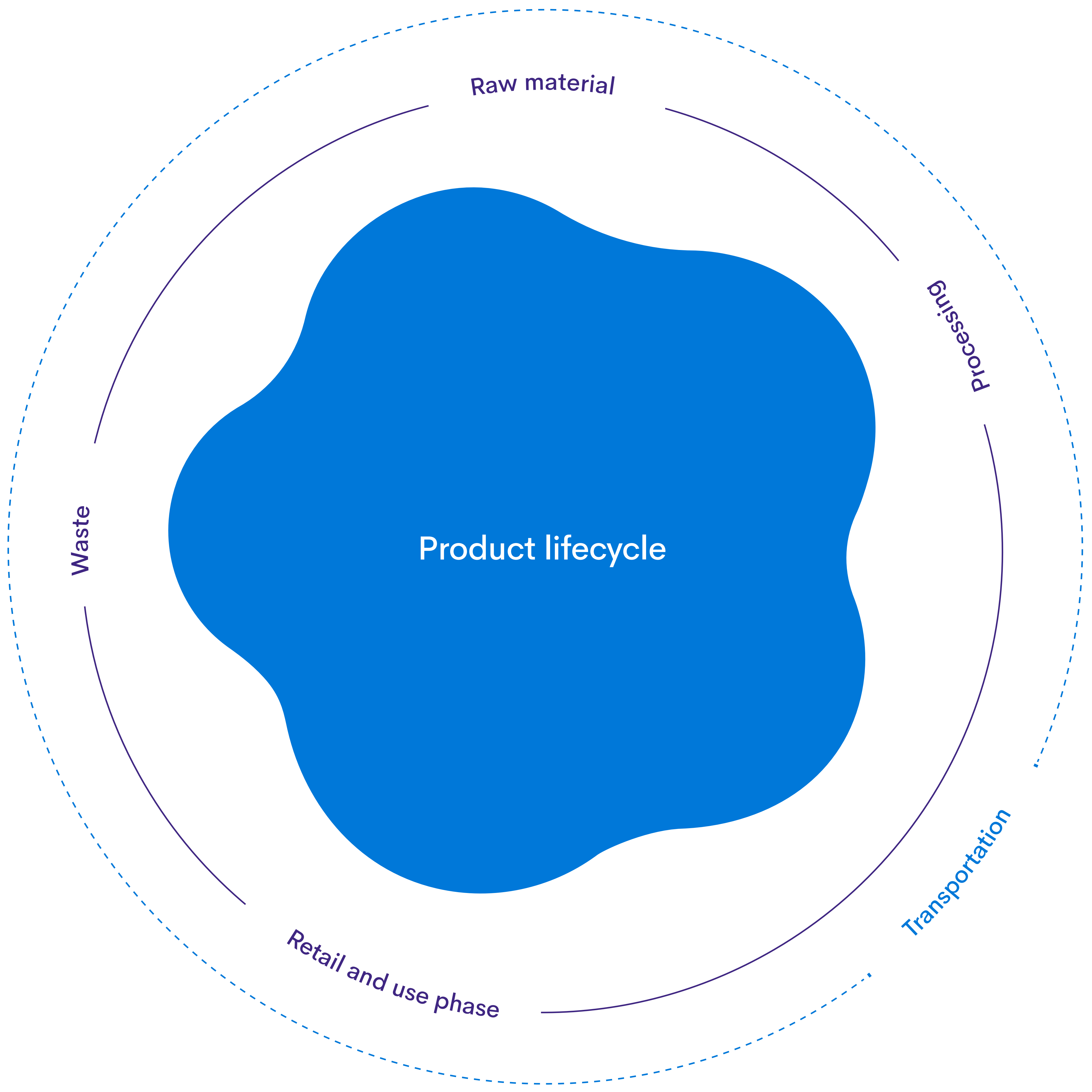
The study has been verified by EcoChain and fully complies to the ISO 14040 and 14044 norms, that ensure quality and transparency of the LCA.

2.4 Analysis approach

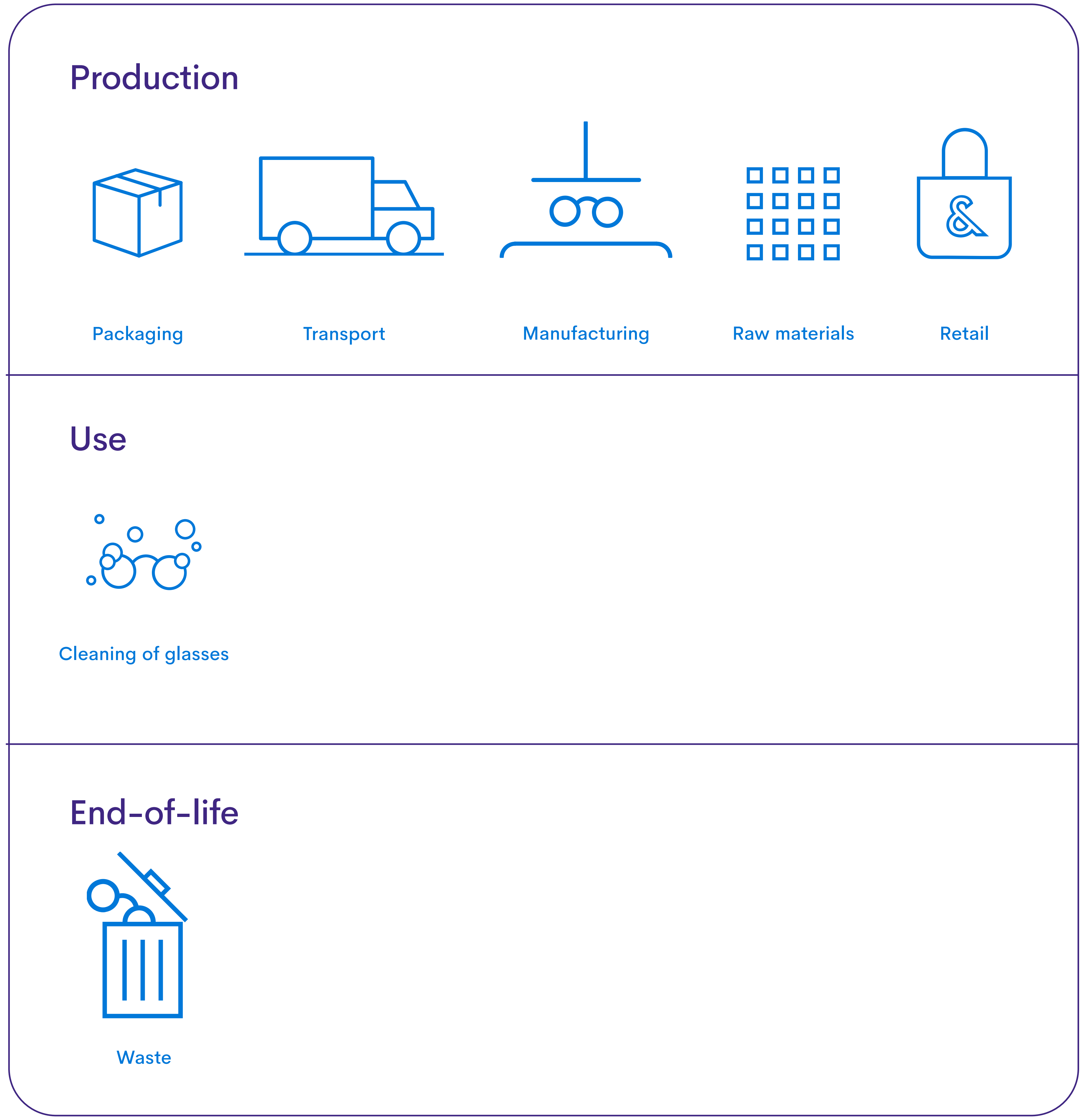
A product lifecycle consists of five phases:

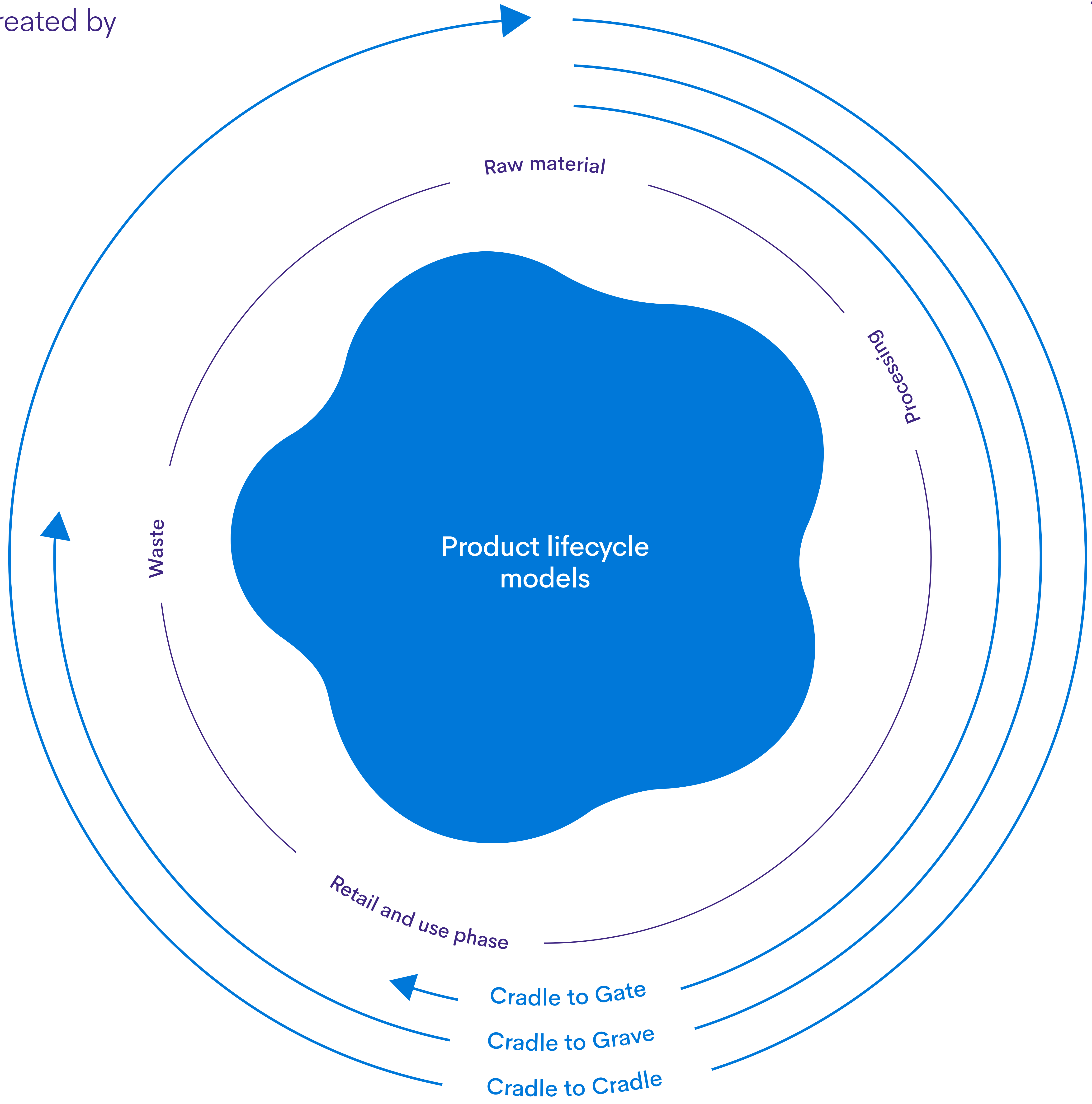
1. Raw Material Extraction
2. Manufacturing & Processing
3. Transportation
4. Usage & Retail
5. End-of-life

This is also referred to as cradle to grave, cradle being the inception of the product with the sourcing of the raw materials, grave being the disposal of the product. Transportation is mentioned as step 3, but can, in reality, occur in between all steps.



In our this report the stages have been analysed as in the below infographic.
For more information on LCA, please refer to this LCA Beginner guide, created by our authorizing partner, Eco Chain.





NB: Other models include cradle-to-gate, cradle-to-cradle, gate-to-gate, well-to-wheel, and Economic input-output life cycle assessment.

CO2 — equivalents, measuring the release of carbon dioxide emissions into the atmosphere (emission)

Toxicity — measuring the release of toxic emissions (emission)

Phosphate — the standard metric of eutrophication, measuring the impact on biological systems (emission)

Usage of non-renewable resources — such as oil, measuring how we impact resource scarcity for future generations (extraction)

Water usage — measuring the impact on water scarcity (extraction)

We specifically chose these categories because they are commonly used by other companies, making them relatable to our key stakeholders (our partners, our own team and our customers). They're also diverse enough to give the full picture of our footprint, helping us set a benchmark. We can then compare and reduce the impact of our products.

03

Goal of the study

3.1 Reasons for carrying out the study

The goal of this study is to create an understanding of the environmental impact of the Neil and Pierce glasses in various configurations and to transparently report on this impact to Ace & Tate's stakeholders. The study analyses the full life cycle of the product (cradle to grave) and all significant supply chain partners were actively engaged to provide information on material, transport and utilities usages to best understand the impact per life cycle stage.

Neil and Pierce were selected out of 122 styles. They are both top selling glasses and have three components that run through the core of Ace & Tate's manufacturing process: metal, titanium and acetate. When the understanding of the environmental impact is on the table, the company aims to incrementally decrease the impact and communicate the journey to its stakeholders throughout this iterative process.

This detailed information will enable Ace & Tate to put carbon labels on the different frames: virgin acetate versus bio acetate and recycled acetate and metal versus titanium. Ace & Tate aims to be able to give customers the full scope and be transparent about their impact.

3.2 Intended applications

The intended outcome of the study is to inform Ace & Tate's stakeholders of their commitment to reduce their environmental impact in the coming years through research & development, supply chain partnerships and to report on progress against these commitments. The analysis is not meant to be used in comparative assertions.

3.3 The target audiences

The target audience consists of both internal and external stakeholders.

Internal stakeholders

The internal stakeholders include all employees, specifically those involved with the product, such as the Supply Chain team, Design team, the stores and the Customers Experience team. The results will be shared with them to provide them with a better understanding of the environmental impact of materials and processes to enable them to make more informed decisions to improve overall performance in the future. Furthermore, the rest of Ace & Tate's organisation as well as the Management Team will be informed so they are aware of the impact of the product they work with, transparently communicate about it and to create awareness. The information communicated will be (a summary of) this document containing also a partial life cycle impact assessment (LCIA) which includes the most relevant/well known impact.

External stakeholders

The information is intended to be communicated to external stakeholders such as customers and all partners in the value chain since the overall performance can only be changed as a whole chain, not only by one company within the value chain.

04

Scope of the study

This section of the report details the object of the analysis as well as the system boundary, specifying which elements of the life cycle inventory analysis are part of the product system.

4.1 Functional unit

The analysis covers two frame styles (Pierce and Neil frames) and a total of 6 configurations of these frame styles.

These are:
1. Pierce virgin acetate
2. Pierce recycled acetate
3. Pierce bio-acetate
4. Pierce clip-on
5. Neil titanium
6. Neil stainless steel

The configurations 1, 2 and 3, only differ in raw material type. Configuration 4 differs from 1, 2 and 3 in types of materials used (the clip-on frame is mostly metal) and production site. The configurations 5 and 6 differ in raw material type, weight, and production site.

The average total weight of the products (including consumer packaging and lenses) as shipped to consumer are as follows:

- The Pierce • **fig. 3** weighs 151,81 grams
- The Pierce clip-on • **fig. 4** weighs 110,27 grams
- The Neil stainless steel • **fig. 5** weighs 154,91 grams
- The Neil titanium • **fig. 6** weighs 142,25 grams

fig. 3

fig. 4

fig. 5

fig. 6

fig. 3 Pierce
fig. 4 Pierce Clip-on

fig. 5 Neil Stainless steel
fig. 6 Neil titanium

The analysis considers the full life cycle of the product, from cradle to grave and does not involve a comparative assertion on quality to other types of eyewear.

Therefore, the declared units are:

1. The production, the use and the end of life waste-treatment of 1 pair of Pierce virgin acetate glasses including frame, lenses and packaging
2. The production, the use and the end of life waste-treatment of 1 pair of Pierce bio-acetate glasses including frame, lenses and packaging
3. The production, the use and the end of life waste-treatment of 1 pair of Pierce recycled acetate glasses including frame, lenses and packaging
4. The production, the use and the end of life waste-treatment of 1 pair of Pierce clip-on glasses including frame, lenses and packaging
5. The production, the use and the end of life waste-treatment of 1 pair of Neil stainless steel glasses including frame, lenses and packaging
6. The production, the use and the end of life waste-treatment of 1 pair of Neil titanium glasses including frame, lenses and packaging

The declared units are consistent with the goal and scope to create an insight that supports Ace & Tate in understanding the environmental impact of its glasses and for the company to be able to communicate this impact to its stakeholders. The declared units represent an average of all types of lenses and production routes possible per pair of glasses. The average is based on sales and route data covering the calendar year 2019, if available.

4.2 System boundary

The system boundary depicts the life cycle stages of the product that are part of the analysis. In the analysis for the Pierce and Neil this study takes into account the environmental impacts related to the production of raw materials required to produce the product, the energy needed to produce the product, the transport required to distribute the product, the energy usage related to cleaning the product and the waste processing of the excess materials discarded during production.

Services, materials, and energy that are not directly connected to the glasses during its life cycle because they do not become the product, make the product, or directly carry the product through its life cycle are defined as non-attributable processes.

These include:

- Corporate activities and services (e.g., research and development, servers, home try on, construction of (new) stores, administrative functions, company sales and marketing)
- Transport of the product user to the retail location
- Transport of employees to and from work

The energy related to retail locations is included in the study as this is specifically part of the Ace & Tate sphere of influence.

The above mentioned activities are not in the scope of the LCA, but are incorporated in our CO2 report, where we measure Ace & Tate's direct emissions (scope 1 +2 +3).

The system boundaries of Neil and Pierce are visualised in fig. 5 and fig. 6.

4.3 General description product system

Both Neil and Pierce are produced in China.
The materials required to produce the glasses are supplied locally. The production and transport of raw materials (including packaging) to produce the products at the sites in China have been taken into account.
When finalising production in the Chinese factories, the frames are mounted with either a demo-lens, a plano lens or a sun lens and packed for transport. The sun and plano lens will not be discarded later in the process.
The demo-lens is replaced by an optical lens and discarded in full.

The glasses are then shipped to the Netherlands.
80% of the glasses need prescription lenses, of which 25% (20% of total glasses) is edged and mounted in a retail location. The remaining 60% of the frames are shipped from the Netherlands for edging and mounting to Thailand or they stay in the Netherlands for edging and mounting.

After edging, the glasses are all sent to the Netherlands where they are packed for final consumer usage in a case with a cloth and including a warranty leaflet.

After packaging the glasses are transported to retail locations or directly to consumers. For 15% of the sales, the glasses come with a complementary organic cotton tote bag.

9% of all glasses are returned by consumers. The glasses are then inspected and categorised by Ace & Tate:

- **Category 1**: The glasses are unworn and in mint condition. They will be cleaned, polished and put back into stock.
- **Category 2**: The glasses have a small defect. They will be cleaned, polished and put into Friends & Family stock (the employees of Ace & Tate have the possibility to buy the frames for a lower price to avoid waste). In 2020 Ace & Tate has launched Reframe, our circular business model, where we repair, refurbish stock and pre-worn frames. Read more here.
- **Category 3**: The glasses have a major defect. They will be stocked for research and development around recycling.

The frames that are resold are attributed with an extra 600 km of truck transport plus the impact of optical lenses.

Fig. 5 and fig. 6 show the boundaries of the two products and the processes taken into account. Pierce and Neil can be produced with various options in the production process. The weight and amounts used present an average relative to the produced amount.

Elaboration on types of acetate

Two types of plasticizer are used to produce acetate frames, a fossil fuel based variant and a bio-based variant. When using the bio-based plasticizer the entire frame is made from bio-based material and therefore referred to in this study as bio-acetate frames. Beside the plasticizer, the overall production process of the frame is similar to the fossil fuel-based plasticizer.

Next to the bio-based plasticizer, the other difference in acetate relates to the usages of recyclate. The producer of the acetate slabs is capable of recycling acetate production waste. The production waste is reinserted in the process. As this recyclate is considered a by-product of the regular acetate slab production and can only be coloured black, the recyclate is in this study regarded as 'burden-free'. Only the usage of utilities, needed to create the slab, is attributed to the production of recycled acetate. This recycled acetate is used to produce Ace & Tate's recycled acetate frame. In this study we attributed no environmental impact to the recycled acetate (burden free). All environmental impact related to the raw material is allocated to the acetate and bio-acetate frames.

Elaboration on Demo or Plano lens installed

When the frame is produced in China, a demo or plano lens is installed in the frame. The demo lens will be removed in the Netherlands, at a retail location or in Thailand. As for now, this waste stream / flow is modelled as waste in the LCA and attributed with a waste incineration proxy from Ecoinvent*.

Elaboration on Edging process

The mounting and edging of the lenses is done in Thailand, in the Netherlands or at a retail location. On average, 28% of the glasses are edged in the Netherlands, 32% in Thailand and the rest are edged in store, not edged (plano) or sun lenses are used.

Frame	Materials	Unit	Weight Avg. Net	Remark
Pierce virgin acetate (excl. lenses + (consumer) packaging)	Frame + hinges (acetate + DEP) Temple wire + screws (stainless steel) Hinges (nickel silver)	gram	8,10 + 3,40 5,37 1,60	No remark
	Total		**18,47**	
Pierce bio-acetate (excl. lenses + (consumer) packaging)	Frame + hinges (acetate + bio DEP) Temple wire + screws (stainless steel) Hinges (nickel silver)	gram	8,10+ 3,40 5,37 1,60	No remark
	Total		**18,47**	
Pierce recycled acetate (excl. lenses + (consumer) packaging)	Frame + hinges (acetate + DEP) Temple wire + screws (stainless steel) Hinges (nickel silver)	gram	8,10 + 3,40 5,37 1,60	The frame + hinges (acetate + DEP) are made of recyclate. As this recyclate is considered a by-product of the regular acetate slab production and can only be coloured black, it is regarded as 'burden-free' in this study.
	Total		**18,47**	

table 1

* For an explanation on Ecoinvent, see chapter 4, page 54

Elaboration on sun or optical lenses

The difference between the sun and the optical lenses is a small amount of pigment, for this small amount of pigment no detailed environmental impact data is available and this material is therefore not taken into account. The sun lenses are installed on all Pierce clip-on frames. They are installed at the production site in China and are directly available for retail and online sales.

Elaboration on production of acetate slab

The production of the Pierce frame requires an extra step compared to the Neil variant; the frame is cut from an acetate slab. The acetate granulate, for which supplier specific data is provided and used, is mixed with the plasticizer DEP or starch-based bio-plasticizer • **table 21** and then rolled into slabs. For this study, energy usage, production waste and plasticizers usage are based on literature and Ecoinvent information to calculate the impact of acetate slab production as limited data was provided by the acetate slab producing company. The slab is then transported to a site in China, the exact distance has been used to calculate the impact of transporting the slab. The production site receiving the slab then cuts the frame from the slab.

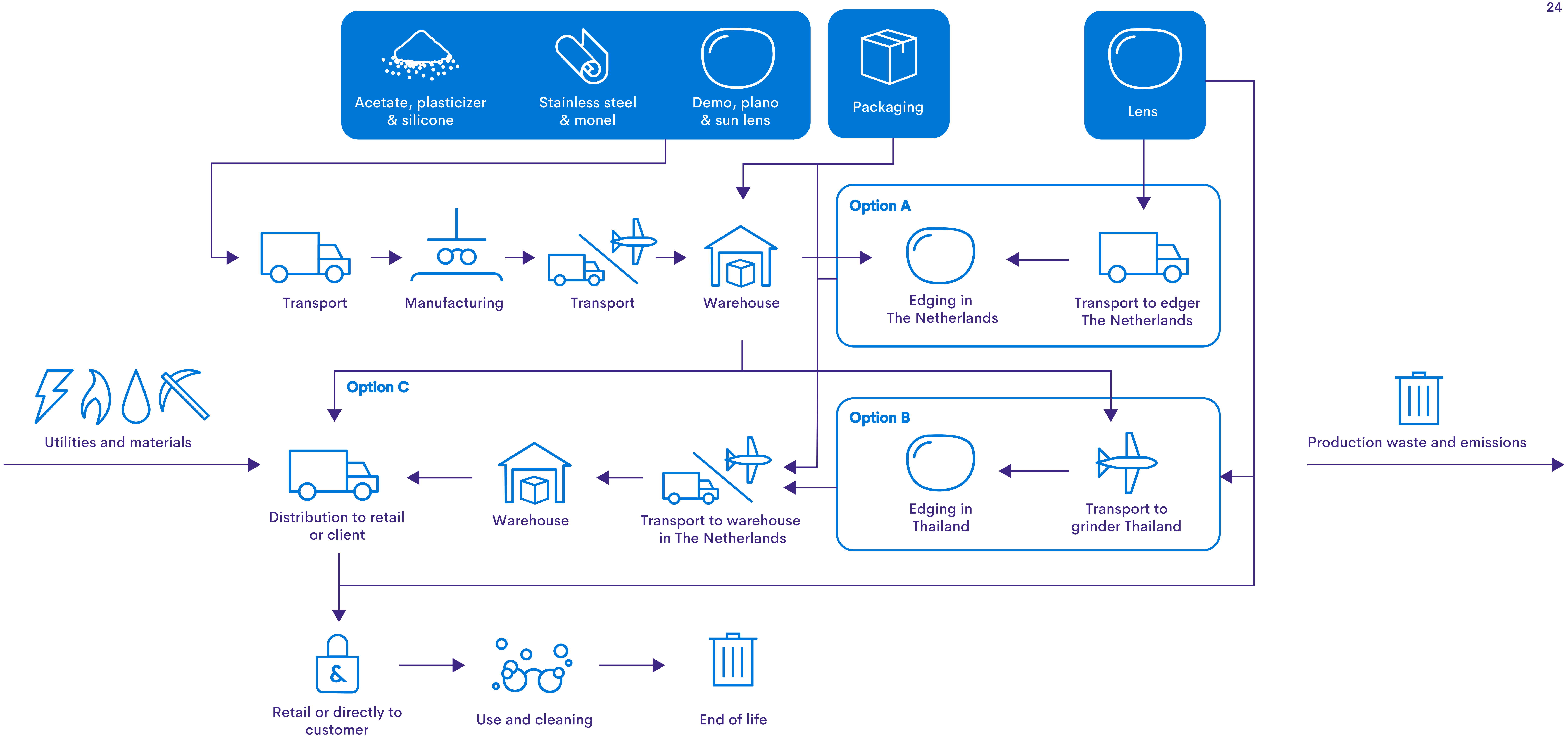


fig. 5 System boundary Neil

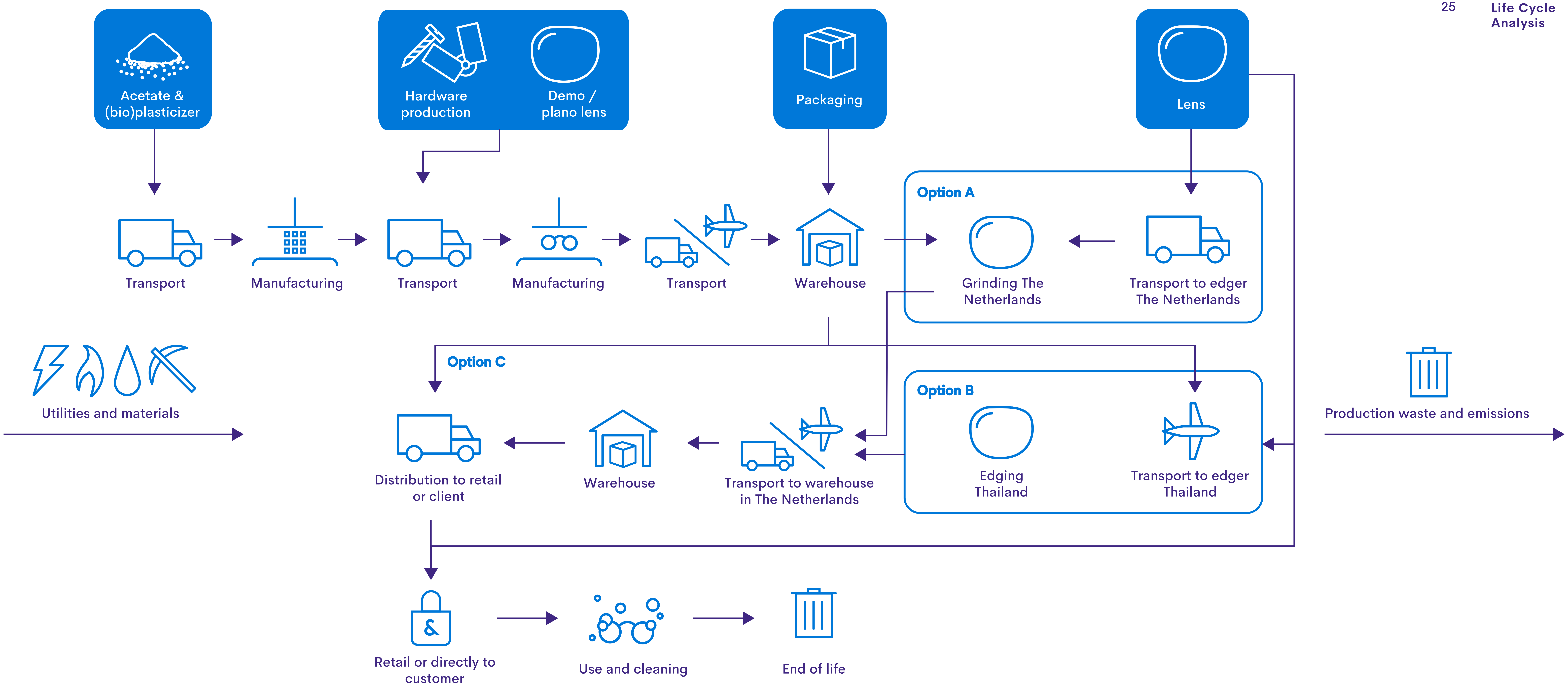


fig. 6 System boundary Pierce

› Use phase

The analysis includes a use phase scenario, this is included in order to understand the environmental impact of the product once the product has been sold to the final consumer. The use phase of glasses is based on a customer survey in which 296 respondents provided input on how a frame lasts and 301 respondents provided input on the frequency of cleaning with warm water and soap. These figures were used to assess the environmental impact related to cleaning a frame and thus the use phase of the product.

› End of life

For the end of life phase, no detailed information is available on how consumers in the various countries discard the glasses at end of life. Therefore, the analysis for the end of life phase is modelled via a municipal waste collection scenario. An incineration scenario is used to assess the impact of the waste phase, this excludes energy generation due to the use of the cut-off model in Ecoinvent.

› Omissions

The utilities data on the production of the acetate slab and the plasticizer usage is estimated based on literature and Ecoinvent. The weight of the slab, the percentage of production waste, and the distance from the acetate supplier to the producer has been used.

The titanium frame producer was not able to provide gross weight data on frame materials, no assumptions have been done to close this gap.

All processes within the system boundary were taken into account although not every supplier was able to provide all the required data. The missing data is modelled using Ecoinvent version 3.6 relating to the production of raw materials and the processing of these materials.
All calculations on raw materials, transport, waste and energy are elaborated upon in **chapter 5**.

› Quantification of energy and material

In the tables below all energy and material input and output are stated in gross and net weight. The difference between nett and gross is production waste, the rest material that is thrown away in the process. The emissions related to the treatment of production waste are attributed to the life cycle stage in which they occur. In **tables 2 – 19** the amount of raw materials is stated, as well as the utilities needed for production and the transport required.

› Electricity production

As a proxy for electricity use, Ecoinvent data is used as described in the life cycle inventory • **chapter 5**.

Pierce and clip-ons

Bill of material

Product	Material	Unit	Weight Avg. Net	Weight Avg. Gross	Waste Avg.
Pierce Virgin acetate frame	Acetate slab production	gram	68,50	All waste in this process step is recycled in the Recycled Acetate Pierce, hence no waste attributed	All waste in this process step is recycled in the Recycled Acetate Pierce, hence no waste attributed
Pierce Virgin acetate frame	Acetate slab to frame	gram	11,50	68,50	57,00
Pierce Virgin acetate frame	Stainless steel (temple wire + screws)	gram	5,37	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Pierce Virgin acetate frame	Nickel silver (hinges)	gram	1,60	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Demo lens	PMMA (Pierce)	gram	4,50	12,50	8,00
CR 39 Optical lens	CR-39	gram	7,94	22,40	14,46
Plano lens	CR-39	gram	7,06	20,22	13,16
Polybag (PE) packaging	Polyethylene	gram	2,20	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
White paper + shipping box packaging	White paper box	gram	10,80	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Cloth (Consumer packaging)	Recycled PET	gram	4,90	5,39	0,49
Shipping box (packaging)	FSC Kraft paper	gram	0,18	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 2 ›

Case (Consumer packaging)	Water-based polyurethane	gram	32,06	40,53	8,47
Case (Consumer packaging)	FSC Kraft paper	gram	4,00	6,05	2,05
Case (Consumer packaging)	Recycled PET	gram	7,00	9,89	2,89
Case (Consumer packaging)	Glue	gram	0,50	0,51	0,01
Case (Consumer packaging)	Recycled polyester	gram	0,40	0,44	0,04
Case (Consumer packaging)	Silicone	gram	1,50	1,51	0,01
Case (Consumer packaging)	Oil paint	gram	2,00	2,08	0,08
Case (packaging)	White paper box	gram	15,89	15,92	0,03
Shipping box (Consumer packaging)	White paper box	gram	141,34	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Paper (warranty leaflet, Consumer packaging)	Recycled paper	gram	3,10	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Tote bag (Consumer packaging)	Organic cotton	gram	44,31	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 2

table 2 Bill of material for Pierce virgin acetate

Product	Material	Unit	Weight Avg. Net	Weight Avg. Gross	Waste Avg.
Pierce Bio-acetate frame	Bio-acetate slab production	gram	68,50	All waste in this process step is recycled in the Recycled Acetate Pierce, hence no waste attributed	All waste in this process step is recycled in the Recycled Acetate Pierce, hence no waste attributed
Pierce Bio-acetate frame	Bio-acetate slab to frame	gram	11,50	68,50	57,00
Pierce Bio-acetate frame	Stainless steel (temple wire + screws)	gram	5,37	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Pierce Bio-acetate frame	Nickel silver (hinges)	gram	1,60	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Demo lens	PMMA (Pierce)	gram	4,50	12,50	8,00
CR 39 Optical lens	CR-39	gram	7,94	22,40	14,46
Plano lens	CR-39	gram	7,06	20,22	13,16
Polybag (PE) packaging	Polyethylene	gram	2,20	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
White paper + shipping box packaging	White paper box	gram	10,80	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Cloth (Consumer packaging)	Recycled PET	gram	4,90	5,39	0,49
Shipping box (packaging)	FSC Kraft paper	gram	0,18	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 3 ›

Case (Consumer packaging)	Water-based polyurethane	gram	32,06	40,53	8,47
Case (Consumer packaging)	FSC Kraft paper	gram	4,00	6,05	2,05
Case (Consumer packaging)	Recycled PET	gram	7,00	9,89	2,89
Case (Consumer packaging)	Glue	gram	0,50	0,51	0,01
Case (Consumer packaging)	Recycled polyester	gram	0,40	0,44	0,04
Case (Consumer packaging)	Silicone	gram	1,50	1,51	0,01
Case (Consumer packaging)	Oil paint	gram	2,00	2,08	0,08
Case (packaging)	White paper box	gram	15,89	15,92	0,03
Shipping box (Consumer packaging)	White paper box	gram	141,34	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Paper (warranty leaflet, Consumer packaging)	Recycled paper	gram	3,10	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Tote bag (Consumer packaging)	Organic cotton	gram	44,31	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 3

Table 3 Bill of material for Pierce bio-acetate

Product	Material	Unit	Weight Avg. Net	Weight Avg. Gross	Waste Avg.
Pierce Recycled acetate frame	Recycled acetate slab production	gram	68,50	All waste in this process step is recycled in the Recycled Acetate Pierce, hence no waste attributed	All waste in this process step is recycled in the Recycled Acetate Pierce, hence no waste attributed
Pierce Recycled acetate frame	Recycled acetate slab to frame	gram	11,50	68,50	57,00
Pierce Recycled acetate frame	Stainless steel (temple wire + screws)	gram	5,37	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Pierce Recycled acetate frame	Nickel silver (hinges)	gram	1,60	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Demo lens	PMMA (Pierce)	gram	4,50	12,50	8,00
CR 39 Optical lens	CR-39	gram	7,94	22,40	14,46
Plano lens	CR-39	gram	7,06	20,22	13,16
Polybag (PE) packaging	Polyethylene	gram	2,20	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
White paper + shipping box packaging	White paper box	gram	10,80	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Cloth (Consumer packaging)	Recycled PET	gram	4,90	5,39	0,49

table 4 ›

Shipping box (packaging)	FSC Kraft paper	gram	0,18	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Water-based polyurethane	gram	32,06	40,53	8,47
Case (Consumer packaging)	FSC Kraft paper	gram	4,00	6,05	2,05
Case (Consumer packaging)	Recycled PET	gram	7,00	9,89	2,89
Case (Consumer packaging)	Glue	gram	0,50	0,51	0,01
Case (Consumer packaging)	Recycled polyester	gram	0,40	0,44	0,04
Case (Consumer packaging)	Silicone	gram	1,50	1,51	0,01
Case (Consumer packaging)	Oil paint	gram	2,00	2,08	0,08
Case (packaging)	White paper box	gram	15,89	15,92	0,03
Shipping box (Consumer packaging)	White paper box	gram	141,34	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Paper (warranty leaflet, Consumer packaging)	Recycled paper	gram	3,10	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Tote bag (Consumer packaging)	Organic cotton	gram	44,31	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 4

Table 4 Bill of material for Pierce recycled acetate

Product	Material	Unit	Weight Avg. Net	Weight Avg. Gross	Waste Avg.
Pierce Clip-on frame	Stainless steel (frame)	gram	12,26	26,75	14,49
Pierce Clip-on frame	Stainless steel (rim)	gram	3,44	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Pierce Clip-on frame	Stainless steel (top bar)	gram	0,60	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Pierce Clip-on frame	Silicone (hook sleeve)	gram	0,15	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Pierce Clip-on frame	Monel (hook)	gram	0,24	0,31	0,07
Sun lens	CR-39	gram	7,98	22,40	14,42
Polybag (PE) packaging	Polyethylene	gram	2,13	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
White paper + shipping box packaging	White paper box	gram	8,59	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Recycled PET	gram	8,00	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Water-based polyurethane	gram	5,14	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Cotton	gram	3,71	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 5 ›

Case (Consumer packaging)	Paper	gram	2,57	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Stainless steel	gram	2,57	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Recycled polyester	gram	1,43	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Viscose	gram	1,43	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Oil paint	gram	0,29	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Shipping box (Consumer packaging)	White paper box	gram	141,34	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Paper (warranty leaflet, Consumer packaging)	Recycled paper	gram	3,10	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Tote bag (Consumer packaging)	Organic cotton	gram	44,31	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 5

Table 5 Bill of material for Pierce clip-on

Neil

Bill of material

Product	Material	Unit	Weight Avg. Net	Weight Avg. Gross	Waste Avg.
Neil Stainless steel frame	Stainless steel (frame)	gram	9,33	16,52	7,20
Neil Stainless steel frame	Acetate (tip)	gram	1,85	7,66	5,82
Neil Stainless steel frame	Stainless steel (windsor rim)	gram	0,79	0,95	0,16
Neil Stainless steel frame	Stainless steel (rim)	gram	3,40	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Stainless steel (bridge)	gram	0,68	1,57	0,90
Neil Stainless steel frame	Silicone (nose pads)	gram	0,20	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Stainless steel (end piece & temple)	gram	5,25	11,55	6,30
Demo lens	PMMA	gram	4,41	8,90	4,49
CR 39 Optical lens	CR-39	gram	7,94	22,40	14,46
Plano lens	CR-39	gram	7,06	20,22	13,16
Polybag (PE) packaging	Polyethylene	gram	2,13	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 6 ›

White paper + shipping box packaging	White paper box	gram	8,59	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Cloth (Consumer packaging)	Recycled PET	gram	4,90	5,39	0,49
Shipping box (packaging)	FSC Kraft paper	gram	0,18	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Water-based polyurethane	gram	32,06	40,53	8,47
Case (Consumer packaging)	FSC Kraft paper	gram	4,00	6,05	2,05
Case (Consumer packaging)	Recycled PET	gram	7,00	9,89	2,89
Case (Consumer packaging)	Glue	gram	0,50	0,51	0,01
Case (Consumer packaging)	Recycled polyester	gram	0,40	0,44	0,04
Case (Consumer packaging)	Silicone	gram	1,50	1,51	0,01
Case (Consumer packaging)	Oil paint	gram	2,00	2,08	0,08
Case (packaging)	White paper box	gram	15,89	15,92	0,03
Shipping box (Consumer packaging)	White paper box	gram	141,34	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 6 ›

Paper (warranty leaflet, Consumer packaging)	Recycled paper	gram	3,10	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Tote bag (Consumer packaging)	Organic cotton	gram	44,31	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 6

Table 6 Bill of material for Neil stainless steel

Product	Material	Unit	Weight Avg. Net	Weight Avg. Gross	Waste Avg.
Neil Titanium frame	Acetate (temple tip)	gram	1,84	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (nose bridge)	gram	0,38	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (rim)	gram	2,24	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (nose pad arm)	gram	0,30	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (end piece)	gram	0,60	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (temple)	gram	2,50	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Silicone (nose pads)	gram	0,28	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (hinges)	gram	0,30	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Stainless steel (screws)	gram	0,07	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Neil Stainless steel frame	Titanium (rim lock)	gram	0,24	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 7 ›

Neil **Stainless steel frame**	Stainless steel (rim lock screws)	gram	0,07	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Demo lens	PMMA	gram	4,41	8,90	4,49
CR 39 Optical lens	CR-39	gram	7,94	22,40	14,46
Plano lens	CR-39	gram	7,06	20,22	13,16
Polybag (PE) packaging	Polyethylene	gram	1,72	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
White paper + shipping box packaging	White paper box	gram	8,59	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Cloth (Consumer packaging)	Recycled PET	gram	4,90	5,39	0,49
Shipping box (packaging)	FSC Kraft paper	gram	0,18	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Case (Consumer packaging)	Water-based polyurethane	gram	32,06	40,53	8,47
Case (Consumer packaging)	FSC Kraft paper	gram	4,00	6,05	2,05
Case (Consumer packaging)	Recycled PET	gram	7,00	9,89	2,89
Case (Consumer packaging)	Glue	gram	0,50	0,51	0,01

table 7 ›

Case (Consumer packaging)	Recycled polyester	gram	0,40	0,44	0,04
Case (Consumer packaging)	Silicone	gram	1,50	1,51	0,01
Case (Consumer packaging)	Oil paint	gram	2,00	2,08	0,08
Case (packaging)	White paper box	gram	15,89	15,92	0,03
Shipping box (Consumer packaging)	White paper box	gram	141,34	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Paper (warranty leaflet, Consumer packaging)	Recycled paper	gram	3,10	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross
Tote bag (Consumer packaging)	Organic cotton	gram	44,31	Not available, no assumptions were made, net is gross	Not available, no assumptions were made, net is gross

table 7

table 7 Bill of material for Neil titanium

Utilities

Bill of material

Product	Utilities for frame production	Unit	Amount
Pierce frame	Electricity (CN)	kWh	0,800
Pierce frame	Water	m^3	0,060

table 8

Product	Utilities for frame production	Unit	Amount
Neil Stainless steel frame	Electricity (CN)	kWh	0,560
Neil Stainless steel frame	Water	m^3	0,007

table 9

Product	Utilities for frame production	Unit	Amount
Neil Titanium frame	Electricity (CN)	kWh	0,670
Neil Titanium frame	Water	m^3	0,002

table 10

Product	Utilities for frame production	Unit	Amount
Pierce Clip-on frame	Electricity (CN)	kWh	0,300
Pierce Clip-on frame	Water	m^3	0,003

table 11

Product	Utilities for frame production	Unit	Amount
Production Cloth	Electricity (CN)	kWh	0,003
Production Cloth	Natural gas	MJ	0,001
Production case	Electricity (CN)	kWh	0,090
Production case	Diesel	kg	0,003
Utilities (retail)	Electricity grey	kWh	0,953
Utilities (retail)	Electricity green	kWh	1,291
Utilities (retail)	Natural gas	m^3	0,068
Utilities (retail)	District heating	MJ	0,823

table 12

table 8 Utility required to produce the Pierce virgin acetate frame, Pierce bio-acetate frame and Pierce recycled acetate frame.
table 9 Utility required to produce the Neil stainless steel frame.

table 10 Utility required to produce the Neil titanium frame.
table 11 Utility required to produce the Pierce clip-on frame.
table 12 Utility data for production of the case, the cloth and retail per frame.

Product	Utilities for frame production	Unit	Amount
Frame (Neil or Pierce)	Electricity	kWh	0,126
Frame (Neil or Pierce)	Natural gas	MJ	0,950
Frame (Neil or Pierce)	Water	m^3	0,000

table 13

Product	Utilities for frame production	Unit	Amount
Edging lenses in the Netherlands	Electricity	kWh	0,253
Edging lenses in the Netherlands	Natural gas	MJ	0,387
Edging lenses in the Netherlands	Water	m^3	0,001
Edging lenses in Thailand	Electricity	kWh	3,983
Edging lenses in Thailand	Water	m^3	0,022
Edging lenses in Thailand	LPG	MJ	0,062

table 14

Product	Utilities for frame production	Unit	Amount
Washing of a pair of glasses	Natural gas	MJ	11,595
Washing of a pair of glasses	Electricity green (NL)	kWh	0,516
Washing of a pair of glasses	Electricity green (NL)	kWh	0,221
Washing of a pair of glasses	Water	m^3	0,092
Washing of a pair of glasses	Soap	gr	30,012

table 15

table 13 Utilities required by warehouse to pack the product (final assembly).

table 14 The utilities required for the full process from blanc to finished lens, including mounting and edging.

table 15 The utilities required during the use phase (washing) of the glasses for the lifetime of the product.

Transport movement	Type of transport	km
Acetate to Hong Kong site (Pierce virgin acetate and Pierce bio-acetate only)	Truck	75
Acetate from Hong King site to manufacturer	Truck	200
Hardware to manufacturer	Truck	235
Demo lens to manufacturer	Truck	75
Plano lens to manufacturer	Truck	75
Packaging to manufacturer	Truck	80
Frame + packaging + demo lens from Manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	138,8
Frame + packaging + demo lens from HK airport to AMS airport	Airplane	9261
Frame + packaging + plano lens from Manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	138,8
Frame + packaging + plano lens from HK airport to AMS airport	Airplane	9261
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Truck	109
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Airplane	9178
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Truck	77

table 16 ›

Lens to edger in the Netherlands	Airplane	10130
Materials lens to edger Thailand	Truck	75
Frame + lens + packaging from edger in the Netherlands to a warehouse in the Netherlands	Truck	109
Frame + lens + packaging from Thailand to a warehouse in the Netherlands	Truck	77
Frame + lens + packaging from Thailand to a warehouse in the Netherlands	Airplane	9178
Tote bag (India to the Netherlands)	Ocean freight	12818
Tote bag (the Netherlands to stores)	Truck	92
Raw materials cloth from China to manufacturer	Truck	555
Raw materials cloth from China to manufacturer	Ocean freight	4097
Finished cloth from manufacturer to a warehouse in the Netherlands option 1	Truck	1585
Finished cloth from manufacturer to a warehouse in the Netherlands option 1	Ocean freight	14365
Finished cloth from manufacturer to a warehouse in the Netherlands option 2	Truck	1879
Finished cloth from manufacturer to a warehouse in the Netherlands option 2	Airplane	12042
Raw materials case to manufacturer	Truck	993

table 16 ›

Case to a warehouse in the Netherlands	Truck	986
Case to a warehouse in the Netherlands	Ocean freight	19685
Case to a warehouse in the Netherlands	Truck	900
Packaging box to a warehouse in the Netherlands (for online)	Truck	75

table 16

Transport movement	Type of transport	km
Metal to manufacturer	Truck	75
Hardware to manufacturer	Truck	75
Demo lens to manufacturer	Truck	75
Plano lens to manufacturer	Truck	75
Packaging to manufacturer	Truck	75
Frame + packaging + demo lens from Manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	155,6
Frame + packaging + demo lens from HK airport to AMS airport	Airplane	9261
Frame + packaging + plano lens from Manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	155,6
Frame + packaging + plano lens from HK airport to AMS airport	Airplane	9261

table 17 ›

table 16 Transport distances used for the Pierce virgin acetate, Pierce bio-acetate and Pierce recycled acetate.

Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Truck	109
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Airplane	9178
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Truck	77
Lens to edger in the Netherlands	Airplane	10130
Materials lens to edger Thailand	Truck	75
Frame + lens + packaging from edger in the Netherlands to a warehouse in the Netherlands	Truck	109
Frame + lens + packaging from Thailand to a warehouse in the Netherlands	Truck	77
Frame + lens + packaging from Thailand to a warehouse in the Netherlands	Airplane	9178
Tote bag (India to the Netherlands)	Ocean freight	12818
Tote bag (the Netherlands to stores)	Truck	92
Raw materials cloth from China to manufacturer	Truck	555
Raw materials cloth from China to manufacturer	Ocean freight	4097
Finished cloth from manufacturer to a warehouse in the Netherlands option 1	Truck	1585
Finished cloth from manufacturer to a warehouse in the Netherlands option 1	Ocean freight	14365

table 17 ›

Finished cloth from manufacturer to a warehouse in the Netherlands option 2	Truck	1879
Finished cloth from manufacturer to a warehouse in the Netherlands option 2	Airplane	12042
Raw materials case to manufacturer	Truck	993
Case to a warehouse in the Netherlands	Truck	986
Case to a warehouse in the Netherlands	Ocean freight	19685
Case to a warehouse in the Netherlands	Truck	900
Packaging box to a warehouse in the Netherlands (for online)	Truck	75

table 17

Transport movement	Type of transport	km
Components of frame to manufacturer	Truck	75
Demo lens to manufacturer	Truck	75
Plano lens to manufacturer	Truck	75
Packaging to manufacturer	Truck	75
Frame + packaging + demo lens from manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	148,7
Frame + packaging + demo lens from HK airport to AMS airport	Airplane	9261

table 18 ›

table 17 Transport distances used for the Neil stainless steel

Frame + packaging + plano lens from Manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	148,7
Frame + packaging + plano lens from HK airport to AMS airport	Airplane	9261
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Truck	109
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Airplane	9178
Frame + demo lens + packaging from a warehouse in the Netherlands to edger in the Netherlands	Truck	77
Lens to edger in the Netherlands	Airplane	10130
Materials lens to edger Thailand	Truck	75
Frame + lens + packaging from edger in the Netherlands to a warehouse in the Netherlands	Truck	109
Frame + lens + packaging from Thailand to a warehouse in the Netherlands	Truck	77
Frame + lens + packaging from Thailand to a warehouse in the Netherlands	Airplane	9178
Tote bag (India to the Netherlands)	Ocean freight	12818
Tote bag (the Netherlands to stores)	Truck	92
Raw materials cloth from China to manufacturer	Truck	555
Raw materials cloth from China to manufacturer	Ocean freight	4097

table 18 ›

Finished cloth from manufacturer to a warehouse in the Netherlands option 1	Truck	1585
Finished cloth from manufacturer to a warehouse in the Netherlands option 1	Ocean freight	14365
Finished cloth from manufacturer to a warehouse in the Netherlands option 2	Truck	1879
Finished cloth from manufacturer to a warehouse in the Netherlands option 2	Airplane	12042
Raw materials case to manufacturer	Truck	993
Case to a warehouse in the Netherlands	Truck	986
Case to a warehouse in the Netherlands	Ocean freight	19685
Case to a warehouse in the Netherlands	Truck	900
Packaging box to a warehouse in the Netherlands (for online)	Truck	75

table 18

Transport movement	Type of transport	km
Metal to manufacturer	Truck	75
Hardware to manufacturer	Truck	75
Plano lens (sun) to manufacturer	Truck	75
Packaging to manufacturer	Truck	21

table 19 ›

table 18 Transport distances used for the Neil titanium

Frame + packaging + plano lens (sun) from manufacturer to HK airport and AMS airport to a warehouse in the Netherlands	Truck	155,6
Frame + packaging + plano lens (sun) from HK airport to AMS airport	Airplane	9261
Tote bag (India to the Netherlands)	Ocean freight	12818
Tote bag (the Netherlands to stores)	Truck	92
Case clip-on to a warehouse in the Netherlands	Truck	986
Case clip-on to a warehouse in the Netherlands	Ocean freight	19685
Case clip-on to a warehouse in the Netherlands	Truck	900
Packaging box to a warehouse in the Netherlands (for online)	Truck	75

table 19

table 19 Transport distances used for the Pierce clip-on

4.4 Cut-off criteria

The end of waste state is determined by the economic cut-off method. The cut-off model is explained by Ecoinvent as:

"The underlying philosophy of this approach is that primary (first) production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. As a consequence, recyclable materials are available burden-free to recycling processes, and secondary (recycled) materials bear only the impacts of the recycling processes. For example, recycled paper only bears the impacts of waste paper collection and the recycling process of turning waste paper into recycled paper. It is free of any burdens of the forestry activities and processing required for the primary production of the paper.

Furthermore, producers of wastes do not receive any credit for recycling or reuse of products resulting out of any waste treatment. For example, heat from the incineration of municipal solid waste can be used to heat houses or offices, and therefore has a value. Nevertheless, the incineration is allocated completely to the treatment of the waste, and therefore the burdens lay with the waste producer. The heat comes burden-free "

This means that when processes raise the value of materials, which is the case for certain recycling processes, the environmental impact of the recycling process is allocated to the life cycle of the reclaimed materials. In this analysis Ecoinvent cut-off processes, including waste treatment processes, are used. The end point of waste is therefore the point at which it is used to create a new product with a positive economic value.
In the case of this study this means that the energy enerated from the incineration of the waste, which has a positive value, is not attributed to a pair of glasses.

05

Life cycle inventory analysis

This chapter entails the details of our data collection procedures, literature use, and calculation procedures. In this inventory analysis all environmental inputs (e.g. resources, energy and waste) were quantified and qualified into environmental impacts through the use of LCA background data from Ecoinvent or LCIA's directly sourced from suppliers.

5.1 Data collection procedures

Own operation

Ace & Tate does not own or operate any assets related to the production of the frames. The emissions related to the operation of the retail locations are the only processes that generate an environmental impact which is attributable to Ace & Tate products. The retail locations sell the glasses and are also responsible for mounting and edging 20% of all lenses (Same-Day-Service). The utilities used to mount and edge the lenses in store are part of the overall utilities data from their stores. All retail locations have been requested to send utility-relevant information for this assessment. If data was not, or only partially available, data has been extrapolated to a full year and/or extrapolated from other stores based on average utilities per m2 to create one average per frame.

Suppliers

All suppliers have been requested to send relevant product information for this assessment. The information requested consisted of the following data-points:

- Is an LCA or Environmental Product Disclosure (EPD) of your material available? If not;
- Can you provide us with information on the Bill of material?
    - Type of material
    - Weight of materials (gross and net)
    - Waste treatment involved
- Can you provide us with the utilities required to produce your product (type and amount)?
- Are there auxiliary materials needed to produce the product (type and amount)?
- Is there any emission occurring to air, water and soil (type and amount per product)?
- Can you provide us with details regarding transport of used materials (km)?

One supplier provided an LCIA, where other material producers provided details on the (intermediate) composition of materials and, where possible, the gross amount of materials. Processing sites provided data on energy, waste, emissions and transport. Data was acquired for all life cycles stages except for the production of the acetate slab, an intermediate product.

5.2 Qualitative and quantitative description of unit processes

In this section each separate process within the life cycle is elaborated upon. This entails the reference used to assess the environmental impact for each process step within the system boundary and provides a brief description of the process step.

Neil frame production including lenses

The Neil is visualized in figure 7.
It is a stainless-steel frame containing either optical or plano lenses (coated, not edged). The frame is completely produced in China.

› Neil frame materials

The Neil frame consists of mainly metal parts and two small acetate tips. The parts are cut on site in China and the rims of the frame are made out of a roll thread stainless steel.
In the table below the reference data used to calculate the environmental impact required to produce the frame is stated.

fig. 2

fig. 20 Neil

Material	References	Source	Motivation
Stainless steel	Steel, chromium steel 18/8, hot rolled//[RoW] steel production, chromium steel 18/8, hot rolled	Ecoinvent 3.6	Corresponds to metal used by site
Titanium	Titanium, primary//[GLO] titanium production, primary	Ecoinvent 3.6	Corresponds to metal used by site
Acetate	Data provided by chemical supplier of acetate: PP200 Cellulose Acetate; Cellulose Acetate Propionate	Ecoinvent 3.6 Acetate producing chemical company	Directly sourced from supplier
Plasticizer DEP	phthalic anhydride//[GLO] market for phthalic anhydride thermoforming, with calendaring//[RoW] thermoforming production, with calendaring	Ecoinvent 3.6	Proxy process based on content
Monel	Nickel, 99.5%//[GLO] market for nickel, 99.5% copper//[GLO] market for copper metal working, average for copper product manufacturing//[GLO] market for metal working, average for copper product manufacturing The ratio is 65% copper and 35% Nickel	Ecoinvent 3.6	Proxy process based on content
Silicone	Polydimethylsiloxane//[GLO] market for polydimethylsiloxane thermoforming, with calendering//[RoW] thermoforming production, with calendaring	Ecoinvent 3.6	Proxy process based on content
Polybag (PE)	Packaging film, low density polyethylene//[GLO] market for packaging film, low density polyethylene	Ecoinvent 3.6	Corresponds to material used by site
Demo lens	Polymethyl methacrylate, sheet//[RoW] polymethyl methacrylate production, sheet	Ecoinvent 3.6	Corresponds to material used by site
CR39 (plano/optical)	Data provided by chemical supplier: Diallyl diglycol carbonate; Glycol Ester; C12H18O7 polymethyl methacrylate, sheet//[RoW] polymethyl methacrylate production, sheet	Ecoinvent 3.6	Proxy process based on content

table 20

table 20 Material references used to calculate the environmental impact of the Neil frame

Pierce frame production including lenses

The Pierce is visualized in **fig. 8**. It is an acetate frame with small steel hardware components containing either optical or plano lenses (coated, not edged). The frame is completely produced in China.

› Pierce frame materials

The Pierce frame consists of mainly acetate and some small hardware components (screws, hinges and core wires). In the table below the reference data used to calculate the environmental impact required to produce the frame is stated.

fig. 8

fig. 8 Pierce

Material	References	Source	Motivation
Nickel silver	Nickel, 99.5%//[GLO] market for nickel, 99.5%copper//[GLO] market for copper metal working, average for copper product manufacturing//[GLO] market for metal working, average for copper product manufacturing zinc//[GLO] market for zinc The ratio is 64% copper and 24% Zinc and 12% Nickel	Ecoinvent 3.6	Proxy process based on content
Stainless steel	Steel, chromium steel 18/8, hot rolled//[RoW] steel production, chromium steel 18/8, hot rolled	Ecoinvent 3.6	Corresponds to metal used by site
Monel	Nickel, 99.5%//[GLO] market for nickel, 99.5% copper//[GLO] market for copper metal working, average for copper product manufacturing//[GLO] market for metal working, average for copper product manufacturing The ratio is 65% copper and 35% Nickel	Ecoinvent 3.6	Proxy process based on content
Acetate (slab)	US: CA 398-30 CT - PP200 Cellulose Acetate; Cellulose Acetate Propionate CAP-482-20 RMG with 2016 acid con Exergy Fiber Ester Flake CA-394-60S no 7R with 2016 usages (Exergy)	Acetate producing chemical company	Directly sourced from supplier
Plasticizer DEP	phthalic anhydride//[GLO] market for phthalic anhydride thermoforming, with calendaring//[RoW] thermoforming production, with calendaring	Ecoinvent 3.6	Proxy process based on content
Plasticizer Bio DEP	Danisco SOFT-N-SAFE White Paper	Danisco SOFT-N-SAFE White Paper	Proxy process based on content
Polybag (PE)	Packaging film, low density polyethylene//[GLO] market for packaging film, low density polyethylene	Ecoinvent 3.6	Corresponds to material used by site
Demo lens	Polymethyl methacrylate, sheet//[RoW] polymethyl methacrylate production, sheet	Ecoinvent 3.6	Corresponds to material used by site
CR39 (plano/optical)	Data provided by chemical supplier: Diallyl diglycol carbonate; Glycol Ester; C12H18O7 polymethyl methacrylate, sheet//[RoW] polymethyl methacrylate production, sheet	Ecoinvent 3.6	Proxy process based on content

table 21 Material references used to calculate the environmental impact of the Pierce frame

table 21

Transport (both Pierce and Neil)

For all transport related emissions three Ecoinvent processes have been used. Table 22 states the references for these transports.

Production (both Pierce and Neil)

The frames are handled in various sites and various countries, including China, Thailand, and the Netherlands and then sold throughout Europe. Since the end of 2019, Ace & Tate has also started shipping to the US.
For the utilities used at the production sites that produce the frames cases and cloth, Chinese data is used. Data from Thailand and the Netherlands is used for the utilities used for the edging of the lenses, and the rest of the utilities relate to retail sites. In table 23 the references used are listed.

Shipping method	Reference	Source	Motivation
Truck	Transport, freight, lorry, unspecified//[RoW] transport, freight, lorry, all sizes, EURO5 to generic market for transport, freight, lorry, unspecified	Ecoinvent 3.6	Corresponds to transport used by site
Airplane	Transport, freight, aircraft, long haul//[GLO] transport, freight, aircraft, belly-freight, long haul	Ecoinvent 3.6	Corresponds to transport used by site
Ocean freight	Transport, freight, sea, container ship//[GLO] transport, freight, sea, container ship	Ecoinvent 3.6	Corresponds to transport used by site

table 22

table 22 References for transport used

Utility type	Reference	Source	Motivation
Electricity NL (retail, warehouse and mounting & edging)	Grey: Electricity, low voltage//[NL] market for electricity, low voltage Green: electricity, high voltage//[NL] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity CN (production of frames and case)	Electricity, medium voltage//[CN] market group for electricity, medium voltage	Ecoinvent 3.6	Corresponds to energy used by site
Electricity TH (mounting and edging)	Electricity, medium voltage//[TH] market for electricity, medium voltage	Ecoinvent 3.6	Corresponds to energy used by site
Natural Gas NL (retail, warehouse and mounting & edging)	Heat, district or industrial, natural gas//[Europe without Switzerland] heat production, natural gas, at industrial furnace >100kW 35,17 MJ per m^3 used to assess impact per m3 natural gas used	Ecoinvent 3.6 Wikipedia (heating values)	Corresponds to energy used by site
Natural Gas CN (production of frames)	Heat, district or industrial, natural gas//[Europe without Switzerland] heat production, natural gas, at industrial furnace >100kW 38,98 MJ per m^3 used to assess impact per m3 natural gas used	Ecoinvent 3.6 Wikipedia (heating values)	Corresponds to energy used by site
Electricity KH (cloth)	Electricity, medium voltage//[KH] market for electricity, medium voltage	Ecoinvent 3.6	Corresponds to energy used by site
LPG	Heat, central or small-scale, natural gas//[GLO] propane extraction, from liquefied petroleum gas	Ecoinvent 3.6	Corresponds to energy used by site
Diesel	diesel, burned in building machine//[GLO] market for diesel, burned in building machine	Ecoinvent 3.6	Corresponds to energy used by site
Water	Tap water//[GLO] market group for tap water	Ecoinvent 3.6	Corresponds to energy used by site
Electricity BE (retail)	Grey: Electricity, low voltage//[BE] market for electricity, low voltage Green: electricity, high voltage//[BE] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity SE (retail)	Grey: Electricity, low voltage//[SE] market for electricity, low voltage Green: electricity, high voltage//[SE] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site

table 23 ›

Electricity DE (retail)	Grey: Electricity, low voltage//[DE] market for electricity, low voltage Green: electricity, high voltage//[DE] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity DK (retail)	Grey: Electricity, low voltage//[DK] market for electricity, low voltage Green: electricity, high voltage//[DK] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity AT (retail)	Grey: Electricity, low voltage//[AT] market for electricity, low voltage Green: electricity, high voltage//[AT] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity IE (retail)	Grey: Electricity, low voltage//[IE] market for electricity, low voltage Green: electricity, high voltage//[IE] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity CH (retail)	Grey: Electricity, low voltage//[CH] market for electricity, low voltage Green: electricity, high voltage//[CH] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity ES (retail)	Grey: Electricity, low voltage//[ES] market for electricity, low voltage Green: electricity, high voltage//[ES] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Electricity UK (retail)	Grey: Electricity, low voltage//[GB] market for electricity, low voltage Green: electricity, high voltage//[GB] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by site
Natural gas AT (retail)	Heat, district or industrial, natural gas//[Europe without Switzerland] heat production, natural gas, at industrial furnace >100kW 35,17 MJ per m3 used to assess impact per m3 natural gas used	Ecoinvent 3.6	Corresponds to energy used by site
Natural gas DE (retail)	Heat, district or industrial, natural gas//[Europe without Switzerland] heat production, natural gas, at industrial furnace >100kW 35,17 MJ per m3 used to assess impact per m3 natural gas used	Ecoinvent 3.6	Corresponds to energy used by site
District heating (retail)	Heat, district or industrial, other than natural gas//[RER] market group for heat, district or industrial, other than natural gas	Ecoinvent 3.6	Corresponds to energy used by site

table 23 Utilities references used for production data and retail

table 23

Packaging (both Pierce and Neil)

The product is packed in various stages of the Life Cycle. The packaging references used are listed in **table 24**.

Packaging material	Reference	Source	Motivation
Polyethylene	Packaging film, low density polyethylene//[GLO] market for packaging film, low density polyethylene	Ecoinvent 3.6	Corresponds to material used by site
Recycled PET	Polyethylene terephthalate, granulate, amorphous, recycled//[RoW] market for polyethylene terephthalate, granulate, amorphous, recycled thermoforming, with calendering//[RoW] thermoforming, with calendering polyethylene terephthalate, granulate, amorphous, recycled//[RoW] market for polyethylene terephthalate, granulate, amorphous, recycled	Ecoinvent 3.6	Corresponds to material used by site
Water-based polyurethane	Polyurethane, rigid foam//[RoW] market for polyurethane, rigid foam	Ecoinvent 3.6	Corresponds to material used by site
FSC Kraft Paper	Kraft paper, unbleached//[RER] kraft paper production, unbleached	Ecoinvent 3.6	Corresponds to material used by site
Recycled polyester	Thermoforming, with calendering//[RoW] thermoforming, with calendering polyethylene terephthalate, granulate, amorphous, recycled//[RoW] market for polyethylene terephthalate, granulate, amorphous, recycled polyethylene, high density, granulate, recycled//[RoW] market for polyethylene, high density, granulate, recycled	Ecoinvent 3.6	Corresponds to material used by site
Glue	ethylene vinyl acetate copolymer//[RER] market for ethylene vinyl acetate copolymer	Ecoinvent 3.6	Corresponds to material used by site
Cotton	fibre, cotton//[GLO] market for fibre, cotton	Ecoinvent 3.6	Corresponds to material used by site
Oil paint	Alkyd paint, white, without solvent, in 60% solution state//[RoW] market for alkyd paint, white, without solvent, in 60% solution state	Ecoinvent 3.6	Corresponds to material used by site

table 24 ›

Silicone	Polydimethylsiloxane//[GLO] market for polydimethylsiloxane thermoforming, with calendering//[RoW] thermoforming production, with calendaring	Ecoinvent 3.6	Proxy process based on content
Viscose	fibre, viscose//[GLO] market for fibre, viscose	Ecoinvent 3.6	Corresponds to material used by site
Recycled paper	Graphic paper, 100% recycled//[GLO] market for graphic paper, 100% recycled	Ecoinvent 3.6	Corresponds to material used by site
Paper	Paper, woodfree, coated//[RER] market for paper, woodfree, coated	Ecoinvent 3.6	Corresponds to material used by site

table 24

Use phase (both Pierce and Neil)

This analysis takes a cradle to gate approach with end of life phase inventory and also considers the use phase. The use phase is calculated based on a survey that was sent to the users of Ace & Tate's glasses.

Packaging material	Reference	Source	Motivation
Natural gas NL	Heat, district or industrial, natural gas//[Europe without Switzerland] heat production, natural gas, at industrial furnace >100kW 35,17 MJ per m3 used to assess impact per m3 natural gas used	Ecoinvent 3.6	Corresponds to energy used by customer
Electricity NL	Grey: Electricity, low voltage//[NL] market for electricity, low voltage Green: electricity, high voltage//[NL] electricity production, wind, 1-3MW turbine, onshore	Ecoinvent 3.6	Corresponds to energy used by customer
Water	Tap water//[GLO] market group for tap water	Ecoinvent 3.6	Corresponds to energy used by customer
Soap	soap//[GLO] market for soap	Ecoinvent 3.6	Corresponds to energy used by customer

table 25

table 24 Packaging material references used
table 25 Use phase references used

End of life (both Pierce and Neil)

The end of life phase is part of the study as it gives a better understanding of the environmental impact of the product when the consumer disposes of it. This is important since the materials chosen when developing glasses impact the environment at end of life. Different business models (e.g. take back system) or other materials can have a positive impact on the end of life phase.

In order to have a clearer understanding of the end of life of their product, Ace & Tate has conducted a survey in which 301 customers participated voluntarily. The findings show that 98% of the participants have never discarded their glasses. **This shows ample opportunity for Ace & Tate to engage in a take-back or resell system.**

However, since the treatment of waste per country is beyond Ace & Tate's control and no data is available specifically on the end of life phase of the frame, the study uses European averages from Ecoinvent to assess the environmental impact related to waste processing (economic cut-off) of all materials used in production.

Production waste is allocated to the process phase where the waste is created. The waste references below are used for both the end of life phase as well as the production waste. The treatment process modelled is based on a 'worst case scenario'. This scenario is based on the highest GWP 100 in Ecoinvent.

Waste processing	Reference	Source	Motivation
Acetate [waste processing]	waste plastic, mixture//[RoW] treatment of waste plastic, mixture, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Silicone [waste processing]	waste plastic, mixture//[RoW] treatment of waste plastic, mixture, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Stainless steel [waste processing]	scrap steel//[RoW] treatment of scrap steel, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Titanium [waste processing]	scrap steel//[RoW] treatment of scrap steel, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
PMMA [waste processing]	waste polypropylene//[RoW] treatment of waste polypropylene, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
CR39 [waste processing]	waste polypropylene//[RoW] treatment of waste polypropylene, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Metal [waste processing]	scrap steel//[RoW] treatment of scrap steel, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Monel [waste processing]	scrap steel//[RoW] treatment of scrap steel, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Nickel silver [waste processing]	scrap steel//[RoW] treatment of scrap steel, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
DEP [waste processing]	waste plastic, mixture//[RoW] treatment of waste plastic, mixture, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
BIO DEP [waste processing]	biowaste//[GLO] treatment of biowaste, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials

table 26 ›

Polyethylene [waste processing]	waste polyethylene//[RoW] treatment of waste polyethylene, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
White paper box [waste processing]	waste paperboard//[RoW] treatment of waste paperboard, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Recycled PET [waste processing]	waste plastic, mixture//[RoW] treatment of waste plastic, mixture, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Water-based polyurethane [waste processing]	waste polyurethane//[RoW] treatment of waste polyurethane, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
FSC Kraft Paper [waste processing]	waste paperboard//[RoW] treatment of waste paperboard, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Recycled polyester [waste processing]	waste polyethylene terephthalate//[RoW] treatment of waste polyethylene terephthalate, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Glue [waste processing]	waste plastic, mixture//[RoW] treatment of waste plastic, mixture, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Viscose [waste processing]	waste polyurethane//[RoW] treatment of waste polyurethane, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Oil paint [waste processing]	waste paint//[RoW] treatment of waste paint, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Recycled paper [waste processing]	waste paperboard//[RoW] treatment of waste paperboard, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Paper [waste processing]	waste paperboard//[RoW] treatment of waste paperboard, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials
Cotton [waste processing]	waste textile, soiled//[RoW] treatment of waste textile, soiled, municipal incineration	Ecoinvent 3.6	Worst case option selected for waste treatment related to type of reference materials

table 26

Table 26 Waste references used

5.3 Sources of published literature

For the analysis supplier specific data and Ecoinvent 3.6 data is used. Ecoinvent data is used to complete the inventory for materials, processes, transport, energy usage and waste processing.

5.4 Calculation procedures

To consistently calculate the environmental impact, the Ecoinvent 3.6 cut-off database is used. Ecoinvent 3.6 is the latest version of the Ecoinvent database that provides well documented process data for thousands of products. To be able to model all processes for which no supplier specific data was available, Ecoinvent was used in this study. Data provided by suppliers on amounts of materials, waste, transport and energy use was directly used in the model.

Because the glasses are produced via various production routes as stated in the scope and boundary, various averages and calculations have been made in a separate Excel to assess the average inventory for the edging process, materials related to lenses and the transport related to these routes.

Furthermore, not all retail locations have data on utilities usage, therefore the data is extrapolated from those locations with data to calculate an average utility use per frame.

5.5 Validation of data

In this LCA the data relating to the manufacturing of the product and the background processes for environmental impacts are recent and geographically representative, meaning that the production locations are within the region for which the relevant Ecoinvent environmental records have been selected. The dataset is up-to-date and representative for the current technology used in the processes involved in manufacturing the products.

5.6 Completeness of environmental impacts and economic flows

All environmental impact flows – from sources such as resources, energy, emissions and waste – were quantified and qualified in environmental impacts. There is no presumption that relevant input or output data has been omitted. All identified environmental impacts have been translated into environmental impact categories. The LCA references were derived from reputable databases which ensure that all relevant environmental impacts were categorised.

5.7 Consistency and reproducibility

The process descriptions and quantities in this study are quantitatively reproducible in accordance with the reference standards that have been used. The references of all sources, both primary and public sources and literature, have been documented in the chapter "References". Additionally, in order to guarantee reproducibility, a project dossier has been composed. This project dossier contains a summary of all the data used in this LCA.

06

Life cycle impact assessment

6.1 LCIA procedures, calculations and impact categories

In this chapter the results of the LCA calculations are presented and discussed. The environmental profile consists of 18 impact categories and a number of parameters. The LCA profile of both products is presented in the tables below. The impact categories are calculated as follows; all environmental emissions from the inventory are multiplied by the characterisation factors from the ReCiPe Hierarchy midpoint impact assessment method v1.13 (without long term), after which these values are added up to provide the total environmental impact per impact category. The ReCiPe model is a method for impact assessment in an LCA that translates emissions and resource extractions into a limited number of environmental impact scores. This method has been chosen as it represents a broad, up to date range of environmental impact categories that are relevant to the products being assessed in this study. Calculations have been done using Ecoinvent and there is no reason to expect any omissions in these calculations. These LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

6.2 LCIA results relative to the LCI and the defined goal and scope

No limitations relative to the defined goal and scope have been identified and the LCIA can be used to achieve the goals formulated in the goal and scope.

07

Life cycle interpretation

7.1 Results

In the tables, on the following pages, the LCIA results are shown per frame, including a comparison between the six different frames. The LCIA results are visualised as a weighted average per pair of glasses. The weighted average is based on the amount plano and optical lenses produced and the relative routes of transport.

Impact category	Unit	Acetate & hinges, screws and core wire	Demo / plano lens	Packaging	Transport to production in China	Production in China	CR39 optical lens	Transport lens and frame	Edging	Transport frame	(Consumer) packaging + transport	Warehouse in the Netherlands	Transport to client / retail	Retail	Use phase	End of life	Total
Agricultural land occupation: ALOP	m2a	5,01E-03	3,38E-05	4,26E-02	2,81E-05	3,69E-02	3,90E-05	4,56E-04	1,00E-02	1,05E-04	3,65E-01	4,67E-03	9,35E-05	8,06E-02	1,12E-01	1,75E-04	**6,58E-01**
Climate change: GWP100	kg CO2-Eq.	4,00E-01	1,41E-01	1,75E-02	2,95E-03	1,06E+00	1,63E-01	2,09E-01	9,60E-01	4,79E-02	7,26E-01	1,46E-01	9,82E-03	5,61E-01	1,10E+00	2,12E-01	**5,76E+00**
Fossil depletion: FDP	kg oil-Eq.	9,01E-02	4,82E-02	8,71E-03	1,08E-03	2,43E-01	5,55E-02	7,18E-02	3,52E-01	1,64E-02	2,27E-01	6,01E-02	3,59E-03	2,15E-01	4,80E-01	3,80E-03	**1,88E+00**
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	5,39E-04	2,89E-05	1,75E-05	2,13E-06	2,75E-04	3,34E-05	9,20E-05	1,74E-03	2,10E-05	2,84E-03	1,46E-05	7,10E-06	9,93E-05	2,93E-03	1,67E-04	**8,80E-03**
Freshwater eutrophication: FEP	kg P-Eq.	8,14E-06	3,26E-06	1,39E-06	2,96E-08	2,59E-05	3,75E-06	4,31E-07	6,32E-05	9,89E-08	1,56E-04	4,82E-06	9,85E-08	3,43E-05	4,90E-04	1,07E-07	**7,91E-04**
Human toxicity: HTPinf	kg 1,4-DC.	1,25E-01	2,33E-03	1,70E-03	6,76E-04	6,14E-02	2,70E-03	2,27E-02	5,31E-02	5,20E-03	1,32E-01	5,01E-03	2,25E-03	4,15E-02	3,18E-02	8,68E-03	**4,96E-01**
Ionising radiation: IRP_HE	kg U235-Eq.	3,39E-03	1,66E-05	8,51E-04	1,86E-04	9,05E-03	1,91E-05	1,29E-02	3,66E-03	2,96E-03	1,92E-02	2,69E-03	6,19E-04	9,81E-02	1,20E-02	1,69E-04	**1,66E-01**
Marine ecotoxicity: METPinf	kg 1,4-DC.	1,53E-03	4,15E-05	2,02E-05	1,16E-05	3,28E-04	4,82E-05	1,41E-04	7,07E-04	3,23E-05	1,95E-03	7,30E-05	3,84E-05	5,19E-04	8,21E-04	1,35E-04	**6,39E-03**
Marine eutrophication: MEP	kg N-Eq.	2,84E-05	3,25E-05	8,89E-06	3,90E-07	1,27E-04	3,75E-05	4,24E-05	6,30E-05	9,68E-06	6,11E-03	6,95E-06	1,30E-06	4,18E-05	7,54E-04	2,46E-05	**7,29E-03**
Metal depletion: MDP	kg Fe-Eq.	4,39E-01	8,32E-05	6,62E-04	1,34E-04	7,14E-03	9,60E-05	7,42E-04	1,20E-02	1,72E-04	4,25E-02	1,93E-03	4,44E-04	2,63E-02	1,74E-02	3,59E-04	**5,49E-01**
Natural land transformation: NLTP	m2	-7,74E-06	-6,07E-08	-8,22E-07	-2,93E-07	-6,90E-05	-7,01E-08	-1,39E-06	-2,08E-05	-3,23E-07	-3,64E-05	-2,83E-06	-9,74E-07	-1,61E-05	-1,17E-05	-3,80E-07	**-1,69E-04**
Ozone depletion: ODPinf	kg CFC-11.	1,73E-08	1,05E-10	1,49E-09	5,20E-10	9,58E-09	1,21E-10	3,78E-08	3,93E-08	8,63E-09	2,38E-06	1,20E-08	1,73E-09	7,07E-08	1,15E-07	1,22E-09	**2,70E-06**
Particulate matter formation: PMFP	kg PM10-Eq.	6,23E-04	1,53E-04	3,69E-05	5,49E-06	2,34E-03	1,76E-04	3,14E-04	8,15E-04	7,18E-05	1,85E-03	6,45E-05	1,83E-05	4,30E-04	5,69E-04	6,34E-05	**7,53E-03**
Photochemical oxidant formation: POFP	kg NMVOC	5,75E-04	4,76E-04	7,93E-05	1,25E-05	3,40E-03	5,48E-04	1,18E-03	1,66E-03	2,69E-04	3,39E-03	1,81E-04	4,16E-05	8,92E-04	1,38E-03	2,56E-04	**1,43E-02**
Terrestrial acidification: TAP100	kg SO2-Eq.	1,68E-03	5,30E-04	7,97E-05	9,51E-06	4,41E-03	6,11E-04	8,57E-04	2,32E-03	1,96E-04	4,81E-03	1,88E-04	3,16E-05	1,19E-03	1,38E-03	1,61E-04	**1,84E-02**
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	3,05E-02	5,59E-06	1,25E-04	1,47E-06	5,70E-05	6,47E-06	6,98E-06	3,48E-05	1,62E-06	9,91E-03	2,36E-06	4,87E-06	2,90E-05	1,74E-02	1,21E-05	**5,80E-02**
Urban land occupation: ULOP	m2a	9,61E-04	1,38E-05	5,28E-04	2,06E-04	7,40E-03	1,60E-05	3,97E-04	1,77E-03	9,47E-05	8,15E-03	3,30E-04	6,84E-04	4,48E-03	2,39E-03	7,30E-05	**2,75E-02**
Water depletion: WDP	m3	5,69E-03	4,91E-04	6,77E-04	4,64E-06	5,72E-03	5,65E-04	9,66E-05	3,93E-03	2,21E-05	1,58E-01	3,42E-04	1,54E-05	2,55E-03	7,91E-03	3,31E-04	**1,86E-01**

table 27 LCIA Pierce virgin acetate

Impact category	Unit	Acetate & hinges, screws and core wire	Demo / plano lens	Packaging	Transport to production in China	Production in China	CR39 optical lens	Transport lens and frame	Edging	Transport frame	(Consumer) packaging + transport	Warehouse in the Netherlands	Transport to client / retail	Retail	Use phase	End of life	Total
Agricultural land occupation: ALOP	m2a	2,06E-01	3,38E-05	4,26E-02	2,81E-05	3,69E-02	3,90E-05	4,56E-04	1,00E-02	1,05E-04	3,65E-01	4,67E-03	9,35E-05	8,06E-02	1,12E-01	1,75E-04	**8,59E-01**
Climate change: GWP100	kg CO2-Eq.	3,61E-01	1,41E-01	1,75E-02	2,95E-03	1,06E+00	1,63E-01	2,09E-01	9,60E-01	4,79E-02	7,26E-01	1,46E-01	9,82E-03	5,61E-01	1,10E+00	2,12E-01	**5,72E+00**
Fossil depletion: FDP	kg oil-Eq.	7,92E-02	4,82E-02	8,71E-03	1,08E-03	2,43E-01	5,55E-02	7,18E-02	3,52E-01	1,64E-02	2,27E-01	6,01E-02	3,59E-03	2,15E-01	4,80E-01	3,80E-03	**1,87E+00**
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	8,31E-04	2,89E-05	1,75E-05	2,13E-06	2,75E-04	3,34E-05	9,20E-05	1,74E-03	2,10E-05	2,84E-03	1,46E-05	7,10E-06	9,93E-05	2,93E-03	1,67E-04	**9,09E-03**
Freshwater eutrophication: FEP	kg P-Eq.	2,90E-05	3,26E-06	1,39E-06	2,96E-08	2,59E-05	3,75E-06	4,31E-07	6,32E-05	9,89E-08	1,56E-04	4,82E-06	9,85E-08	3,43E-05	4,90E-04	1,07E-07	**8,12E-04**
Human toxicity: HTPinf	kg 1,4-DC.	1,39E-01	2,33E-03	1,70E-03	6,76E-04	6,14E-02	2,70E-03	2,27E-02	5,31E-02	5,20E-03	1,32E-01	5,01E-03	2,25E-03	4,15E-02	3,18E-02	8,68E-03	**5,11E-01**
Ionising radiation: IRP_HE	kg U235-Eq.	1,33E-02	1,66E-05	8,51E-04	1,86E-04	9,05E-03	1,91E-05	1,29E-02	3,66E-03	2,96E-03	1,92E-02	2,69E-03	6,19E-04	9,81E-02	1,20E-02	1,69E-04	**1,76E-01**
Marine ecotoxicity: METPinf	kg 1,4-DC.	1,82E-03	4,15E-05	2,02E-05	1,16E-05	3,28E-04	4,82E-05	1,41E-04	7,07E-04	3,23E-05	1,95E-03	7,30E-05	3,84E-05	5,19E-04	8,21E-04	1,35E-04	**6,68E-03**
Marine eutrophication: MEP	kg N-Eq.	2,95E-04	3,25E-05	8,89E-06	3,90E-07	1,27E-04	3,75E-05	4,24E-05	6,30E-05	9,68E-06	6,11E-03	6,95E-06	1,30E-06	4,18E-05	7,54E-04	2,46E-05	**7,56E-03**
Metal depletion: MDP	kg Fe-Eq.	4,40E-01	8,32E-05	6,62E-04	1,34E-04	7,14E-03	9,60E-05	7,42E-04	1,20E-02	1,72E-04	4,25E-02	1,93E-03	4,44E-04	2,63E-02	1,74E-02	3,59E-04	**5,50E-01**
Natural land transformation: NLTP	m2	-2,57E-05	-6,07E-08	-8,22E-07	-2,93E-07	-6,90E-05	-7,01E-08	-1,39E-06	-2,08E-05	-3,23E-07	-3,64E-05	-2,83E-06	-9,74E-07	-1,61E-05	-1,17E-05	-3,80E-07	**-1,87E-04**
Ozone depletion: ODPinf	kg CFC-11.	2,28E-08	1,05E-10	1,49E-09	5,20E-10	9,58E-09	1,21E-10	3,78E-08	3,93E-08	8,63E-09	2,38E-06	1,20E-08	1,73E-09	7,07E-08	1,15E-07	1,22E-09	**2,70E-06**
Particulate matter formation: PMFP	kg PM10-Eq.	6,88E-04	1,53E-04	3,69E-05	5,49E-06	2,34E-03	1,76E-04	3,14E-04	8,15E-04	7,18E-05	1,85E-03	6,45E-05	1,83E-05	4,30E-04	5,69E-04	6,34E-05	**7,60E-03**
Photochemical oxidant formation: POFP	kg NMVOC	6,48E-04	4,76E-04	7,93E-05	1,25E-05	3,40E-03	5,48E-04	1,18E-03	1,66E-03	2,69E-04	3,39E-03	1,81E-04	4,16E-05	8,92E-04	1,38E-03	2,56E-04	**1,44E-02**
Terrestrial acidification: TAP100	kg SO2-Eq.	2,04E-03	5,30E-04	7,97E-05	9,51E-06	4,41E-03	6,11E-04	8,57E-04	2,32E-03	1,96E-04	4,81E-03	1,88E-04	3,16E-05	1,19E-03	1,38E-03	1,61E-04	**1,88E-02**
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	3,05E-02	5,59E-06	1,25E-04	1,47E-06	5,70E-05	6,47E-06	6,98E-06	3,48E-05	1,62E-06	9,91E-03	2,36E-06	4,87E-06	2,90E-05	1,74E-02	1,21E-05	**5,81E-02**
Urban land occupation: ULOP	m2a	1,11E-03	1,38E-05	5,28E-04	2,06E-04	7,40E-03	1,60E-05	3,97E-04	1,77E-03	9,47E-05	8,15E-03	3,30E-04	6,84E-04	4,48E-03	2,39E-03	7,30E-05	**2,76E-02**
Water depletion: WDP	m3	5,28E-03	4,91E-04	6,77E-04	4,64E-06	5,72E-03	5,65E-04	9,66E-05	3,93E-03	2,21E-05	1,58E-01	3,42E-04	1,54E-05	2,55E-03	7,91E-03	3,31E-04	**1,86E-01**

table 28 LCIA Pierce bio-acetate

Impact category	Unit	Acetate & hinges, screws and core wire	Demo / plano lens	Packaging	Transport to production in China	Production in China	CR39 optical lens	Transport lens and frame	Edging	Transport frame	(Consumer) packaging + transport	Warehouse in the Netherlands	Transport to client / retail	Retail	Use phase	End of life	Total
Agricultural land occupation: ALOP	m2a	2,71E-03	3,38E-05	4,26E-02	2,17E-05	3,69E-02	3,90E-05	4,56E-04	1,00E-02	1,05E-04	3,65E-01	4,67E-03	9,35E-05	8,06E-02	1,12E-01	1,75E-04	**6,56E-01**
Climate change: GWP100	kg CO2-Eq.	3,50E-02	1,41E-01	1,75E-02	4,88E-04	1,06E+00	1,63E-01	2,09E-01	9,60E-01	4,79E-02	7,26E-01	1,46E-01	9,82E-03	5,61E-01	1,10E+00	2,12E-01	**5,39E+00**
Fossil depletion: FDP	kg oil-Eq.	8,94E-03	4,82E-02	8,71E-03	1,78E-04	2,43E-01	5,55E-02	7,18E-02	3,52E-01	1,64E-02	2,27E-01	6,01E-02	3,59E-03	2,15E-01	4,80E-01	3,80E-03	**1,79E+00**
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	7,12E-05	2,89E-05	1,75E-05	3,53E-07	2,75E-04	3,34E-05	9,20E-05	1,74E-03	2,10E-05	2,84E-03	1,46E-05	7,10E-06	9,93E-05	2,93E-03	1,67E-04	**8,33E-03**
Freshwater eutrophication: FEP	kg P-Eq.	5,84E-06	3,26E-06	1,39E-06	4,90E-09	2,59E-05	3,75E-06	4,31E-07	6,32E-05	9,89E-08	1,56E-04	4,82E-06	9,85E-08	3,43E-05	4,90E-04	1,07E-07	**7,89E-04**
Human toxicity: HTPinf	kg 1,4-DC.	1,08E-01	2,33E-03	1,70E-03	1,12E-04	6,14E-02	2,70E-03	2,27E-02	5,31E-02	5,20E-03	1,32E-01	5,01E-03	2,25E-03	4,15E-02	3,18E-02	8,68E-03	**4,79E-01**
Ionising radiation: IRP_HE	kg U235-Eq.	9,15E-04	1,66E-05	8,51E-04	3,08E-05	9,05E-03	1,91E-05	1,29E-02	3,66E-03	2,96E-03	1,92E-02	2,69E-03	6,19E-04	9,81E-02	1,20E-02	1,69E-04	**1,63E-01**
Marine ecotoxicity: METPinf	kg 1,4-DC.	9,47E-04	4,15E-05	2,02E-05	1,91E-06	3,28E-04	4,82E-05	1,41E-04	7,07E-04	3,23E-05	1,95E-03	7,30E-05	3,84E-05	5,19E-04	8,21E-04	1,35E-04	**5,80E-03**
Marine eutrophication: MEP	kg N-Eq.	1,24E-05	3,25E-05	8,89E-06	6,45E-08	1,27E-04	3,75E-05	4,24E-05	6,30E-05	9,68E-06	6,11E-03	6,95E-06	1,30E-06	4,18E-05	7,54E-04	2,46E-05	**7,27E-03**
Metal depletion: MDP	kg Fe-Eq.	4,37E-01	8,32E-05	6,62E-04	2,21E-05	7,14E-03	9,60E-05	7,42E-04	1,20E-02	1,72E-04	4,25E-02	1,93E-03	4,44E-04	2,63E-02	1,74E-02	3,59E-04	**5,47E-01**
Natural land transformation: NLTP	m2	-6,26E-06	-6,07E-08	-8,22E-07	-4,85E-08	-6,90E-05	-7,01E-08	-1,39E-06	-2,08E-05	-3,23E-07	-3,64E-05	-2,83E-06	-9,74E-07	-1,61E-05	-1,17E-05	-3,80E-07	**-1,67E-04**
Ozone depletion: ODPinf	kg CFC-11.	1,49E-09	1,05E-10	1,49E-09	8,60E-11	9,58E-09	1,21E-10	3,78E-08	3,93E-08	8,63E-09	2,38E-06	1,20E-08	1,73E-09	7,07E-08	1,15E-07	1,22E-09	**2,68E-06**
Particulate matter formation: PMFP	kg PM10-Eq.	3,91E-04	1,53E-04	3,69E-05	9,08E-07	2,34E-03	1,76E-04	3,14E-04	8,15E-04	7,18E-05	1,85E-03	6,45E-05	1,83E-05	4,30E-04	5,69E-04	6,34E-05	**7,30E-03**
Photochemical oxidant formation: POFP	kg NMVOC	2,70E-04	4,76E-04	7,93E-05	2,07E-06	3,40E-03	5,48E-04	1,18E-03	1,66E-03	2,69E-04	3,39E-03	1,81E-04	4,16E-05	8,92E-04	1,38E-03	2,56E-04	**1,40E-02**
Terrestrial acidification: TAP100	kg SO2-Eq.	1,08E-03	5,30E-04	7,97E-05	1,57E-06	4,41E-03	6,11E-04	8,57E-04	2,32E-03	1,96E-04	4,81E-03	1,88E-04	3,16E-05	1,19E-03	1,38E-03	1,61E-04	**1,78E-02**
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	1,98E-05	5,59E-06	1,25E-04	2,42E-07	5,70E-05	6,47E-06	6,98E-06	3,48E-05	1,62E-06	9,91E-03	2,36E-06	4,87E-06	2,90E-05	1,74E-02	1,21E-05	**2,76E-02**
Urban land occupation: ULOP	m2a	7,14E-04	1,38E-05	5,28E-04	3,40E-05	7,40E-03	1,60E-05	3,97E-04	1,77E-03	9,47E-05	8,15E-03	3,30E-04	6,84E-04	4,48E-03	2,39E-03	7,30E-05	**2,71E-02**
Water depletion: WDP	m3	2,61E-04	4,91E-04	6,77E-04	7,68E-07	5,72E-03	5,65E-04	9,66E-05	3,93E-03	2,21E-05	1,58E-01	3,42E-04	1,54E-05	2,55E-03	7,91E-03	3,31E-04	**1,81E-01**

table 29 LCIA Pierce recycled acetate

Impact category	Unit	Acetate & hinges, screws and core wire	Demo / plano lens	Packaging	Transport to production in China	Production in China	CR39 optical lens	Transport lens and frame	Edging	Transport frame	(Consumer) packaging + transport	Warehouse in the Netherlands	Transport to client / retail	Retail	Use phase	End of life	Total
Agricultural land occupation: ALOP	m2a	1,19E-02	2,65E-05	3,40E-02	5,96E-06	1,17E-02	4,32E-05	4,65E-04	1,00E-02	1,07E-04	3,65E-01	4,67E-03	9,64E-05	8,06E-02	1,12E-01	1,75E-04	**6,31E-01**
Climate change: GWP100	kg CO2-Eq.	2,02E-01	1,09E-01	1,51E-02	6,26E-04	5,59E-01	1,80E-01	2,13E-01	9,60E-01	4,88E-02	7,26E-01	1,46E-01	1,01E-02	5,61E-01	1,10E+00	1,97E-01	**5,03E+00**
Fossil depletion: FDP	kg oil-Eq.	5,07E-02	3,83E-02	7,75E-03	2,29E-04	1,23E-01	6,15E-02	7,31E-02	3,52E-01	1,67E-02	2,27E-01	6,01E-02	3,70E-03	2,15E-01	4,80E-01	3,77E-03	**1,71E+00**
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	1,86E-04	2,21E-05	1,45E-05	4,52E-07	1,21E-04	3,69E-05	9,36E-05	1,74E-03	2,14E-05	2,84E-03	1,46E-05	7,31E-06	9,93E-05	2,93E-03	1,54E-04	**8,27E-03**
Freshwater eutrophication: FEP	kg P-Eq.	6,82E-06	2,59E-06	1,14E-06	6,28E-09	1,28E-05	4,16E-06	4,39E-07	6,32E-05	1,01E-07	1,56E-04	4,82E-06	1,02E-07	3,43E-05	4,90E-04	1,06E-07	**7,76E-04**
Human toxicity: HTPinf	kg 1,4-DC.	5,61E-02	1,68E-03	1,42E-03	1,43E-04	3,25E-02	2,98E-03	2,31E-02	5,31E-02	5,30E-03	1,32E-01	5,01E-03	2,31E-03	4,15E-02	3,18E-02	8,19E-03	**3,98E-01**
Ionising radiation: IRP_HE	kg U235-Eq.	4,52E-03	1,28E-05	7,13E-04	3,94E-05	3,59E-03	2,11E-05	1,32E-02	3,66E-03	3,01E-03	1,92E-02	2,69E-03	6,38E-04	9,81E-02	1,20E-02	1,71E-04	**1,61E-01**
Marine ecotoxicity: METPinf	kg 1,4-DC.	9,56E-04	2,95E-05	1,69E-05	2,45E-06	1,61E-04	5,30E-05	1,43E-04	7,07E-04	3,29E-05	1,95E-03	7,30E-05	3,96E-05	5,19E-04	8,21E-04	1,29E-04	**5,63E-03**
Marine eutrophication: MEP	kg N-Eq.	2,45E-05	2,58E-05	7,21E-06	8,26E-08	6,68E-05	4,15E-05	4,31E-05	6,30E-05	9,86E-06	6,11E-03	6,95E-06	1,34E-06	4,18E-05	7,54E-04	2,43E-05	**7,22E-03**
Metal depletion: MDP	kg Fe-Eq.	6,51E-02	6,48E-05	5,62E-04	2,83E-05	3,33E-03	1,06E-04	7,59E-04	1,20E-02	1,75E-04	4,25E-02	1,93E-03	4,58E-04	2,63E-02	1,74E-02	3,56E-04	**1,71E-01**
Natural land transformation: NLTP	m2	-1,78E-05	-4,67E-08	-7,00E-07	-6,21E-08	-3,65E-05	-7,75E-08	-1,42E-06	-2,08E-05	-3,29E-07	-3,64E-05	-2,83E-06	-1,00E-06	-1,61E-05	-1,17E-05	-4,02E-07	**-1,46E-04**
Ozone depletion: ODPinf	kg CFC-11.	3,17E-07	8,12E-11	1,23E-09	1,10E-10	3,46E-09	1,34E-10	3,85E-08	3,93E-08	8,79E-09	2,38E-06	1,20E-08	1,78E-09	7,07E-08	1,15E-07	1,21E-09	**2,99E-06**
Particulate matter formation: PMFP	kg PM10-Eq.	8,89E-04	1,21E-04	3,13E-05	1,16E-06	1,23E-03	1,95E-04	3,20E-04	8,15E-04	7,32E-05	1,85E-03	6,45E-05	1,88E-05	4,30E-04	5,69E-04	6,26E-05	**6,67E-03**
Photochemical oxidant formation: POFP	kg NMVOC	6,59E-04	3,78E-04	6,80E-05	2,65E-06	1,81E-03	6,07E-04	1,20E-03	1,66E-03	2,74E-04	3,39E-03	1,81E-04	4,29E-05	8,92E-04	1,38E-03	2,52E-04	**1,28E-02**
Terrestrial acidification: TAP100	kg SO2-Eq.	8,58E-04	4,21E-04	6,75E-05	2,01E-06	2,35E-03	6,76E-04	8,72E-04	2,32E-03	1,99E-04	4,81E-03	1,88E-04	3,26E-05	1,19E-03	1,38E-03	1,59E-04	**1,55E-02**
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	4,86E-03	4,18E-06	9,98E-05	3,10E-07	1,22E-05	7,15E-06	7,14E-06	3,48E-05	1,65E-06	9,91E-03	2,36E-06	5,02E-06	2,90E-05	1,74E-02	1,16E-05	**3,24E-02**
Urban land occupation: ULOP	m2a	2,49E-03	1,07E-05	4,28E-04	4,36E-05	3,90E-03	1,77E-05	4,10E-04	1,77E-03	9,65E-05	8,15E-03	3,30E-04	7,05E-04	4,48E-03	2,39E-03	8,64E-05	**2,53E-02**
Water depletion: WDP	m3	1,69E-03	3,88E-04	5,58E-04	9,84E-07	1,44E-03	6,26E-04	9,84E-05	3,93E-03	2,26E-05	1,58E-01	3,42E-04	1,59E-05	2,55E-03	7,91E-03	3,25E-04	**1,78E-01**

table 30 LCIA Neil stainless steel

Impact category	Unit	Acetate & hinges, screws and core wire	Demo / plano lens	Packaging	Transport to production in China	Production in China	CR39 optical lens	Transport lens and frame	Edging	Transport frame	(Consumer) packaging + transport	Warehouse in the Netherlands	Transport to client / retail	Retail	Use phase	End of life	Total
Agricultural land occupation: ALOP	m2a	1,01E-02	2,65E-05	3,39E-02	2,83E-06	1,40E-02	4,32E-05	3,21E-04	1,00E-02	7,19E-05	3,65E-01	4,67E-03	9,10E-05	8,06E-02	1,12E-01	1,66E-04	**6,31E-01**
Climate change: GWP100	kg CO2-Eq.	2,85E-01	1,09E-01	1,39E-02	2,97E-04	6,68E-01	1,43E-01	1,47E-01	9,60E-01	3,29E-02	7,26E-01	1,46E-01	9,55E-03	5,61E-01	1,10E+00	2,03E-01	**5,11E+00**
Fossil depletion: FDP	kg oil-Eq.	8,74E-02	3,83E-02	6,87E-03	1,09E-04	1,47E-01	2,84E-02	5,05E-02	3,52E-01	1,13E-02	2,27E-01	6,01E-02	3,49E-03	2,15E-01	4,80E-01	3,72E-03	**1,71E+00**
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	1,61E-04	2,21E-05	1,39E-05	2,15E-07	1,45E-04	1,98E-03	6,47E-05	1,74E-03	1,45E-05	2,84E-03	1,46E-05	6,90E-06	9,93E-05	2,93E-03	1,51E-04	**1,02E-02**
Freshwater eutrophication: FEP	kg P-Eq.	1,30E-05	2,59E-06	1,10E-06	2,98E-09	1,53E-05	1,19E-04	3,03E-07	6,32E-05	6,79E-08	1,56E-04	4,82E-06	9,58E-08	3,43E-05	4,90E-04	1,03E-07	**9,00E-04**
Human toxicity: HTPinf	kg 1,4-DC.	1,88E-02	1,68E-03	1,34E-03	6,80E-05	3,89E-02	1,77E-02	1,60E-02	5,31E-02	3,57E-03	1,32E-01	5,01E-03	2,19E-03	4,15E-02	3,18E-02	8,69E-03	**3,73E-01**
Ionising radiation: IRP_HE	kg U235-Eq.	9,66E-03	1,28E-05	6,73E-04	1,87E-05	4,29E-03	3,16E-03	9,09E-03	3,66E-03	2,03E-03	1,92E-02	2,69E-03	6,02E-04	9,81E-02	1,20E-02	1,62E-04	**1,65E-01**
Marine ecotoxicity: METPinf	kg 1,4-DC.	2,17E-04	2,95E-05	1,60E-05	1,16E-06	1,93E-04	6,46E-04	9,89E-05	7,07E-04	2,22E-05	1,95E-03	7,30E-05	3,73E-05	5,19E-04	8,21E-04	1,38E-04	**5,47E-03**
Marine eutrophication: MEP	kg N-Eq.	4,42E-05	2,58E-05	7,06E-06	3,93E-08	7,99E-05	5,29E-03	2,98E-05	6,30E-05	6,65E-06	6,11E-03	6,95E-06	1,26E-06	4,18E-05	7,54E-04	2,43E-05	**1,25E-02**
Metal depletion: MDP	kg Fe-Eq.	3,73E-03	6,48E-05	5,24E-04	1,35E-05	3,98E-03	6,89E-03	5,22E-04	1,20E-02	1,18E-04	4,25E-02	1,93E-03	4,32E-04	2,63E-02	1,74E-02	3,45E-04	**1,17E-01**
Natural land transformation: NLTP	m2	-1,44E-05	-4,67E-08	-6,50E-07	-2,95E-08	-4,37E-05	-4,57E-06	-9,78E-07	-2,08E-05	-2,22E-07	-3,64E-05	-2,83E-06	-9,48E-07	-1,61E-05	-1,17E-05	-3,65E-07	**-1,54E-04**
Ozone depletion: ODPinf	kg CFC-11.	4,49E-07	8,12E-11	1,18E-09	5,24E-11	4,13E-09	8,19E-09	2,66E-08	3,93E-08	5,93E-09	2,38E-06	1,20E-08	1,68E-09	7,07E-08	1,15E-07	1,19E-09	**3,12E-06**
Particulate matter formation: PMFP	kg PM10-Eq.	5,92E-04	1,21E-04	2,92E-05	5,53E-07	1,47E-03	4,59E-04	2,21E-04	8,15E-04	4,93E-05	1,85E-03	6,45E-05	1,78E-05	4,30E-04	5,69E-04	6,23E-05	**6,75E-03**
Photochemical oxidant formation: POFP	kg NMVOC	1,02E-03	3,78E-04	6,26E-05	1,26E-06	2,17E-03	6,36E-04	8,27E-04	1,66E-03	1,85E-04	3,39E-03	1,81E-04	4,05E-05	8,92E-04	1,38E-03	2,51E-04	**1,31E-02**
Terrestrial acidification: TAP100	kg SO2-Eq.	1,17E-03	4,21E-04	6,30E-05	9,57E-07	2,81E-03	1,83E-03	6,02E-04	2,32E-03	1,34E-04	4,81E-03	1,88E-04	3,07E-05	1,19E-03	1,38E-03	1,58E-04	**1,71E-02**
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	2,04E-05	4,18E-06	9,96E-05	1,47E-07	1,47E-05	8,47E-03	4,91E-06	3,48E-05	1,11E-06	9,91E-03	2,36E-06	4,74E-06	2,90E-05	1,74E-02	1,24E-05	**3,60E-02**
Urban land occupation: ULOP	m2a	1,16E-03	1,07E-05	4,19E-04	2,07E-05	4,67E-03	1,30E-03	2,80E-04	1,77E-03	6,51E-05	8,15E-03	3,30E-04	6,65E-04	4,48E-03	2,39E-03	6,99E-05	**2,58E-02**
Water depletion: WDP	m3	1,96E-03	3,88E-04	5,36E-04	4,67E-07	1,72E-03	1,38E-01	6,79E-05	3,93E-03	1,52E-05	1,58E-01	3,42E-04	1,50E-05	2,55E-03	7,91E-03	3,18E-04	**3,15E-01**

table 31 LCIA Neil titanium

Impact category	Unit	Acetate & hinges, screws and core wire	Demo / plano lens	Packaging	Transport to production in China	Production in China	CR39 optical lens	Transport lens and frame	Edging	Transport frame	(Consumer) packaging + transport	Warehouse in the Netherlands	Transport to client / retail	Retail	Use phase	End of life	Total
Agricultural land occupation: ALOP	m2a	1,10E-02	5,40E-05	3,40E-02	5,30E-06	6,27E-03	0,00E+00	0,00E+00	0,00E+00	2,96E-04	2,84E-01	4,67E-03	8,42E-05	8,06E-02	1,12E-01	1,17E-04	**5,33E-01**
Climate change: GWP100	kg CO2-Eq.	1,48E-01	2,25E-01	1,51E-02	5,56E-04	2,99E-01	0,00E+00	0,00E+00	0,00E+00	1,35E-01	3,89E-01	1,46E-01	8,84E-03	5,61E-01	1,10E+00	1,09E-01	**3,14E+00**
Fossil depletion: FDP	kg oil-Eq.	4,03E-02	7,69E-02	7,75E-03	2,03E-04	6,58E-02	0,00E+00	0,00E+00	0,00E+00	4,64E-02	1,02E-01	6,01E-02	3,23E-03	2,15E-01	4,80E-01	2,67E-03	**1,10E+00**
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	1,28E-04	4,61E-05	1,45E-05	4,02E-07	6,50E-05	0,00E+00	0,00E+00	0,00E+00	5,95E-05	2,52E-03	1,46E-05	6,39E-06	9,93E-05	2,93E-03	7,24E-05	**5,96E-03**
Freshwater eutrophication: FEP	kg P-Eq.	7,35E-06	5,20E-06	1,14E-06	5,58E-09	6,87E-06	0,00E+00	0,00E+00	0,00E+00	2,79E-07	1,51E-04	4,82E-06	8,87E-08	3,43E-05	4,90E-04	7,53E-08	**7,01E-04**
Human toxicity: HTPinf	kg 1,4-DC.	6,90E-02	3,72E-03	1,42E-03	1,27E-04	1,74E-02	0,00E+00	0,00E+00	0,00E+00	1,47E-02	4,84E-02	5,01E-03	2,02E-03	4,15E-02	3,18E-02	4,70E-03	**2,40E-01**
Ionising radiation: IRP_HE	kg U235-Eq.	3,94E-03	2,64E-05	7,13E-04	3,51E-05	1,92E-03	0,00E+00	0,00E+00	0,00E+00	8,37E-03	9,29E-03	2,69E-03	5,57E-04	9,81E-02	1,20E-02	1,20E-04	**1,38E-01**
Marine ecotoxicity: METPinf	kg 1,4-DC.	1,02E-03	6,62E-05	1,69E-05	2,17E-06	8,62E-05	0,00E+00	0,00E+00	0,00E+00	9,12E-05	1,08E-03	7,30E-05	3,46E-05	5,19E-04	8,21E-04	7,92E-05	**3,89E-03**
Marine eutrophication: MEP	kg N-Eq.	2,43E-05	5,19E-05	7,21E-06	7,35E-08	3,58E-05	0,00E+00	0,00E+00	0,00E+00	2,74E-05	6,41E-03	6,95E-06	1,17E-06	4,18E-05	7,54E-04	1,75E-05	**7,37E-03**
Metal depletion: MDP	kg Fe-Eq.	7,48E-02	1,33E-04	5,62E-04	2,52E-05	1,78E-03	0,00E+00	0,00E+00	0,00E+00	4,83E-04	2,10E-02	1,93E-03	4,00E-04	2,63E-02	1,74E-02	2,48E-04	**1,45E-01**
Natural land transformation: NLTP	m2	-1,74E-05	-9,69E-08	-7,00E-07	-5,52E-08	-1,96E-05	0,00E+00	0,00E+00	0,00E+00	-9,06E-07	-1,93E-05	-2,83E-06	-8,77E-07	-1,61E-05	-1,17E-05	-2,95E-07	**-8,98E-05**
Ozone depletion: ODPinf	kg CFC-11.	2,37E-07	1,67E-10	1,23E-09	9,79E-11	1,85E-09	0,00E+00	0,00E+00	0,00E+00	2,44E-08	2,43E-08	1,20E-08	1,56E-09	7,07E-08	1,15E-07	8,74E-10	**4,90E-07**
Particulate matter formation: PMFP	kg PM10-Eq.	8,86E-04	2,44E-04	3,13E-05	1,03E-06	6,58E-04	0,00E+00	0,00E+00	0,00E+00	2,03E-04	1,15E-03	6,45E-05	1,64E-05	4,30E-04	5,69E-04	4,49E-05	**4,30E-03**
Photochemical oxidant formation: POFP	kg NMVOC	6,56E-04	7,59E-04	6,80E-05	2,36E-06	9,72E-04	0,00E+00	0,00E+00	0,00E+00	7,61E-04	1,83E-03	1,81E-04	3,74E-05	8,92E-04	1,38E-03	1,79E-04	**7,72E-03**
Terrestrial acidification: TAP100	kg SO2-Eq.	1,13E-03	8,45E-04	6,75E-05	1,79E-06	1,26E-03	0,00E+00	0,00E+00	0,00E+00	5,54E-04	3,36E-03	1,88E-04	2,84E-05	1,19E-03	1,38E-03	1,15E-04	**1,01E-02**
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	2,83E-05	8,92E-06	9,98E-05	2,76E-07	6,56E-06	0,00E+00	0,00E+00	0,00E+00	4,55E-06	1,05E-02	2,36E-06	4,38E-06	2,90E-05	1,74E-02	7,26E-06	**2,81E-02**
Urban land occupation: ULOP	m2a	2,36E-03	2,21E-05	4,28E-04	3,87E-05	2,09E-03	0,00E+00	0,00E+00	0,00E+00	2,62E-04	3,87E-03	3,30E-04	6,16E-04	4,48E-03	2,39E-03	6,63E-05	**1,70E-02**
Water depletion: WDP	m3	8,79E-04	7,82E-04	5,58E-04	8,74E-07	7,71E-04	0,00E+00	0,00E+00	0,00E+00	6,26E-05	1,66E-01	3,42E-04	1,39E-05	2,55E-03	7,91E-03	2,28E-04	**1,81E-01**

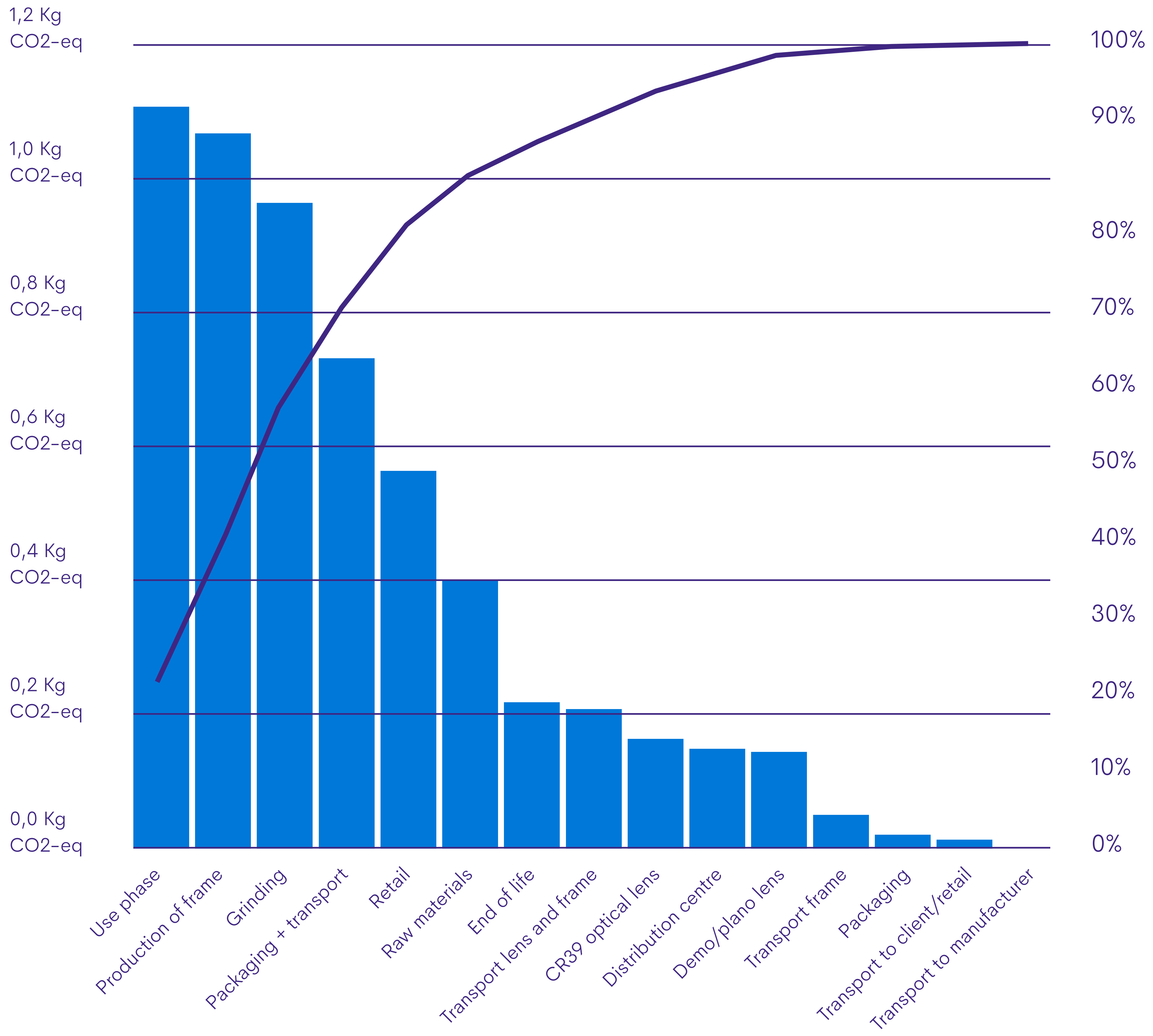
table 32 LCIA Pierce clip-on

Impact category	Unit	Pierce Virgin acetate	Pierce Bio-acetate	Pierce Recycled acetate	Neil Stainless steel	Neil Titanium	Pierce Clip-on
Agricultural land occupation: ALOP	m2a	6,58E-01	8,59E-01	6,56E-01	6,31E-01	6,31E-01	5,33E-01
Climate change: GWP100	kg CO2-Eq.	5,76E+00	5,72E+00	5,39E+00	5,03E+00	5,11E+00	3,14E+00
Fossil depletion: FDP	kg oil-Eq.	1,88E+00	1,87E+00	1,79E+00	1,71E+00	1,71E+00	1,10E+00
Freshwater ecotoxicity: FETPinf	kg 1,4-DC.	8,80E-03	9,09E-03	8,33E-03	8,27E-03	1,02E-02	5,96E-03
Freshwater eutrophication: FEP	kg P-Eq.	7,91E-04	8,12E-04	7,89E-04	7,76E-04	9,00E-04	7,01E-04
Human toxicity: HTPinf	kg 1,4-DC.	4,96E-01	5,11E-01	4,79E-01	3,98E-01	3,73E-01	2,40E-01
Ionising radiation: IRP_HE	kg U235-Eq.	1,66E-01	1,76E-01	1,63E-01	1,61E-01	1,65E-01	1,38E-01
Marine ecotoxicity: METPinf	kg 1,4-DC.	6,39E-03	6,68E-03	5,80E-03	5,63E-03	5,47E-03	3,89E-03
Marine eutrophication: MEP	kg N-Eq.	7,29E-03	7,56E-03	7,27E-03	7,22E-03	1,25E-02	7,37E-03
Metal depletion: MDP	kg Fe-Eq.	5,49E-01	5,50E-01	5,47E-01	1,71E-01	1,17E-01	1,45E-01
Natural land transformation: NLTP	m2	-1,69E-04	-1,87E-04	-1,67E-04	-1,46E-04	-1,54E-04	-8,98E-05
Ozone depletion: ODPinf	kg CFC-11.	2,70E-06	2,70E-06	2,68E-06	2,99E-06	3,12E-06	4,90E-07
Particulate matter formation: PMFP	kg PM10-Eq.	7,53E-03	7,60E-03	7,30E-03	6,67E-03	6,75E-03	4,30E-03
Photochemical oxidant formation: POFP	kg NMVOC	1,43E-02	1,44E-02	1,40E-02	1,28E-02	1,31E-02	7,72E-03
Terrestrial acidification: TAP100	kg SO2-Eq.	1,84E-02	1,88E-02	1,78E-02	1,55E-02	1,71E-02	1,01E-02
Terrestrial ecotoxicity: TETPinf	kg 1,4-DC.	5,80E-02	5,81E-02	2,76E-02	3,24E-02	3,60E-02	2,81E-02
Urban land occupation: ULOP	m2a	2,75E-02	2,76E-02	2,71E-02	2,53E-02	2,58E-02	1,70E-02
Water depletion: WDP	m3	1,86E-01	1,86E-01	1,81E-01	1,78E-01	3,15E-01	1,81E-01

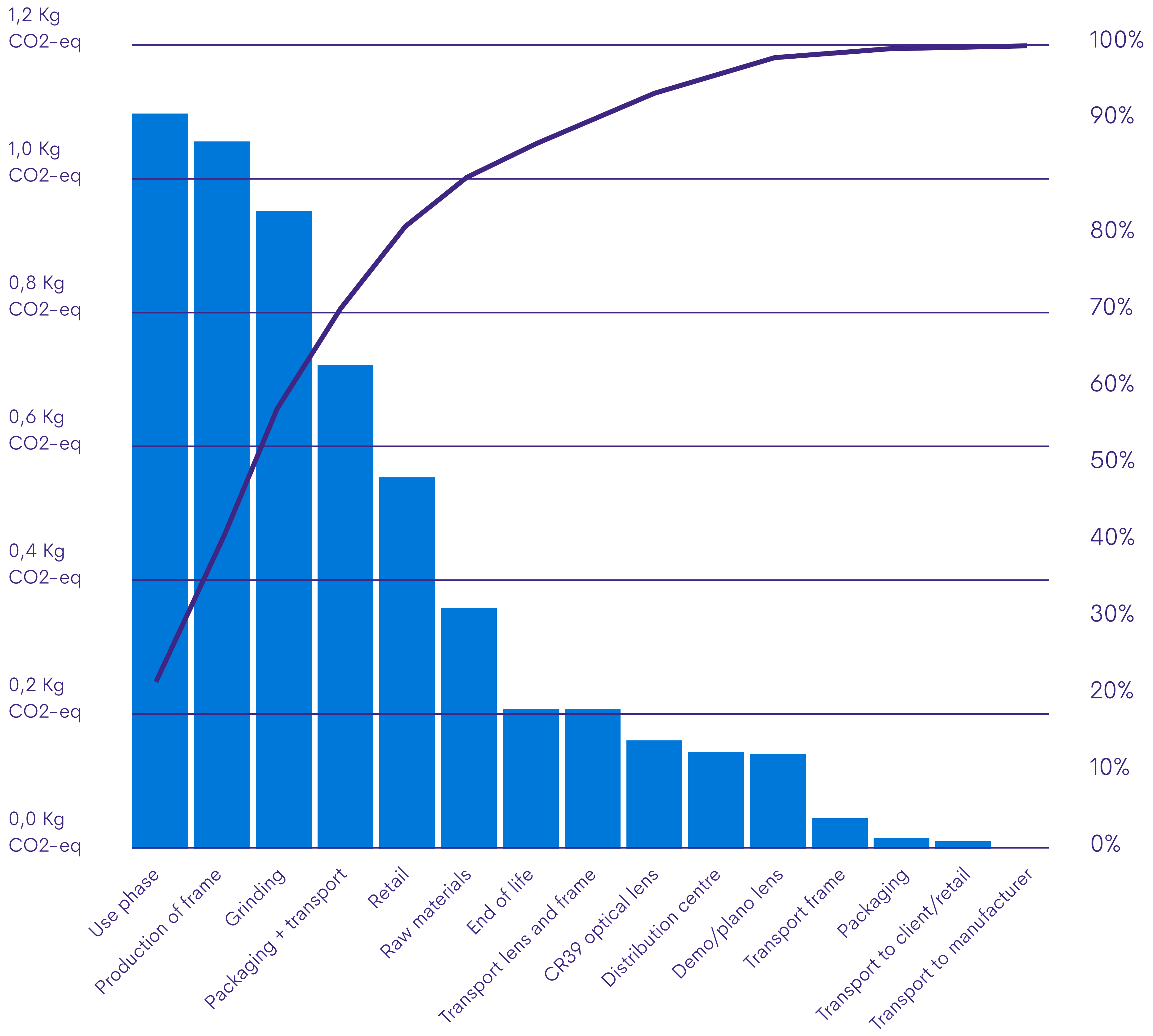
table 33 LCIA comparison of the six frames

Pareto analysis

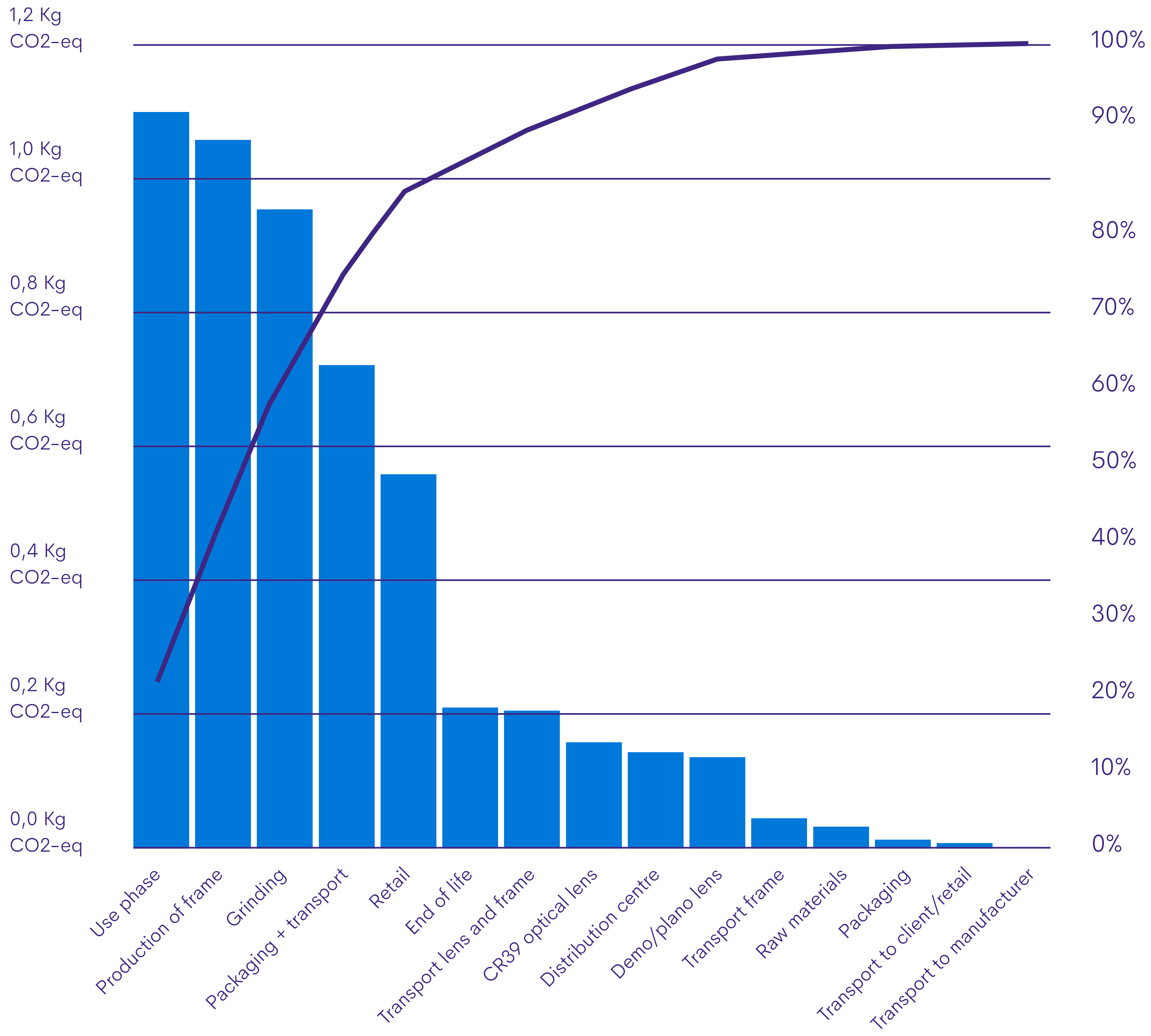
The six pareto (gravity) analyses in Graph 1 to Graph 6 visualise the most impactful stages in the life cycle on the impact category Global Warming Potential (GWP, in CO2 -eq.).



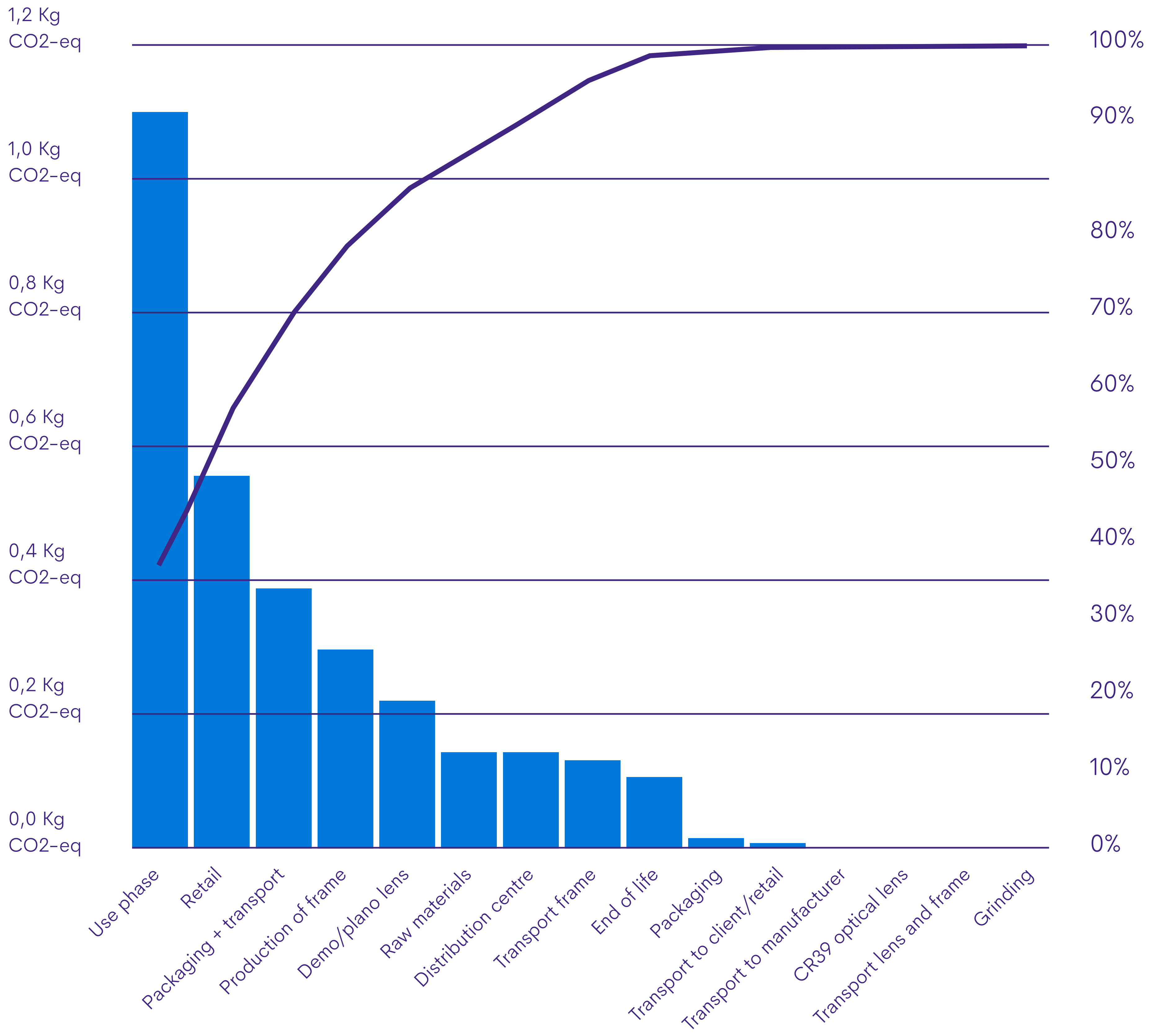
graph 1 Pareto analysis Pierce virgin acetate



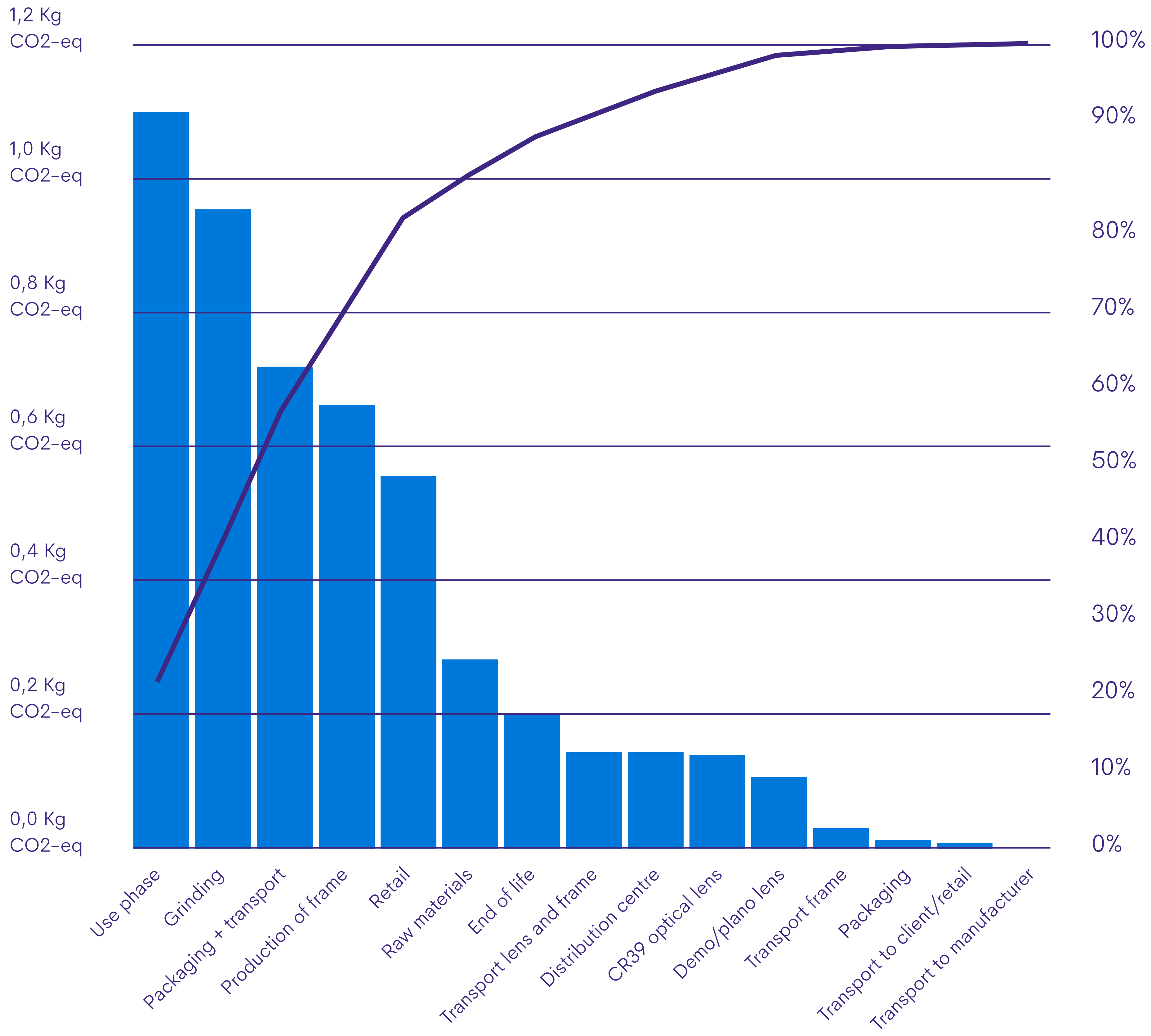
graph 2 Pareto analysis Pierce bio-acetate



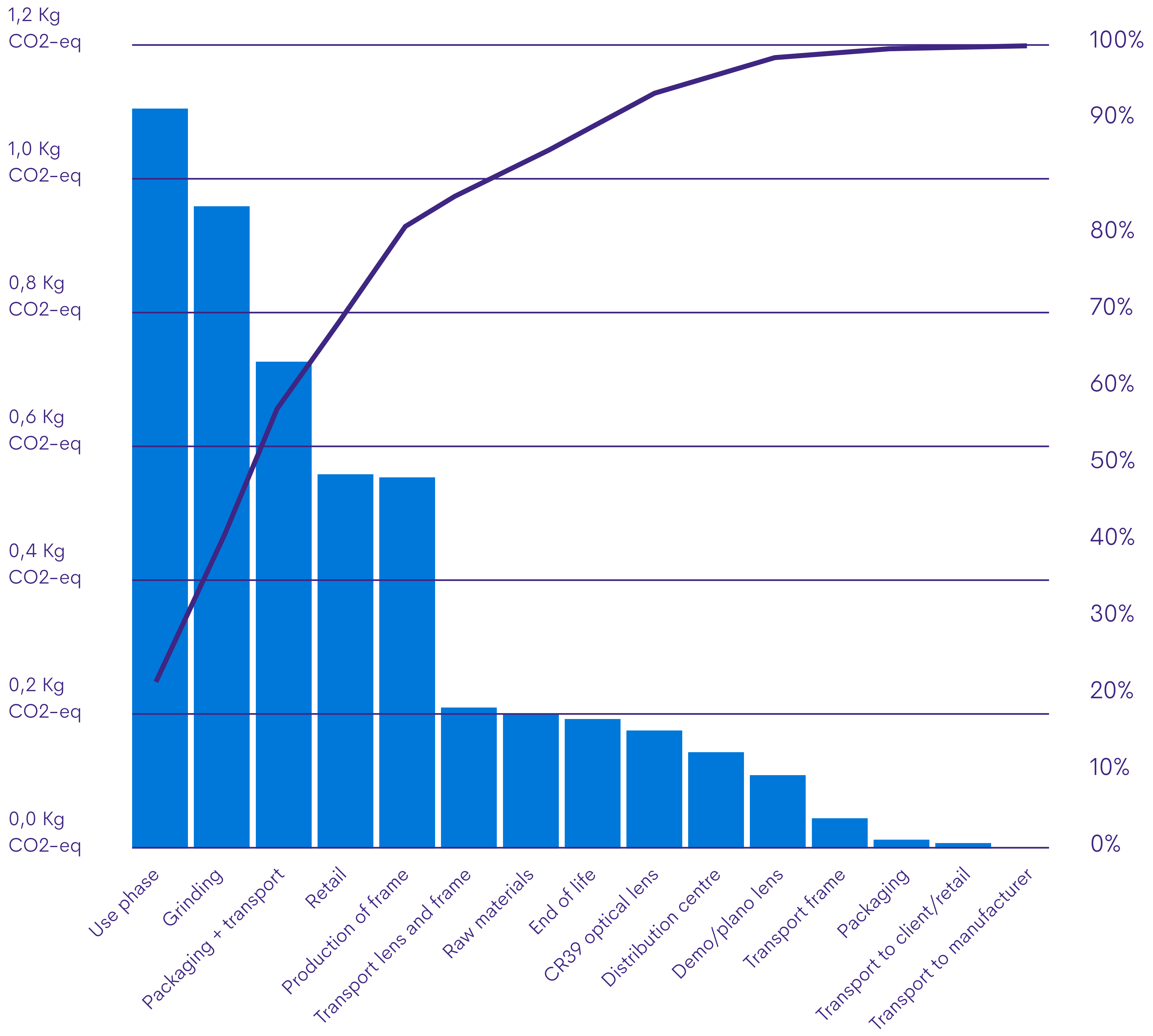
graph 3 Pareto analysis Pierce recycled acetate



graph 4 Pareto analysis Pierce clip-on



graph 5 Pareto analysis Neil stainless steel



graph 6 Pareto analysis Neil titanium

› Pareto interpretation Pierce

Graphs **1**, **2** and **4** visualise the relatively high impact of the use phase of the Pierce. Cleaning the frames attributes +/- 19% of the total impact. This is similar to production which is also +/- 19% of total impact. Edging adds 17%. These three life cycle impact stages account for +/-60% of the impact on CO2 -eq.

Use phase

The use phase scenario is based on the customer survey, depicting an average life span of 2,16 years in which the frames are cleaned, on average 184 times. Lukewarm water is advised to clean the glasses with a drop of soap. We used an average of 500 ml water per time cleaned, with an average temperature increase of water of 37 degrees Celsius. This requires 0,022 kwh per cleaning. The energy mix required to heat the water is based on Dutch averages regarding gas-connected houses (81%), non-gas connected houses (19% is connected to just the electricity grid) and type of electricity used; grey (30%) or green (70%). Specifically, the usage of natural gas as an energy source to heat water has a significant impact (72%) on this stage.

Production frame

The production of the frame in China relates to the energy required to produce the frame from the acetate slab. According to data derived from the site, 0,8 kWh was used by the main factory producing for Ace & Tate. The relatively high CO2 intensity of the Chinese energy mix in Ecoinvent is the main contributor to the impact on CO2 -eq. This life cycle step is further analysed in section 8.2 in a sensitivity analysis to understand the impact of the value on the total amount of CO2 -eq.

Edging & mounting

The edging is an energy intensive process with 4 kWh used in Thailand for the full process from blanc to finished lenses, including mounting and edging. As 21% of Neil products and 43% of Pierce products are edged in Thailand, only part of the full 4 kWh is attributed.

› Pareto interpretation Neil (excluding clip-on)

Graph 5 and 6 visualise, similar to the Pierce, a relatively high impact of the use phase of the Neil (almost 20%). Edging of the lenses combined with transport and consumer packaging of the final product attribute almost another 40%, which implies that these three stages in the life cycle equal approximately 60% of the impact on CO2 -eq.

Edging

The edging of the frames occurs partially in Thailand which is, compared to edging in stores and in the Netherlands relatively energy intensive at 3,9 kwh.

Consumer packaging

Some of the packaging materials have a relatively high impact, specifically the water based polyurethane case, the paper box in which the glasses are sent to consumers and the cotton tote bag.

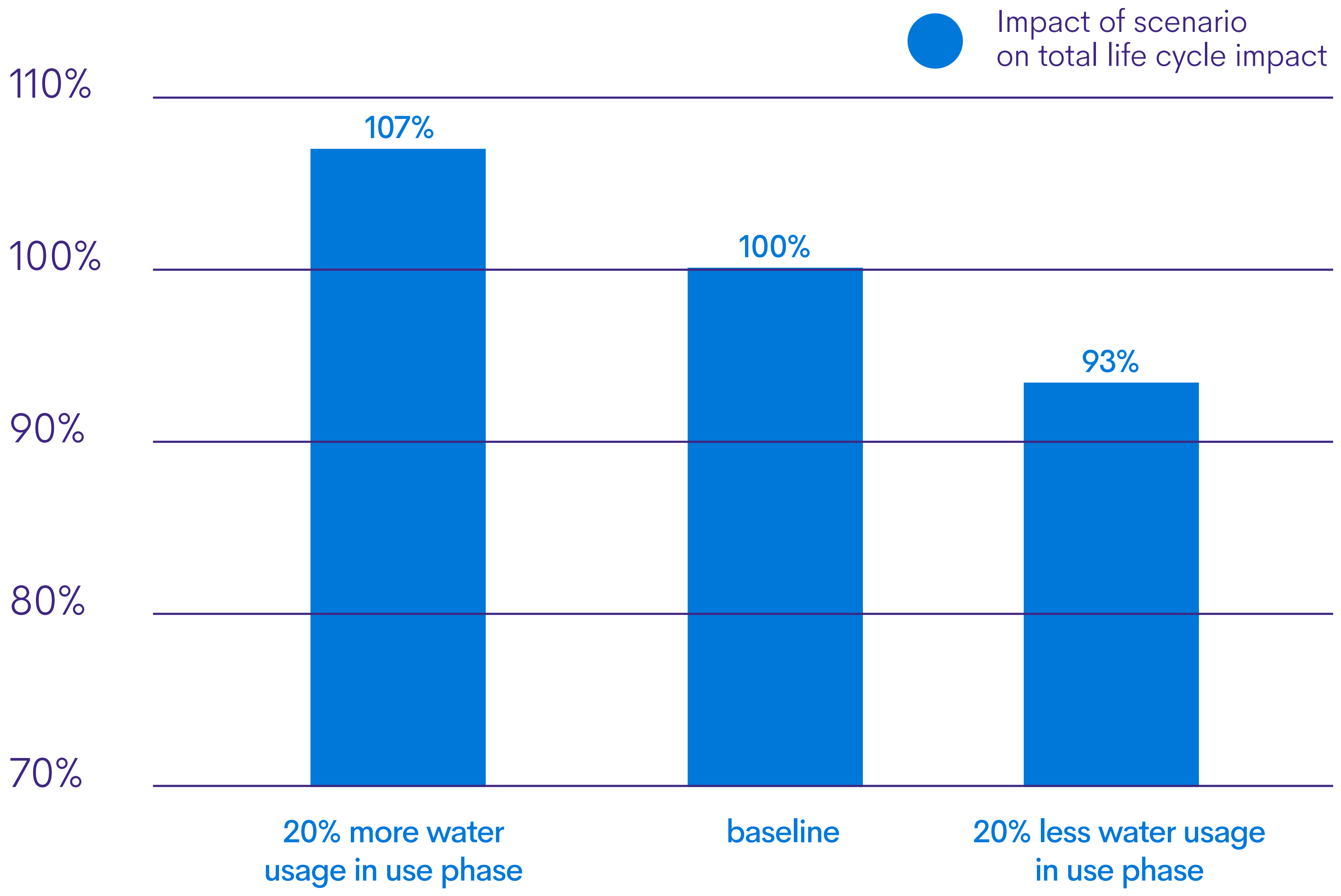
7.2 Sensitivity analysis

A sensitivity analysis aims to determine the influence of variations in assumptions, methods and data on the results. Mainly, the sensitivity of the most significant issues identified is checked. The purpose is to compare the results obtained using given assumptions, methods or data with the results obtained using altered assumptions, methods or data. In sensitivity analyses, typically the influence of varying the results on the assumptions and data by some range (e.g. a range of 25%) is checked. Both results are then compared. Sensitivity can be expressed as the percentage of change or as the absolute deviation in the results. On this basis, significant changes in the results (e.g. larger than 10 %) can be identified.

Sensitivity analysis use phase

For all frames the use phase is responsible for most of the impact and is therefore the subject of our sensitivity analysis. This is to understand the relative impact of assumptions in general of our analysis and in this phase specifically. In graph 7 the relative impact of a 20% increase and decrease in heated water usage is visualised for the Pierce clip-on. This frame is chosen for our sensitivity analysis as its use phase has a relative high impact on the total life cycle compared to other frame types.

The relative impact is 7% of the total environmental impact category GWP and is therefore within the boundary depicted in 8.2. As this is the most impactful overall life cycle stage for all frames, all other assumptions are within the 10% boundary when assuming a possible 20% deviation in a sensitivity analysis.



graph 7 Sensitivity analysis Pierce clip-on 20% difference in water usage.

7.3 Data quality assessment

Data sourced from suppliers

The data sourced from suppliers was up-to-date and supplier specific, making it representative in both geography and time. This mainly relates to the weight of materials used, transport distances between companies and utilities usages the data gathered is consistent.

Materials

Data from Ecoinvent is used per life cycle inventory step. Ideally the data is iteratively phased out by actual material specific data.

08

Critical review

Name and affiliation of reviewers

Lex Roes – EcoChain

Critical review report

"The LCA study under review has been performed thoroughly and accurately. Sufficient work has been put into the gathering of actual foreground data. For other data, LCA databases were used. A proper database (Ecoinvent) was selected for this. Details of the life cycle and the choice of reference data to model the life cycle have been clearly described. An appropriate impact assessment method (Recipe) was selected for the calculations. Sufficient interpretation of the results was done to check the validity of the results and fulfil the scope of the study.

Therefore, my conclusion is that the LCA report fully complies with the ISO 14044 norm, which ensures quality and transparency of the LCA."

References

ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines

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We are working on it.

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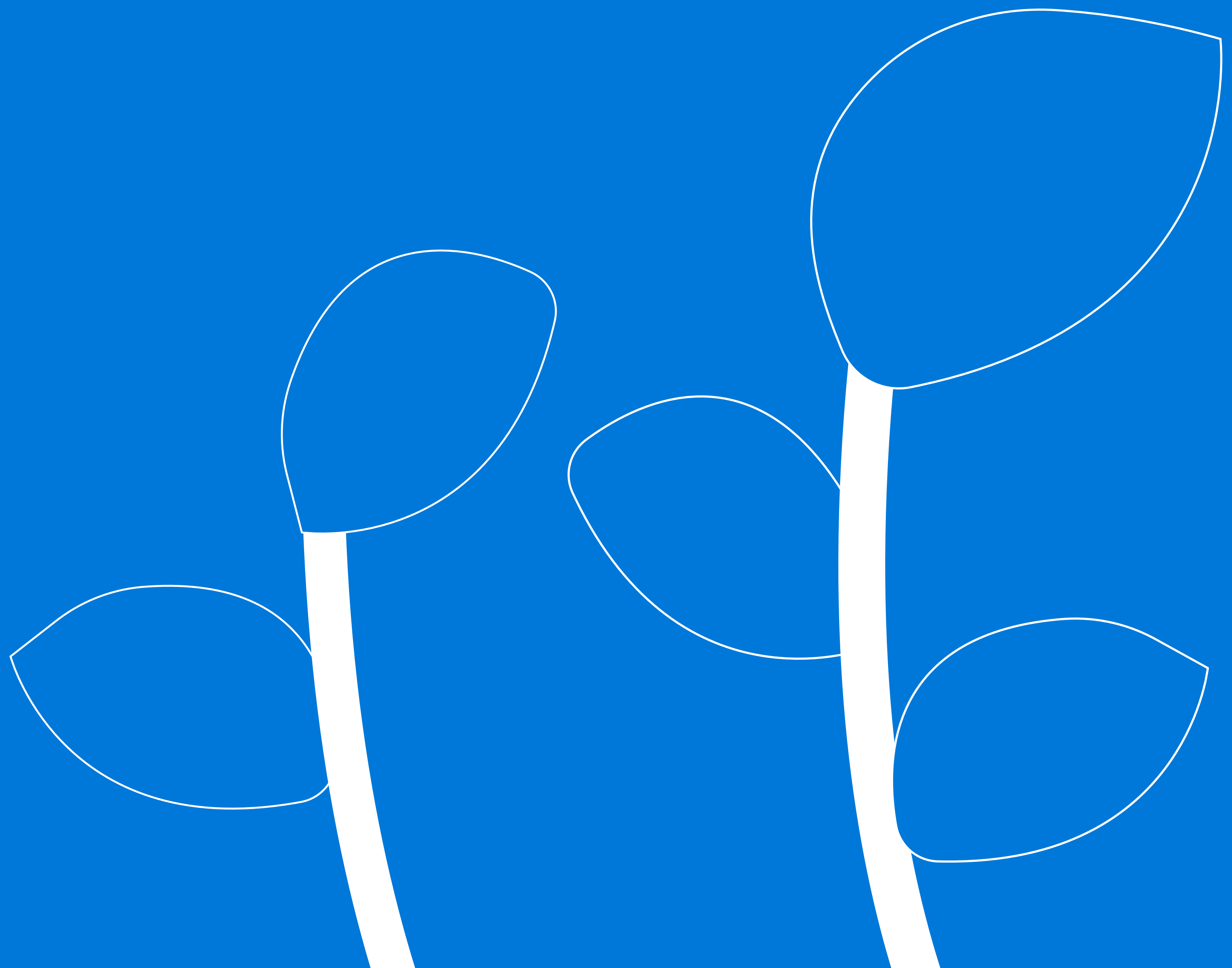

ace & tate