

LightSpray™ Technology: Innovating Athletic Footwear

Case Study of the Cloudmonster 3 Hyper – Prospective LCA



May 2026

vaayu

Executive Summary

02–04

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Executive Summary

The innovation team at Swiss athletic shoe and performance sportswear company On has invested the past seven years into developing LightSpray™ technology, an innovative athletic footwear production technology. This report, conducted by Vaayu on behalf of On, evaluates the climate change impact of LightSpray™ as it scales, using life cycle assessment (LCA). The analysis assessed a US men's size 10 LightSpray Cloudmonster 3 Hyper, produced using LightSpray™ technology in South Korea, and compared the findings to the Cloudmonster 3 Hyper Conventional process (referred to as the 'Conventional' model in this analysis).

Overview of LightSpray™ technology

LightSpray™ condenses traditional upper production, which typically requires approximately 200 steps across multiple factories for On, into a single, fully automated process. An automated robotic arm sprays specialized filament onto a last, creating an ultra-light, one-piece upper within a few minutes. The process requires less space than conventional manufacturing, avoids production waste such as pattern cutting waste and other material losses typical of conventional multi-component shoe manufacturing, and produces uppers with fewer carbon emissions compared to

On's other athletic shoes. It also eliminates the need for adhesives by bonding the upper directly to the sole in the current production setup.

The streamlined production potentially lowers the product carbon footprint (PCF) from material sourcing, material processing, shoe assembly, and transportation. Incorporating a secondary process for colour and branding application, the technology further reduces production time, enhancing manufacturing efficiency.



Scope of the analysis

The LCA compares the product carbon footprint of the Conventional shoe manufacturing system with that of the LightSpray™ technology system across all life cycle stages, from raw material extraction to end-of-life.

Both systems were analysed from a cradle-to-grave perspective, with global warming potential (GWP), measured in kg CO₂e, as the primary metric. Estimates were derived from prospective LCA models for the Baseline and three scenarios, covering variables including emissions from electricity use and the degree of air freight.

Results and comparative analysis

Baseline results indicate that On's LightSpray Cloudmonster 3 Hyper, produced using LightSpray™ technology could **reduce** the GWP by around **3.5 kg CO₂e** (using the functional unit of one pair of men's US size 10 athletic shoes).

This reduction amounts to around **24%** of the Conventional product system's carbon footprint estimate, and for the upper, around a **65%** reduction. LightSpray™ resulted in a significant reduction across most scenarios..

This significant reduction is attributed to a streamlined shoe production process, reduced components, reduced material requirements, and the elimination of several manufacturing and transportation steps.

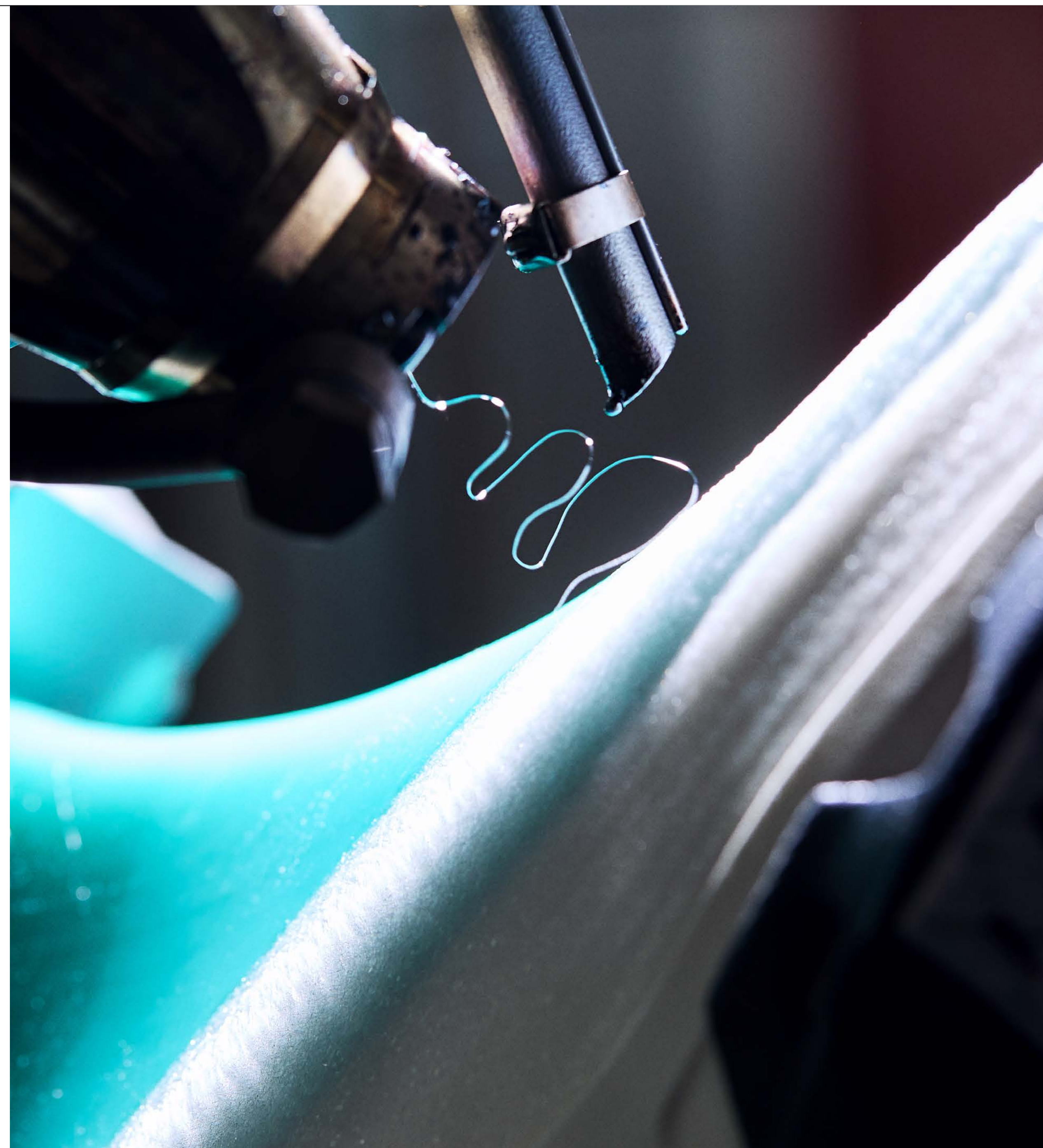
Limitations and further research

While the findings are promising, the analysis acknowledges certain limitations. As a prospective LCA, these results are inherently estimative and assumption-dependent, as is LCA more broadly.

Further primary data collection and analysis will be required as LightSpray™ technology scales to validate and refine the impact profile. Since the production technology is still new, the On team has collected data for only a limited period (production data collected in January). To create even more robust assessments in the future, On would need to collect data over a longer period of time. This is especially relevant given that, at the time of this report, the technology and production are in a ramp-up phase.

Conclusion

LCA results from this analysis indicate significant reductions in the PCF, measured in kg CO₂e, from the use of LightSpray™ technology in the production of athletic footwear. By potentially reducing the PCF and enhancing production efficiency, LightSpray™ technology can help On align with its global sustainability goals. Further research and development as the technology continues to scale will be crucial to realise LightSpray™'s potential fully and to validate the findings of this LCA.



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2. Introduction

2.1 Athletic Footwear Innovation

On recently developed LightSpray™ technology, a novel additive manufacturing technique aimed at revolutionising On's athletic footwear production. It facilitates the fabrication of an ultralight, single-piece shoe upper through a singular, streamlined process. Since introducing LightSpray™ in 2024, On has been building the operational framework for automated shoe production from the ground up. What began as a four-year development journey, followed by the opening of On's first factory in Switzerland in 2025, has now advanced significantly in scalable manufacturing.

On has now opened its second global LightSpray™ factory, this time in South Korea¹. The Korean facility features 32 fully automated robots and has launched the LightSpray Cloudmonster 3 Hyper as the first shoe upper to be sprayed there.

The robots are set to increase the brand's global LightSpray™ production capacity 30-fold in 2026, and South Korea's position as a global leader in robotics and automation, combined with On's work in the region, made it the strategic choice for the second LightSpray™ facility. The expansion marks a significant step for the brand in scaling the technology globally, with further production growth planned over the coming years.

The performance of LightSpray™ technology may vary depending on specific upper designs and selected shoe models, as material composition, weight, and manufacturing requirements differ across products. This study focuses specifically on the LightSpray Cloudmonster 3 Hyper as the representative LightSpray™ case for assessment, as it is the first model that On is producing at the new South Korean facility. For this shoe model, the technology enables the extrusion of 1.5 to 2

kilometres of a unique, continuous filament around a rotating shoe last, operated by a robotic arm, creating the upper in approximately 3 - 4 minutes per shoe. In the LightSpray Cloudmonster 3 Hyper, LightSpray™ technology enables the production of a remarkably lightweight shoe upper, averaging 47.5 grams for one US men's size 10, or 95 grams for a pair of shoes.

This upper is directly bonded to the bottom unit without adhesives, resulting in a high-performance running shoe designed to be lightweight. It is also notable that the upper contains only one component, eliminating many components and subsequent assembly processes. This streamlines manufacturing, avoids production waste such as pattern cutting waste and other material losses typical of conventional multi-component shoe manufacturing, and eliminates the need for further processing of both the upper and the

¹ More on the opening of On's new facility in South Korea is available at <https://press.on-running.com/-1wgx4h>.



entire footwear. By transforming the supply chain, LightSpray™ has the potential to reduce the product carbon footprint of On's athletic shoes.

Unlike conventional additive manufacturing robots, which move only along fixed directions (typically the x, y, and z axes), this robotic arm can move in multiple directions and angles, often with six or more degrees of freedom. This wide range of motion facilitates material deposition in various directions (vertically, horizontally, and along curves and angles), enabling complex geometries without additional supports. Additionally, the robotic arm can be fitted with various extrusion heads, enabling the processing of a wide range of materials. The technology incorporates an expedited process for applying colour and branding elements. At a secondary station, a robotic mechanism selects the shoe last, activates the polymer via a plasma process, and uses UV inkjet printing to precisely deposit colour on the upper. The robotic arm introduces a new level of versatility and precision into the manufacturing process.

LightSpray™ technology was designed to improve on the current athletic footwear production at On. In this analysis, the Cloudmonster 3 Hyper was used as the benchmark for the Conventional method currently employed at On. This was compared to the LightSpray Cloudmonster 3

Hyper: the same style of shoe model, but with the upper made using LightSpray™ technology instead of the Conventional system.

The US men's size 10 upper for the Cloudmonster 3 Hyper (Conventional model) is made with 100% recycled polyester (with negligible other materials used for small components like the logo) and weighs 306g per shoe. In comparison, the LightSpray Cloudmonster 3 Hyper (LightSpray™ model) is made with Thermoplastic Polyurethane (TPU) and weighs just 232g per shoe, and has "Sprayed in Korea" visible on the inside sole. Both models employ On's CloudTec® for impact absorption, comprising Helion™ HF Hyper Foam in the shoe bottom for maximum energy return and a bottom layer of Helion™ foam for durability. While both athletic shoes are developed for running and comfort, the LightSpray™ shoe upper doesn't have laces, and the material used is lighter on the foot. It is engineered for those who want to run faster and further, in what On calls "the ultimate super trainer for long runs and tempo runs". The shoe debuts with a limited release in North America in March 2026, with a full global launch in April 2026.

2.2 This Comparative LCA

While On's new LightSpray™ technology was previously found to offer significant potential to reduce the carbon footprint of its athletic shoes

(LightSpray™ technology: Prospective LCA, 2024²), it has since moved from the ideation phase into scaling. It is worth noting that the results of this analysis differ from those reported in Vaayu's 2024 LCA of LightSpray™ production in Switzerland. These differences are primarily attributable to the latest updates to the assessed shoe model, production scaling, and the relocation of manufacturing from Switzerland to South Korea. With that transition comes changes in the technology's climate impact, driven by increased production and the introduction of new or altered variables, such as manufacturing location, suppliers/factories, production set-ups, and electricity use.

This 2026 investigation offers updated insights into the carbon footprint impacts of LightSpray™ technology as it scales, using prospective attributional LCA. The comparative assessment was once again carried out by Vaayu on behalf of On, building on the previous LCA conducted together in 2024. The prospective LCA LightSpray™ results were compared with those from an attributional LCA of the current Conventional technology used by On to produce the same style shoe but with a different upper manufacturing technology.



²The 2024 report is available at <https://s3.us-east-1.amazonaws.com/cdn.on-running.com/sustainability/lightspray-life-cycle-assessment-full-report.pdf>.

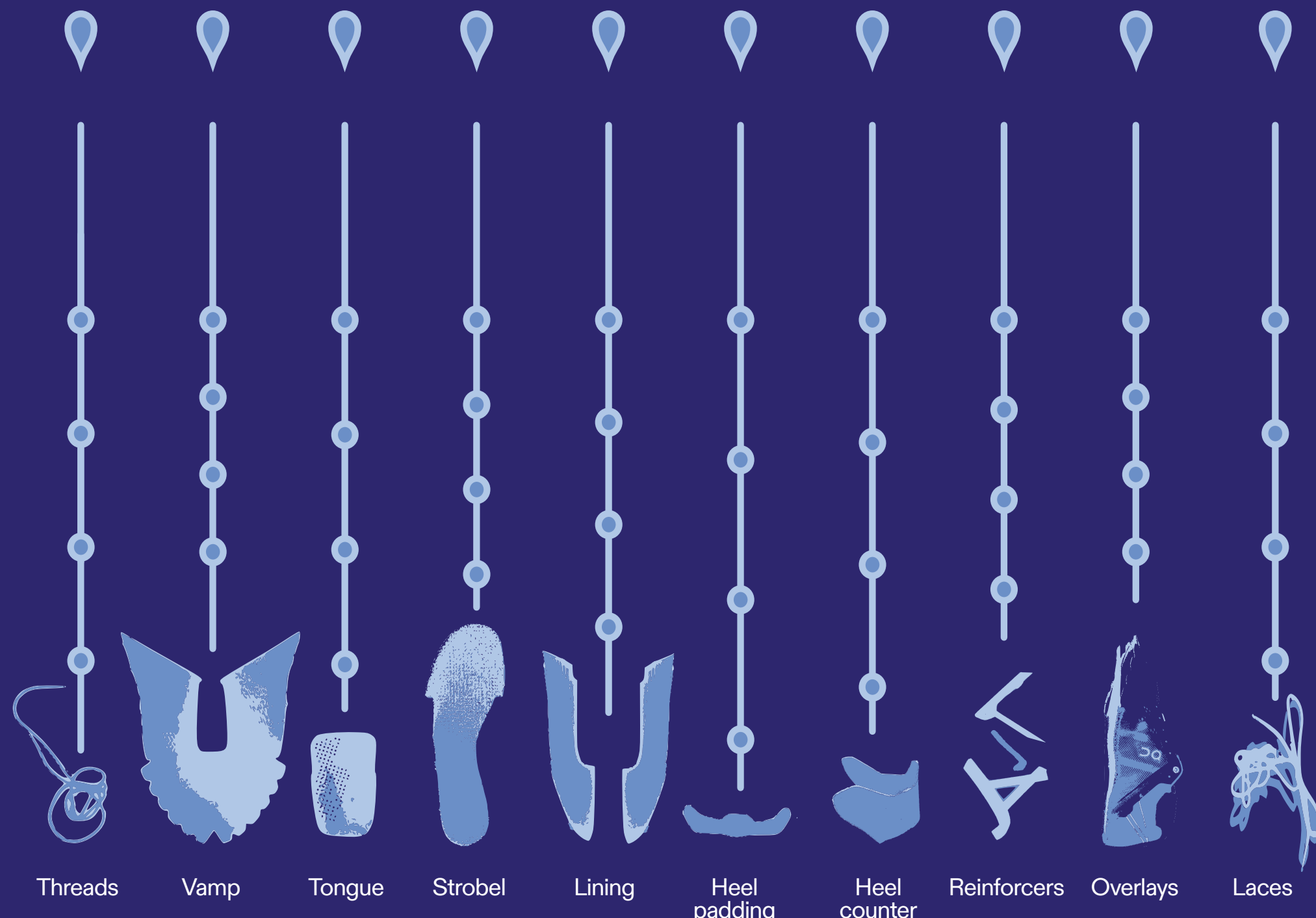
Conventional footwear making vs. LightSpray™

BASE MATERIALS

T2 / T3 FACTORIES

T1 FACTORY

FINAL SHOE



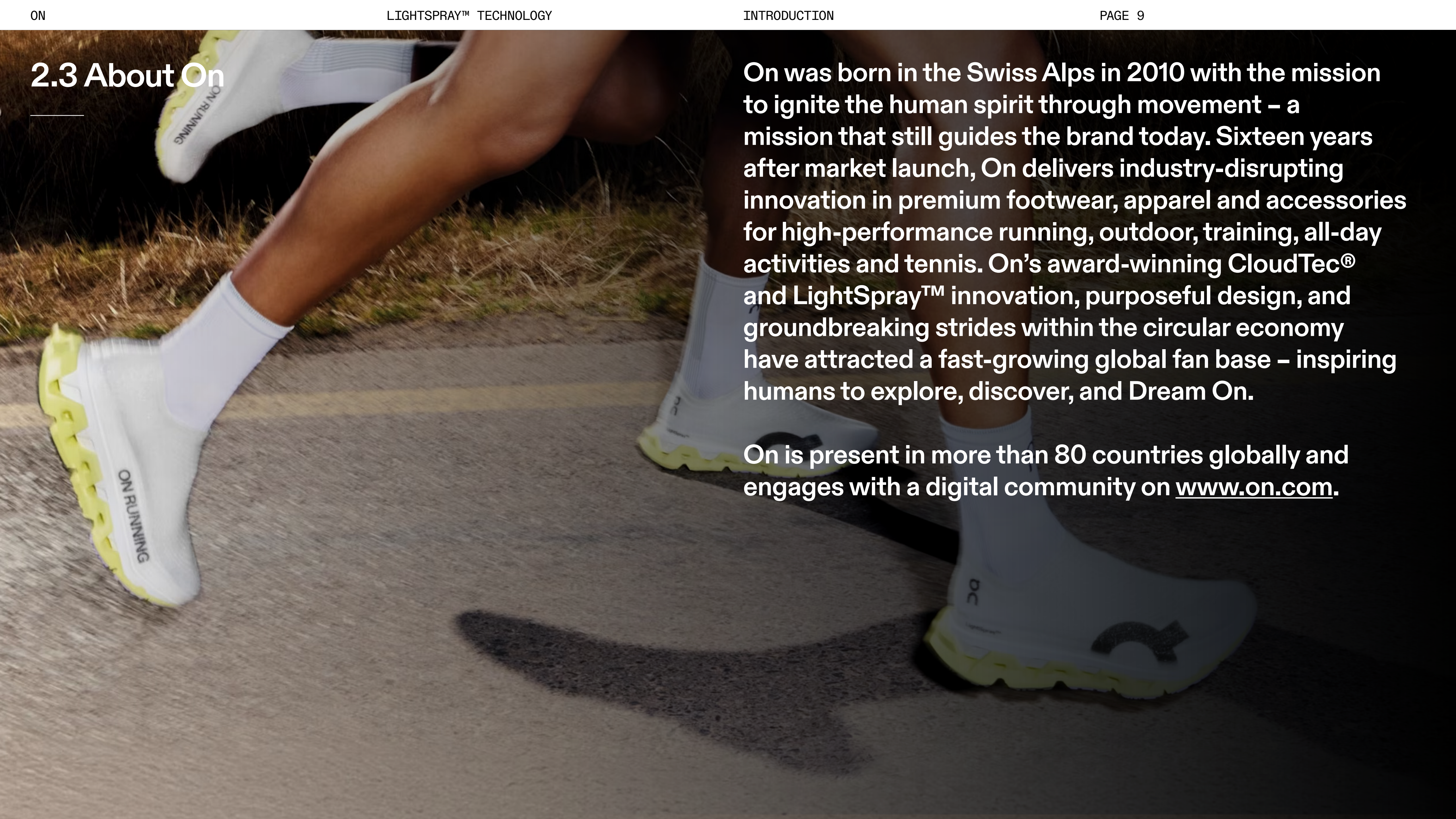
APPROX. 200 STEPS



*This solely refers to the upper manufacturing and final assembly process



2.3 About On



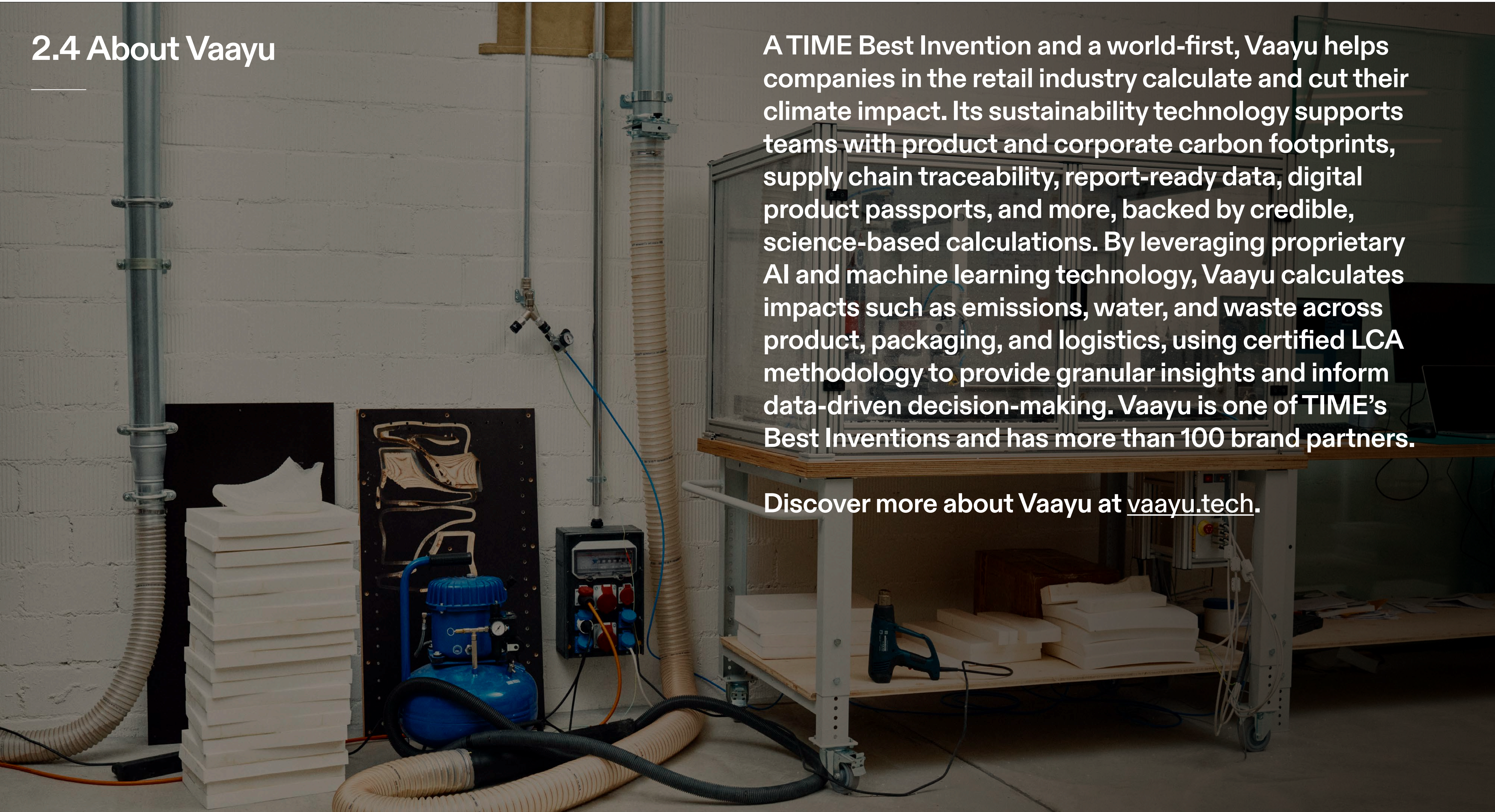
On was born in the Swiss Alps in 2010 with the mission to ignite the human spirit through movement – a mission that still guides the brand today. Sixteen years after market launch, On delivers industry-disrupting innovation in premium footwear, apparel and accessories for high-performance running, outdoor, training, all-day activities and tennis. On's award-winning CloudTec® and LightSpray™ innovation, purposeful design, and groundbreaking strides within the circular economy have attracted a fast-growing global fan base – inspiring humans to explore, discover, and Dream On.

On is present in more than 80 countries globally and engages with a digital community on www.on.com.

2.4 About Vaayu

A TIME Best Invention and a world-first, Vaayu helps companies in the retail industry calculate and cut their climate impact. Its sustainability technology supports teams with product and corporate carbon footprints, supply chain traceability, report-ready data, digital product passports, and more, backed by credible, science-based calculations. By leveraging proprietary AI and machine learning technology, Vaayu calculates impacts such as emissions, water, and waste across product, packaging, and logistics, using certified LCA methodology to provide granular insights and inform data-driven decision-making. Vaayu is one of TIME's Best Inventions and has more than 100 brand partners.

Discover more about Vaayu at vaayu.tech.



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3. Goal and Scope

3.1 Purpose

The goal of this analysis is to assess the lower climate-impact potential of On's LightSpray™ technology, a development designed to reduce the climate impact of On's athletic shoes as production scales.

The analysis is structured around several specific objectives:

- **Prospective attributional LCA of LightSpray™ technology, applied to a specific shoe model:** Conduct a prospective attributional LCA for LightSpray™ technology, applied to the manufacturing of the LightSpray Cloudmonster 3 Hyper shoe model.
- **Attributional LCA of the Conventional technology, applied to the same style shoe model:** Conduct an attributional LCA for the existing Conventional technology, applied to the manufacturing of the Cloudmonster 3 Hyper.
- **Comparative analysis:** Execute a comparative analysis between the Cloudmonster 3 Hyper and the LightSpray Cloudmonster 3 Hyper, including three different LightSpray™ manufacturing/freight scenarios (the Conventional versus the LightSpray™ technology).
- **Additional insights:** Uncover and report additional insights.

This assessment was conducted in accordance with ISO 14040 and ISO 14044 requirements for life cycle assessment. It is a single-category LCA, focusing exclusively on climate change as the impact category, measured as Global Warming Potential (GWP) in kg CO₂e. This focus on the product carbon footprint reflects On's current company climate goals, which prioritise reducing greenhouse gas emissions across its product portfolio.

3.2 System Boundary and Process Systems

Two product systems were compared in this analysis: one athletic footwear production system that uses On's LightSpray™ and the other that uses On's Conventional technology.

Both systems were assessed from cradle to grave. The analysis covered seven life cycle stages, from raw material extraction and processing to the end of the product's life. Further details on each life cycle stage are shown in Table 1.



Table 1. Life Cycle Stages and Unit Processes Included in the Assessment

Life Cycle Stage	Unit Processes Included
Raw Material Extraction and Processing	<ul style="list-style-type: none"> – Production or extraction of raw textile, rubber, plastic materials, and trims – Transport of raw materials to the component manufacturing plant
Manufacturing and Assembly	<ul style="list-style-type: none"> – Yarn production, fabric manufacturing, wet processing, and dyeing – Upper stitching, midsole production, outsole production, and insole production – Stock fitting and shoe assembly – Transportation of intermediate products between manufacturing and assembly
Packaging	<ul style="list-style-type: none"> – Packaging production – End-of-life of packaging
Inbound Transportation	<ul style="list-style-type: none"> – Transportation from the manufacturing location to the warehouse
Distribution	<ul style="list-style-type: none"> – Transportation from the warehouse to retail – Transportation from the warehouse to the final client
Product Use	<ul style="list-style-type: none"> – Customer use and care of the product
End-of-Life	<ul style="list-style-type: none"> – Disposal of the product at the end of its useful life



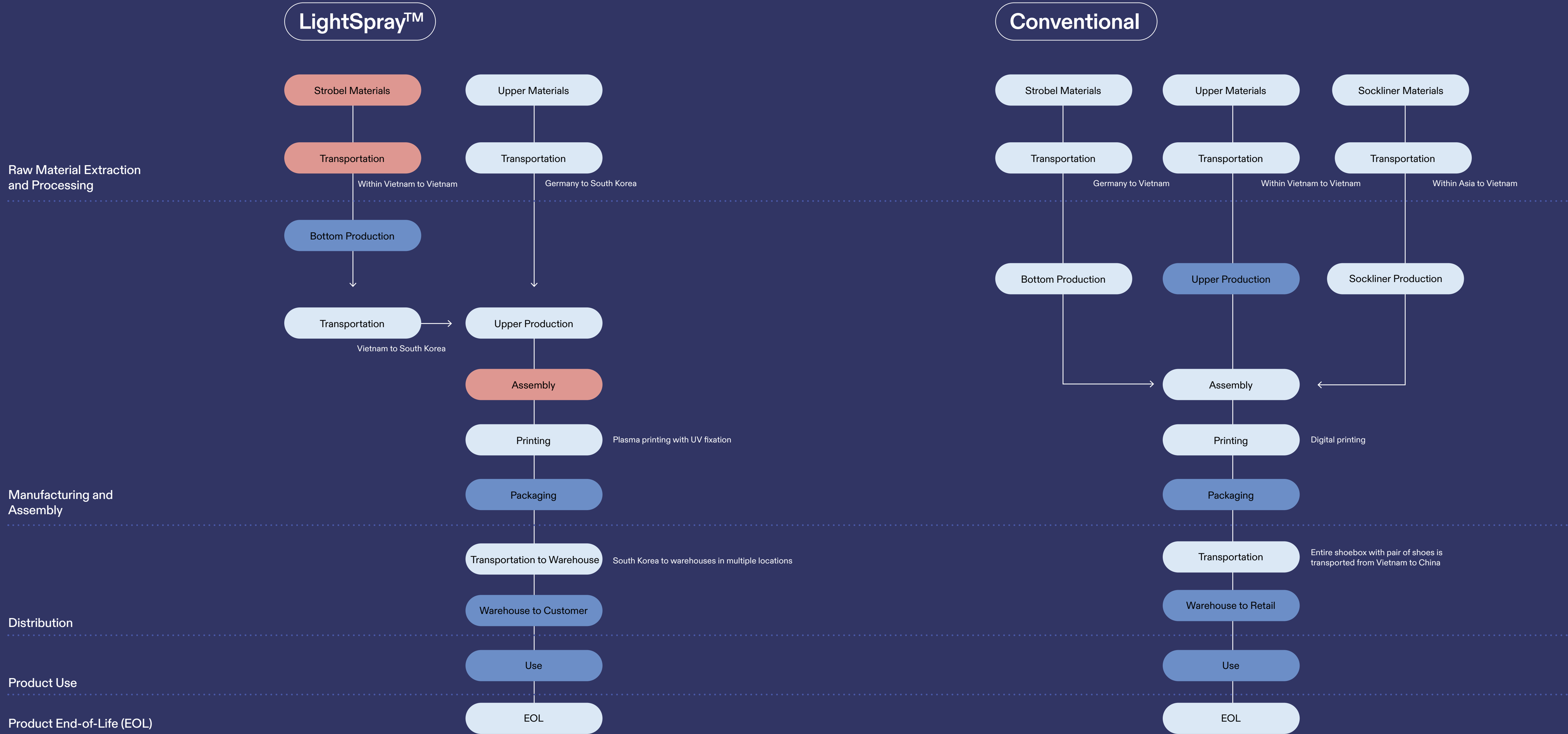
This system boundary is illustrated in Figure 1 and aligns with the Product Environmental Footprint Category Rules (PEFCR) for Apparel & Footwear³.

³ More information on the PEFCR for Apparel & Footwear is available at <https://pefapparelandfootwear.eu/>.

Figure 1: Model System Boundary (Adapted from the PEFCR for Apparel & Footwear)



Figure 2: Comparing the Two Product Systems



3.3 Functional Unit

One functional unit was used to assess the impact of LightSpray™: one pair of **athletic running shoes in a men's US size 10**. Calculating one whole pair of running shoes enabled a full product comparison from cradle to grave, with no need to allocate upper versus bottom impacts.

3.4 Scenarios

In addition to calculating the Baseline, three scenarios were investigated to estimate the impact of LightSpray™ technology. The methodology for each scenario is explained in this section.

Baseline: Baseline of the LightSpray Cloudmonster 3 Hyper

The location-based emission factor for the upper manufacturing (and consequently, shoe assembly) in South Korea was assumed. The LightSpray™ process uses the conventional energy mix of South Korea. Inbound transport was modeled the same way as the Conventional shoe, with only 7% by air freight and the rest by sea. This reflects On's actual inbound transport data for the Conventional shoe, applied consistently to the LightSpray™ Baseline.

Scenario 1: Change to the LightSpray Cloudmonster 3 Hyper – 100% Air Freight for Inbound Transport

The worst-case scenario assumed that inbound transport in the LightSpray™ system occurs 100% by air, while transportation for the Conventional shoe system remains the same.

Scenario 2: Change to the LightSpray Cloudmonster 3 Hyper – Renewable Energy for Manufacturing the Shoe's Upper

This scenario, with only a minor change to the Baseline, assumed that the LightSpray™ system uses 100% renewable energy at the LightSpray™ production site, while the energy for the Conventional shoe system remains the same, as it is being produced in a different production location.

Scenario 3: Changes to the LightSpray Cloudmonster 3 Hyper – Renewable Energy for Manufacturing the Shoe's Upper & Lower-Emission Autoclave Foaming for Manufacturing the Shoe's Bottom

The most optimistic scenario assumes not only that the LightSpray™ system uses 100% renewable energy, but also that the LightSpray™ shoe's autoclave foaming manufacturing stage for the shoe bottom has a lower climate impact. At this stage, this is a purely theoretical scenario that enables On to test how further optimisations, such as an optimised midsole production process, more efficient production of supercritical gas, a closed-loop system, and reduced defect rates, could change the impact of the LightSpray™ production process.

3.5 Main Assumptions and Limitations

This section outlines the assumptions and limitations inherent in the analysis, providing a framework for further understanding the scope and constraints of this analysis and highlighting



any potential barriers to the applicability or interpretation of the results.

Assumptions

Applicable to both the Cloudmonster 3 Hyper and the LightSpray Cloudmonster 3 Hyper models:

- Distribution uses two routes, e-commerce and retail stores: the distances and transport modes were based on the PEFCR for Apparel & Footwear.
- Use phase and end-of-life modelled based on the PEFCR for Apparel & Footwear.

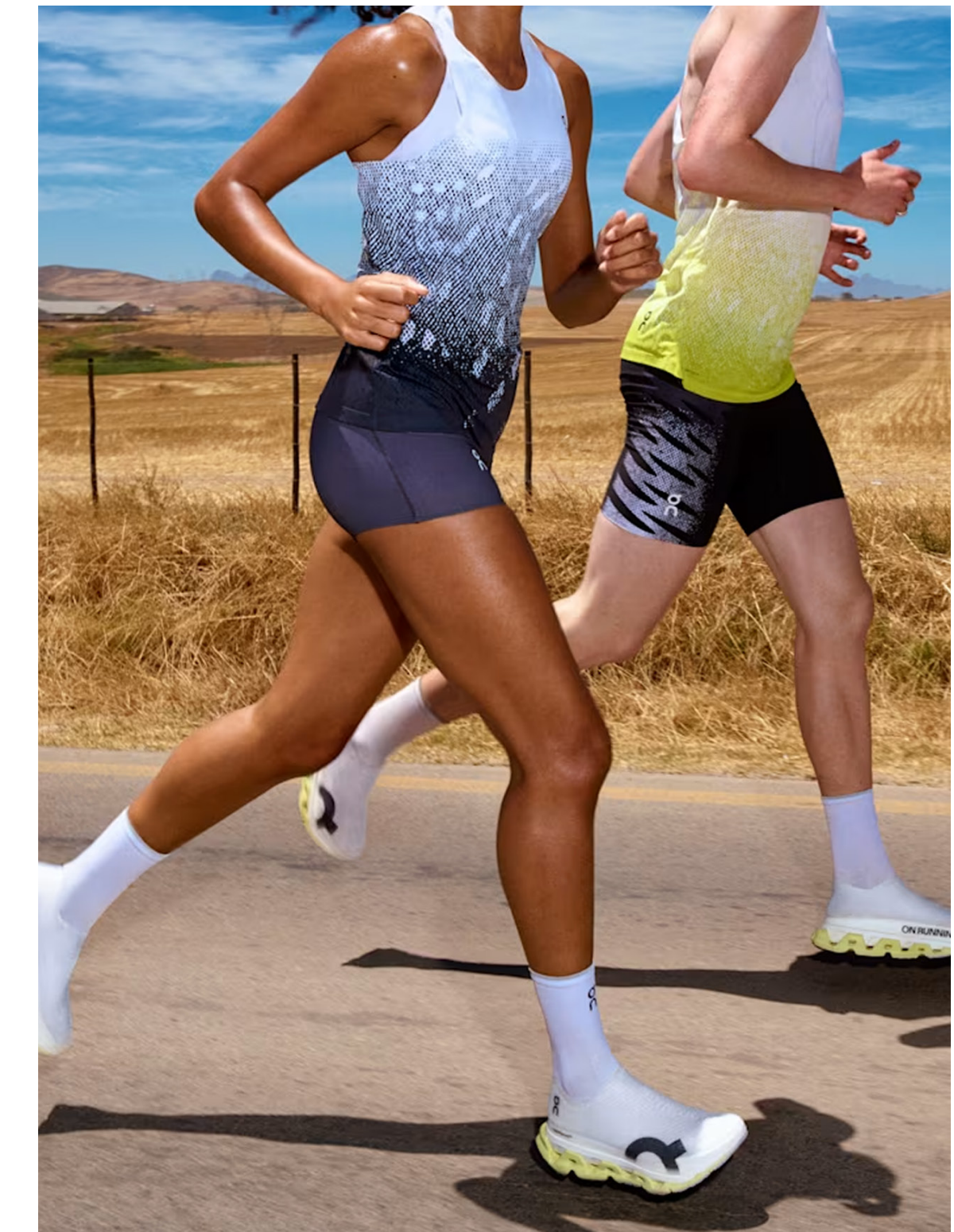
Applicable only to the Conventional Cloudmonster 3 Hyper shoe model:

- When the country of origin of a component was not assigned, Vietnam was assumed, as the main product assembly occurs there.
- Laminated components have the following mass split: TPU/PU: 20%, textile 80%.
- Packaging materials for some components, such as outer tape, were assumed to be the same as those used for the LightSpray™ system.

Limitations

The limitations of the analysis acknowledge the constraints and challenges that may affect the interpretation and applicability of its findings. These limitations include:

- Primary data regarding autoclave foaming was not available: the emission factor was based on estimates rather than on actual energy-use measurements for this process.
- Production of the robot arm and the infrastructure for the Conventional method were out of scope.
- Further efficiencies that can be gained through scale, once the technology achieves full commercialisation and steady state, were not included in this analysis.
- To take a conservative approach, the potential for higher recyclability of the LightSpray™ product was not included in the end-of-life model.
- As a single-category assessment, this LCA focuses solely on climate change impact (PCF, measured in kg CO₂e) and does not capture other potential environmental impacts. This scope was chosen to align with On's current climate goals.



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4. Life Cycle Inventory

This section outlines the life cycle inventory data used in the calculations for both of On's manufacturing systems.

The emission factors used refer to the amount (in kg) of greenhouse gases (GHGs) per unit process, including carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF₆), and perfluorocarbons (PFCs).

Background data, such as electricity mix, energy technology emission factors, and material impacts, were assumed to remain the same between the two systems.

4.1 Data Sources and Data Quality Assessment

Vaayu's carbon modelling is designed to rely on a combination of primary data (from direct measurement of a known process, which may be site-specific) and secondary data (from published and peer-reviewed literature, established emission factors, and other representative data). Vaayu's purpose-built impact modelling engine and database prioritise primary data whenever available, which can be added via manual enrichment or automated extraction.

The included data were assessed and categorised by Vaayu according to standard quality criteria, including geographical coverage, temporal relevance, technological coverage, completeness, and methodological quality, so that the most relevant and reliable data can be automatically selected when computing a product footprint.

Like all LCA studies, Vaayu's calculations are estimates subject to uncertainty, including both variation and systematic error.



4.2 Weights Per Part (g)

Primary data on part and component masses were obtained by weighing athletic footwear, particularly the Cloudmonster 3 Hyper, produced using the Conventional technology. These data were mainly used for modelling the Conventional technology.

Table 2: Mass Per Shoe Part for the Cloudmonster 3 Hyper (the Conventional Model)

Placement Footwear	Net Material Weight Per Piece (g)	Placement Footwear	Net Material Weight Per Piece (g)
Upper	111.2	Medial Foxing Reinforcement	2.9
Vamp	27	Toe Box	9.4
Eyrow TPU	4.2	Counter	6.5
Foxing Lateral	4.7	Add-Ons	3.7
Foxing Medial	3.1	Tip Reinforcement Tape	0.1
Heel Logo	0.1	Collar Reinforcement Tape	0.1
Top Tongue	3.2	Lace	3.5
Tongue Bottom	4	Sockliner	20.3
Tongue Foam	1.2	Moulded Sockliner	20.3
Tongue Bottom Nasa	0.1	Insole	4.3
Vamp Lining	11.2	Insole	4.3
Collar Lining	7.2	Bottom	166.7
Collar Foam	5.2	Outsole	41.3
Eyrow Lining	7	Top Midsole	67.4
Collar Reinforcement Lateral	11	Bottom Midsole	58
Lateral Foxing Reinforcement	3.3		

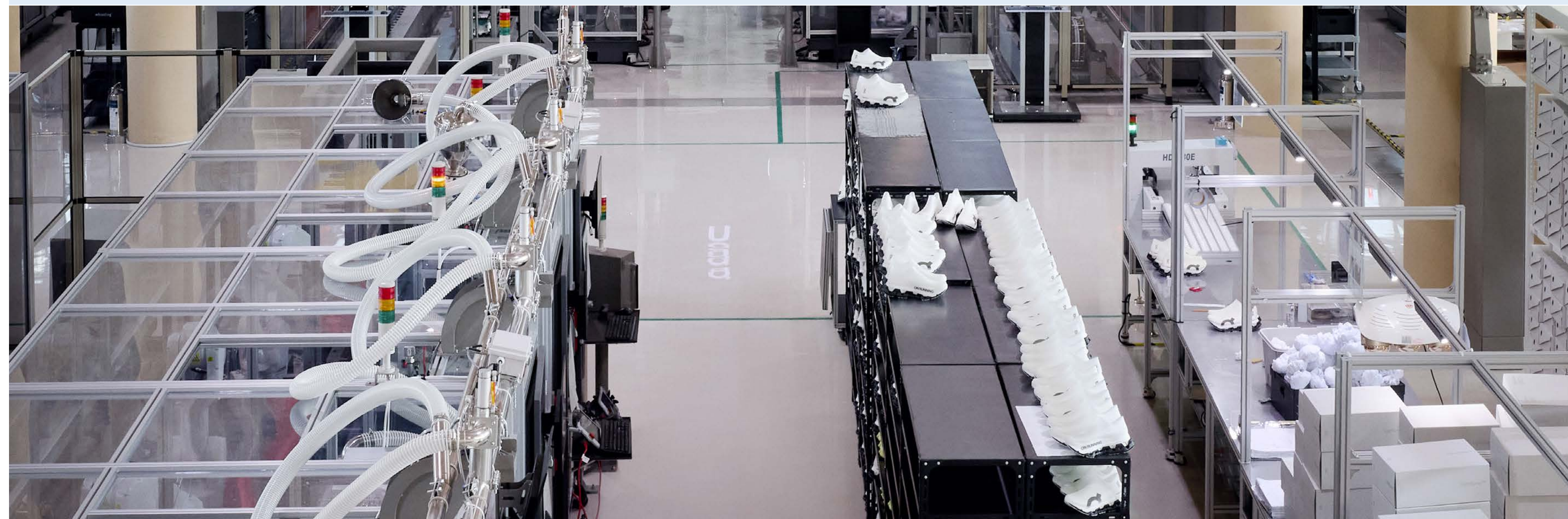
4.3 Conventional Model (Cloudmonster 3 Hyper) Inventory

In the Conventional process, On provided the type and origin of the materials used for shoe production. Mass per material composition was derived based on the part and component mass. Transportation of materials to the manufacturing plant in Vietnam and the subsequent shipment of finished shoes to different warehouses in the Americas, Asia, and Europe, using primary data on material origins, estimated masses, modes of transportation, and estimated transportation distances. The end-of-life (EOL) phase was analysed based on product mass, and secondary data on average waste treatment for fashion articles was applied.

Table 3: Conventional Model (Cloudmonster 3 Hyper) System Parameters

Life Cycle Stage	Unit Process	Amount (Average)	Unit of Measurement	Emission Factor Source	Note
Raw Material Extraction and Processing	Upper materials (see Appendix A for details)	118.6	g	Vaayu	
	Upper transportation	See Appendix B	km	Vaayu	
	Add-on materials (see Appendix A for details)	3.7	g	Vaayu	
	Add-on materials transportation	See Appendix B	km	Vaayu	
	Sockliner materials (see Appendix A for details)	20.3	g	Vaayu	
	Sockliner transportation	See Appendix B	km	Vaayu	
	Insole materials (see Appendix A for details)	4.3	g	Vaayu	
	Insole transportation	See Appendix B	km	Vaayu	
	Bottom materials (see Appendix A for details)	166.7	g	Vaayu	
	Bottom transportation	See Appendix B	km	Vaayu	
Manufacturing and Assembly	Energy consumption for shoe assembly	2.44	kWh/kg	Vaayu	
Inbound Transport	Transport from Vietnam to Americas Region	17082 by ship 14030 by plane	km	Vaayu	Only 7% of transport is done via plane
	Transport from Vietnam to Europe Region	16555 by ship 9905 by plane	km	Vaayu	Only 7% of transport is done via plane

Life Cycle Stage	Unit Process	Amount (Average)	Unit of Measurement	Emission Factor Source	Note
Inbound Transport	Transport from Vietnam to Asia Region	3812 by ship 3531 by plane	km	Vaayu	Only 7% of transport is done via plane
Distribution	Warehouse to local warehouse	500 by road	km	Vaayu	
	E-commerce	250 by road	km	Vaayu	76% ecommerce route
	Retail store	1200 by road	km	Vaayu	24% retail store route
Use Phase	Product use across the entire lifetime	612.5	g	Vaayu	
End-of-Life	Footwear EOL Model	612.5	g	Vaayu	



4.4 LightSpray™ Inventory

For LightSpray™, the source of virgin TPU pellets was identified as Germany, with no further material preparation such as grinding and mixing with additives or plasticisers. No post-processing of the upper component was needed in LightSpray™. The other key step in making the shoes was adding designs through printing, which, in LightSpray™'s new method, would involve plasma printing with UV fixation for better results. Primary data on estimated energy consumption and ink usage were used.



Table 4: LightSpray™ Technology System Parameters

Life Cycle Stage	Component	Process/Material	Amount	Unit Measurement	Note
Raw Material Extraction and Processing	Bottom - Top Midsole	Material - PEBAX	185	g	
		Transportation of PEBAX from France to Vietnam	16166	km	Done via cargo ship
	Bottom - Bottom Midsole	Material - EVA	132	g	
		Transportation of EVA within Vietnam	1732	km	Done via truck
	Bottom - Outsole	Material - Synthetic Rubber	114	g	
		Transportation of Synthetic Rubber from China to Vietnam	2627	km	Done via truck
Upper	Upper Material — Thermoplastic Polyurethane (TPU) Pellets	118 (gross weight before production, 95 net weight after waste)	g		
		Transportation of TPU from Germany to South Korea	20453	km	
Manufacturing and Assembly	Bottom	Transportation of Bottom from Vietnam to South Korea — Road	6041	km	
	Upper	LightSpray™ Process and Printing	0.86	kWh	

Life Cycle Stage	Component	Process/Material	Amount	Unit Measurement	Note
Inbound Transport	Shoes	Transport from South Korea to Americas Region	13803 by ship 10615 by plane	km	Only 7% of transport is done via plane
	Shoes	Transport from South Korea to Europe Region	19994 by ship 9003 by plane	km	Only 7% of transport is done via plane
	Shoes	Transport from South Korea to Asia Region	1075 by ship 897 by plane	km	Only 7% of transport is done via plane
Distribution	Shoes	From warehouse to local warehouse	500 by road	km	
	Shoes	E-commerce	250 by road	km	76% e-commerce route
	Shoes	Retail store	1200 by road	km	24% retail store route
Use Phase	Shoes	Product use across the entire lifetime	464	g	Vaayu. 464g represents the weight of a pair of shoes
End-of-Life	Shoes	Collection and waste treatment of used shoes	464	g	



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<small>‘Conventional’ Technology: Cloudmonster 3 Hyper Product Carbon Footprint LightSpray™ Technology Baseline: LightSpray Cloudmonster 3 Hyper Product Carbon Footprint Product Carbon Footprint for Other Scenarios</small>	
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5. Life Cycle Impact Analysis

The greenhouse gas estimates from the life cycle inventory were converted to the midpoint indicator value for GWP (in kg CO₂e) using the IPCC 2021 impact assessment method.

The following sections summarise the impact analysis results for each scenario.



5.1 ‘Conventional’ Technology: Cloudmonster 3 Hyper Product Carbon Footprint

In this section, the Baseline GWP estimates for the Conventional model’s product system are provided. Key findings include the following data.

Raw material extraction and processing

22.7%

The upper materials are the second-highest GWP contributors in this stage, with a GWP of 0.97 kg CO₂e.

The add-on materials have a GWP of 0.03 kg CO₂e.

The sockliner materials contribute 0.32 kg CO₂e GWP.

The insole materials have a GWP of 0.03 kg CO₂e.

The bottom materials (outsole and midsoles) are the largest contributors to GWP in this stage, accounting for 1.97 kg CO₂e.

Material processing

55%

Material processing contributes significantly to GWP, accounting for 8.03 kg CO₂e, or 55% of the total GWP.

Among the material processing, bottom production material processing contributes 5.67 kg CO₂e GWP.

Assembly

7.9%

The assembly stage contributes 1.15 kg CO₂e GWP.

Inbound transport

4.6%

Inbound transport contributes 0.67 kg CO₂e GWP.

Distribution

2.1%

The transportation GWP for the boxed pair of shoes from the warehouse was estimated at 0.31 kg CO₂e.

Product use

0.7%

Product-use-phase GWP was estimated at 0.1 kg CO₂e.

End-of-life

3.9%

EOL contributed marginally, with an estimated GWP of 0.57 kg CO₂e.

Upper allocated global warming potential

The GWP specifically allocated to the upper stage is estimated as 3.58 kg CO₂e.

3.58 kg CO₂e

Total global warming potential

14.62 kg CO₂e

The total calculated GWP was 14.62 kg CO₂e.

Table 5: Conventional Model GWP Estimate Per Life Cycle Stage (Baseline)

Raw Material Extraction and Processing	Upper	Materials	0.97
	Add-ons	Materials	0.03
	Sockliner	Materials	0.32
	Insole	Materials	0.03
	Bottom Midsole	Materials	0.67
	Top Midsole	Materials	0.96
	Outsole	Materials	0.34
Manufacturing and Assembly	Upper	Production	2.19
	Add-ons	Production	0.09
	Sockliner	Production	0.07
	Insole	Production	0.02
	Bottom	Production	5.67
	Assembly of the entire shoe	Production	1.15
Packaging	-	-	0.46
Inbound Transport	Transportation to the warehouse	-	0.67
Distribution	Warehouse to the customer	-	0.31
Product Use	-	-	0.1
End-of-Life	-	-	0.57
TOTAL	-	-	14.62



5.2 LightSpray™ Technology

Baseline: LightSpray Cloudmonster 3 Hyper Product Carbon Footprint

Provided in this section is a breakdown of the estimated GWP in kg CO₂e across various life cycle stages of the LightSpray™ product system, from raw materials extraction to end-of-life.

Raw material extraction and processing

24.7% Upper materials production contributes 0.72 kg CO₂e GWP.

The top/bottom midsole combined accounts for 1.66 kg CO₂e GWP, which has a significant impact on the raw materials stage.

Outsole contributes 0.37 kg CO₂e GWP.

Manufacturing and assembly

4.6% Upper production and assembly contribute marginally to GWP, accounting for 0.51 kg CO₂e, or less than 5% of the total.

56.6% Midsoles and outsoles account for 5.8 kg CO₂e GWP, which is among the highest across all production stages.

Inbound transportation

3.6% Inbound transportation, from the assembly site to the warehouse, was estimated at 0.4 kg CO₂e GWP, with a higher impact than distribution because the shipping distance from Korea to Europe and North America is longer.

Distribution

Transportation from the warehouse to the final customer was estimated to be 0.27 kg CO₂e GWP. Road transport is assumed for this stage.

2.4%

Product use

0.7% Product use emissions were estimated at 0.08 kg CO₂e.

End-of-life

3.9% EOL contributes marginally, with an estimated GWP of 0.43 kg CO₂e.

Upper allocated global warming potential

The GWP specifically allocated to the upper stage is estimated as 1.23 kg CO₂e.

1.23 kg CO₂e

Total global warming potential

11.13 kg CO₂e

The total GWP is 11.13 kg CO₂e, about 23.9% lower than that of the Conventional shoe.

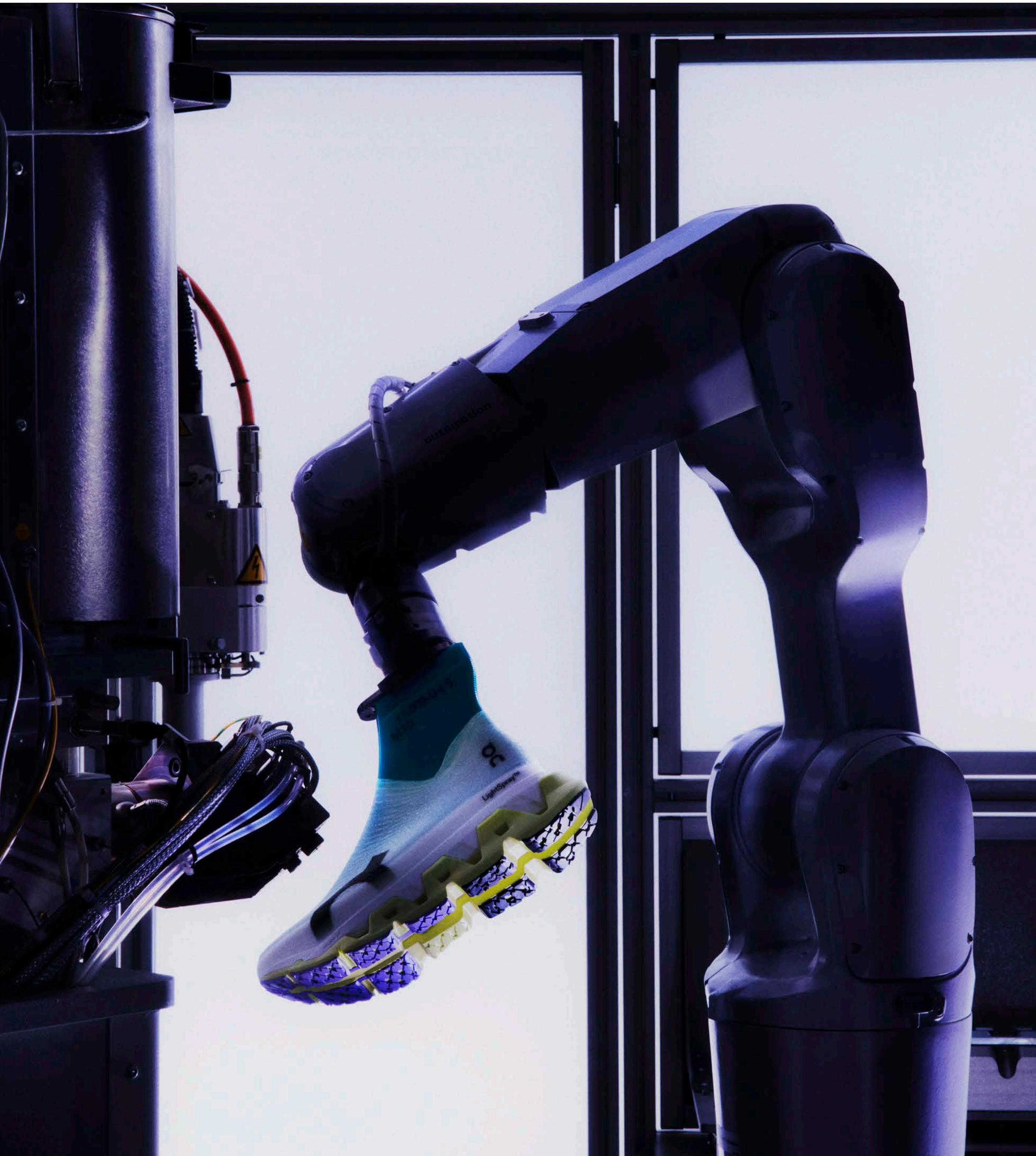


Table 6: LightSpray™ GWP Estimate Per LightSpray Cloudmonster 3 Hyper Life Cycle Stage (Baseline)

Life Cycle Stage	Unit Process		GWP kg (CO ₂ e)
Raw Material Extraction and Processing	Upper	Materials	0.72
	Top midsole	Materials	0.87
	Bottom midsole	Materials	0.79
	Outsole	Materials	0.37
Manufacturing and Assembly	Upper	Production and assembly	0.51
	Midsoles and outsole	Production and assembly	5.79
Packaging	-	-	0.9
Inbound Transport	Transportation to the warehouse	-	0.4
Distribution	Warehouse to the customer	-	0.27
Product Use	-	-	0.08
End-of-Life	-	-	0.43
TOTAL	-	-	11.13



5.3 Product Carbon Footprint for Other Scenarios

This section summarises the impact estimates for both product systems across the three scenarios investigated, with main considerations centred on electricity consumption and the transportation of shoes/shoe parts by air.



Table 7: Life Cycle GWP Estimates for LightSpray™ for All Scenarios

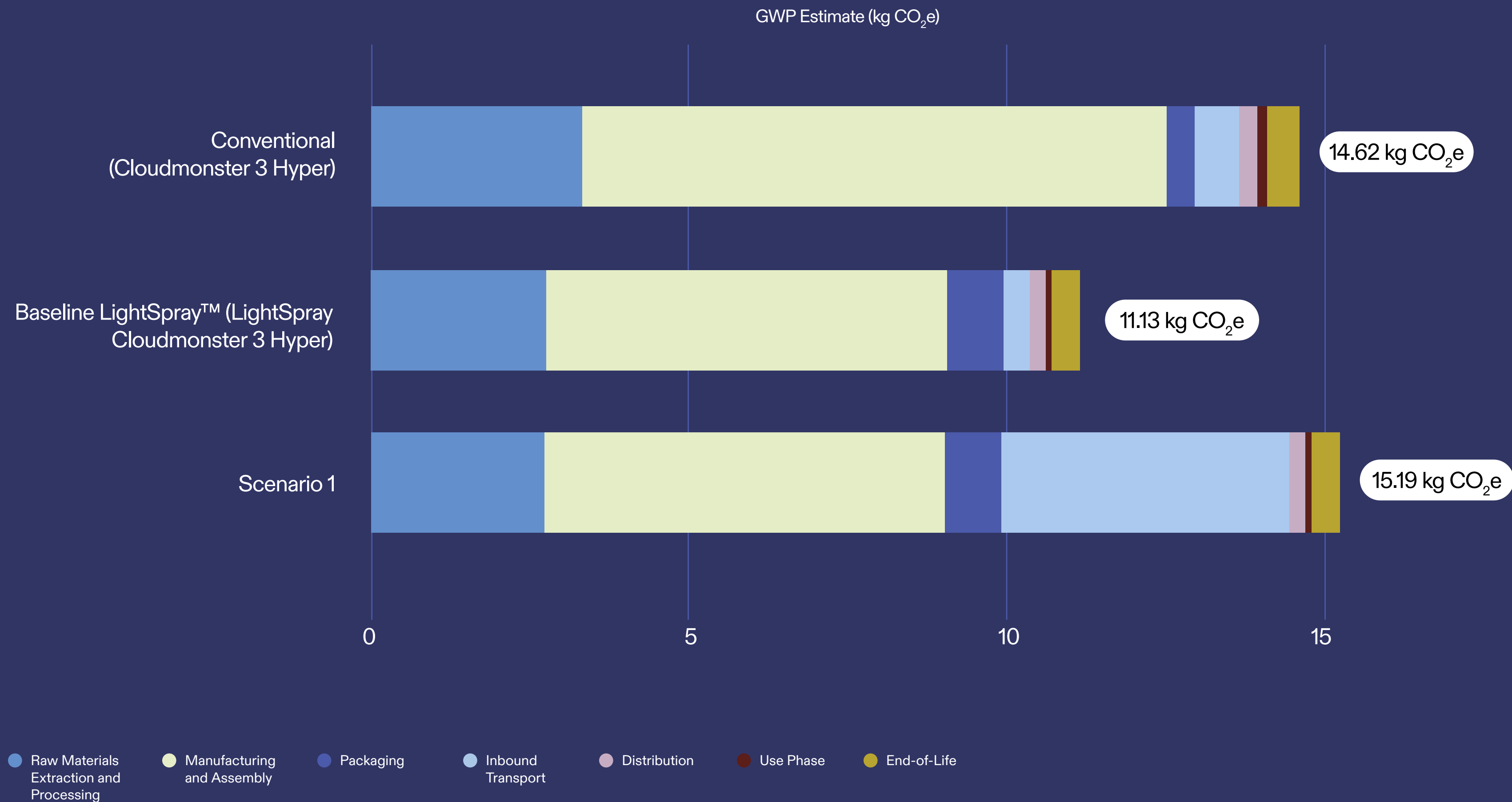
Life Cycle Stage	Unit Process		Baseline: Baseline of the LightSpray Cloudmonster 3 Hyper	Scenario 1: Change to the LightSpray Cloudmonster 3 Hyper – 100% Air Freight for Inbound Transport	Scenario 2: Change to the LightSpray Cloudmonster 3 Hyper – Renewable Energy for Manufacturing the Shoe's Upper	Scenario 3: Changes to the LightSpray Cloudmonster 3 Hyper – Renewable Energy for Manufacturing the Shoe's Upper & Lower-Emission Autoclave Foaming for Manufacturing the Shoe's Bottom
			GWP (kg CO ₂ e)	GWP (kg CO ₂ e)	GWP (kg CO ₂ e)	GWP (kg CO ₂ e)
Raw Material Extraction and Processing	Upper	Materials	0.72	0.72	0.72	0.72
	Top midsole	Materials	0.87	0.87	0.87	0.87
	Bottom midsole	Materials	0.79	0.79	0.79	0.79
	Outsole	Materials	0.37	0.37	0.37	0.37
Manufacturing and Assembly	Upper	Production and assembly	0.51	0.51	0.07	0.07
	Midsoles and outsole	Production and assembly	5.79	5.79	5.79	4.77
Packaging	-	-	0.9	0.9	0.9	0.9
Inbound Transport	Transportation to the warehouse	-	0.4	4.47	0.4	0.4
Distribution	Warehouse to the customer	-	0.27	0.27	0.27	0.27
Product Use	-	-	0.08	0.08	0.08	0.08
End-of-Life	-	-	0.43	0.43	0.43	0.43
TOTAL	-	-	11.13	15.19	10.69	9.67

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Figure 4: GWP Comparison: Conventional and LightSpray™ Technology Product Systems (Scenario 1)

Scenario 1

GWP Comparison: Change to the LightSpray Cloudmonster 3 Hyper – 100% Air Freight for Inbound Transport



6.2 Scenario Comparisons

Scenario 1: Change to the LightSpray Cloudmonster 3 Hyper – 100% Air Freight for Inbound Transport

In this scenario, the only change is the transportation of the product from the manufacturing site to On's logistics distribution sites in Asia, Europe, and North America. In this scenario, all transportation is conducted exclusively by air. Results demonstrate how logistics can play a crucial role in a product's total footprint and the significant climate impact of air freight transport. The total climate change result of the LightSpray Cloudmonster 3 Hyper, manufactured with LightSpray™ technology, is now 4% higher than that of the Conventional shoe. Inbound transport emissions increase by 4.06 kg CO₂e, a very considerable increase. In Scenario 1, emissions from inbound transport account for 29% of the product's total footprint, compared to only 4% in the Baseline.

Scenario 2: Change to the LightSpray Cloudmonster 3 Hyper – Renewable Energy for Manufacturing the Shoe’s Upper

In this scenario, the only difference relative to the Baseline is that the LightSpray™ technology is operated using 100% renewable energy. For this scenario, a realistic energy mix for South Korea was modelled, accounting for the country's main renewable energy technologies. Emissions from processing the upper of the LightSpray Cloudmonster 3 Hyper decreased from 0.51 to 0.07 kg CO₂e, representing an 86% reduction. The product's total emissions were reduced by 4%. Therefore, the use of renewable energy alongside this innovative manufacturing technology has the potential to achieve further emissions reductions when compared with the Conventional shoe manufacturing. If we compare the production of the LightSpray Cloudmonster 3 Hyper upper alone, including materials, to that of the Conventional shoe, there is a 78% reduction in emissions for this component.

Figure 5: GWP Comparison: Conventional and LightSpray™ Technology Product Systems (Scenario 2)

Scenario 2

GWP Comparison: Change to the LightSpray Cloudmonster 3 Hyper – Renewable Energy for Manufacturing the Shoe’s Upper

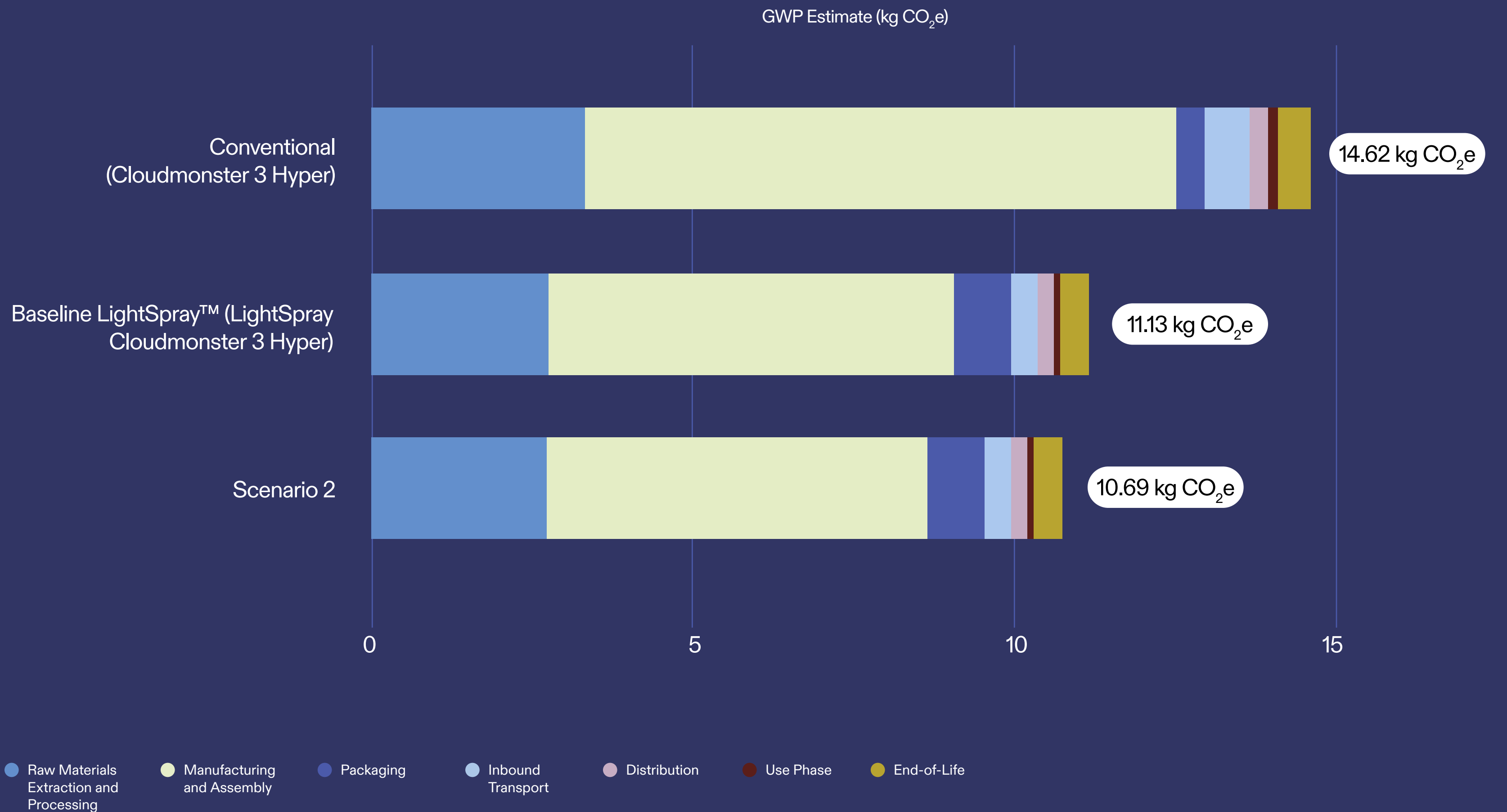
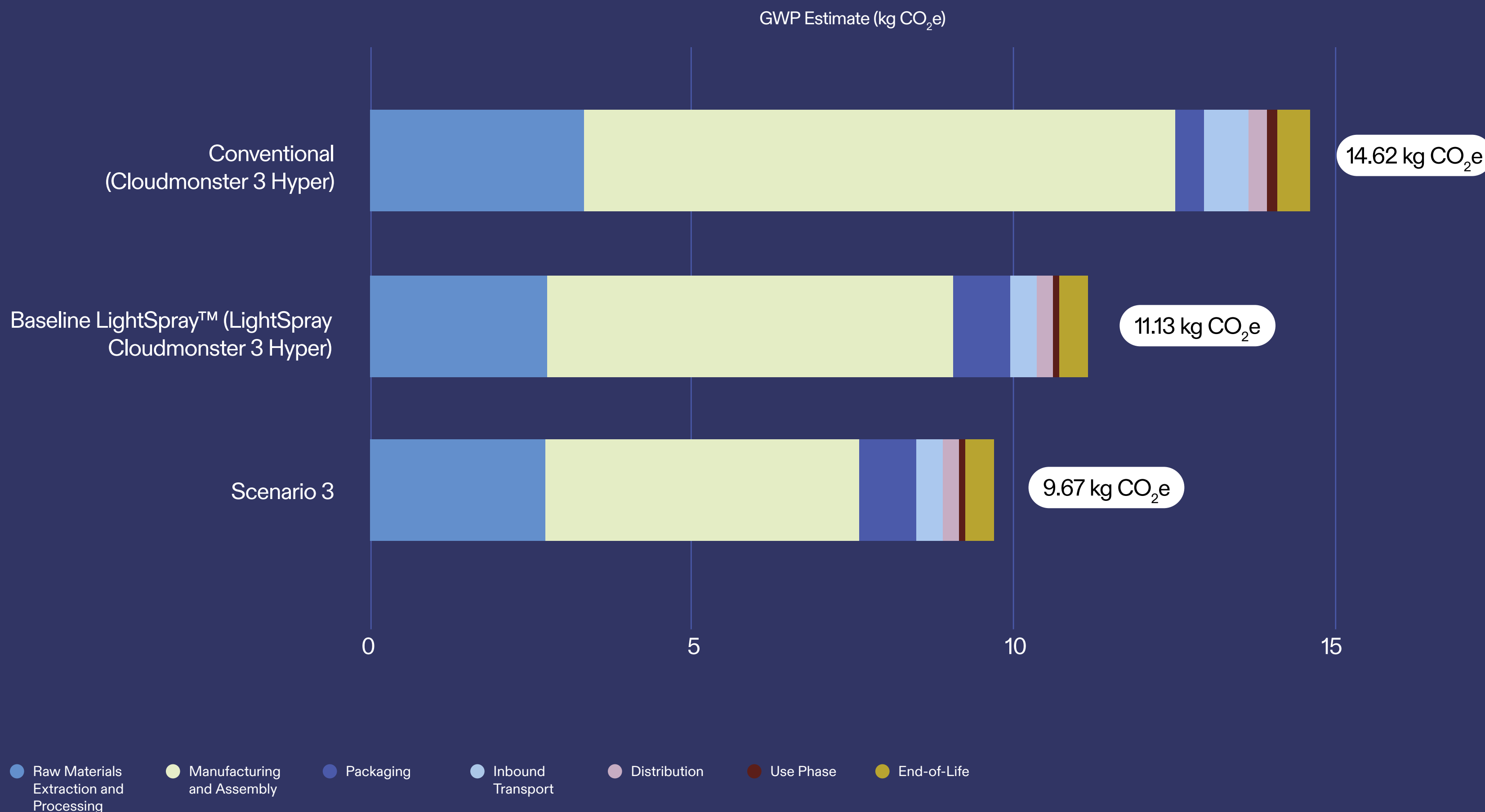


Figure 6: GWP Comparison: Conventional and LightSpray™ Technology Product Systems (Scenario 3)

Scenario 3

GWP Comparison: Changes to the LightSpray Cloudmonster 3 Hyper — Renewable Energy for Manufacturing the Shoe's Upper & Lower-Emission Autoclave Foaming for Manufacturing the Shoe's Bottom



Scenario 3: Changes to the LightSpray Cloudmonster 3 Hyper — Renewable Energy for Manufacturing the Shoe's Upper & Lower-Emission Autoclave Foaming for Manufacturing the Shoe's Bottom

This theoretical scenario presents an optimised manufacturing process for the LightSpray™ technology. Not only is 100% renewable energy used in the innovative process, but the manufacturing of the bottom of the shoe is also improved from a climate impact perspective. For this scenario, it was assumed that the emission factor for the autoclave foaming (material) process used to manufacture part of the bottom can be reduced by 22%. Results now show the manufacturing and assembly stage decreasing from 6.3 to 4.84 kg CO₂e, representing a 24% reduction. The overall footprint of the shoe drops by 13%. This scenario underscores the importance of optimising the manufacturing of all shoe components. While the LightSpray™ process shows substantial improvements in shoe upper manufacturing, there remains room for improvement in the bottom of the shoe. The total footprint of the LightSpray Cloudmonster 3 Hyper in this scenario is 34% lower than that of the Conventional shoe, demonstrating significant improvements and underscoring the importance of renewable energy use and energy efficiency in the manufacturing of all components.

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7. Conclusion

Based on the results of this prospective attributional LCA analysis, several key conclusions can be drawn regarding the product Carbon footprint of LightSpray™ technology as it is scaled, compared with the Conventional athletic footwear production method employed by On.

Results indicated that, when comparing the Cloudmonster 3 Hyper with the LightSpray Cloudmonster 3 Hyper, LightSpray™ technology can reduce the climate change impact of an athletic shoe relative to the conventional upper manufacturing system within the defined system boundary (unit processes excluding bottom production, packaging, and use phase).

In the Baseline, LightSpray™ technology yielded a significant reduction in emissions per pair of athletic shoes, driven primarily by reductions in upper manufacturing emissions. A key contributor is the reduction in upper material production, process, and transport per pair, attributable to lower material mass and the use of a single material type rather than a Conventional multi-material construction (>10 material types), which also lowers inbound material transport demand. The technology also reduces product mass, which is expected to reduce weight-dependent impacts in downstream transport and, where modelled, in the use and end-of-life phases.

Scenario analysis showed that the magnitude and direction of potential benefits are sensitive to logistics and energy choices. Using 100% air freight from manufacturing to regional distribution (Scenario 1), the LightSpray™ shoe's total climate change result becomes higher than the Conventional comparator, with inbound transport increasing and contributing a significant portion



towards total product emissions, versus a much lesser amount in the Baseline. By contrast, operating the LightSpray™ process on 100% renewable electricity using a South Korea–representative renewable mix (Scenario 2) reduces upper-processing emissions and lowers total product emissions relative to the Baseline. Further optimisation of the shoe bottom manufacturing (Scenario 3), modelled as a reduction in the autoclave foaming emission factor, decreases manufacturing and assembly stage emissions, reducing the total footprint considerably versus the Baseline and achieving a significantly lower total footprint than the Conventional shoe.

Overall, the results in this report support LightSpray™ technology as a high-potential decarbonisation pathway for footwear manufacturing, and it can be further optimised by minimising air freight and improving energy and material performance across all components used to create On's athletic shoes.

In the future, the On team plans to explore the LightSpray™ reduction levers investigated in this report and more. Potential reduction pathways include improving raw material sources to lower the product carbon footprint of the raw materials used (for example, bio-based alternatives), improving overall production efficiency (for example, scaling up production capacity to lower the electricity required per pair produced), optimising logistics, and reducing the PCF stemming from the bottom unit.

These measures have the potential to further lower the PCF of On's athletic shoe production via LightSpray™ as the technology scales.



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8. Recommendations for Further Analysis

Several future recommendations are proposed to further enhance the reliability and comprehensiveness of the analysis and to maintain, or even surpass, the projected efficiencies and carbon footprint reductions of LightSpray™ technology.

1. Enhanced data collection and verification

- Extended data sample size: Increasing the sample size for measurements, particularly those involving energy consumption and material throughput as production scales up, will yield more statistically significant results and reduce the margin of error in the analysis and its conclusions. LightSpray™ technology is still in its early stages, and as commercialisation and scale-up continue, On will have the opportunity to collect data over a longer period of time to make results more representative and increase future efficiency.
- Primary data collection for the autoclave foaming process: This is a very important contributor to the manufacturing impact of both the Cloudmonster 3 Hyper and the LightSpray Cloudmonster 3 Hyper shoes. Data collection is an industry-wide problem, given the complex nature of supply chains and supplier/brand relationships. The accuracy of results and potential reduction in scenarios would be enhanced with this data.

2. Inclusion of all relevant environmental impacts

- Production infrastructure: Consider the broader environmental impacts of manufacturing and maintaining the robotic arm and other infrastructure used in both the LightSpray™ and Conventional production methods. Although

this is not expected to reverse the analysis's conclusions, it would help understand the full life cycle impacts of the technology and identify additional areas for technological improvement with respect to environmental impacts beyond climate change.

3. Economies of scale

- Production efficiency at scale: Investigate the potential efficiencies that could be realised once LightSpray™ technology is fully implemented at a commercial scale. This includes economies of scale in material use, energy consumption, and cost efficiency.

4. Future technological and environmental scenario analysis

- Projection of technological changes: Analyse how advancements in related technologies, such as changes in the electricity grid, improvements in energy efficiency, the adoption of more sustainable raw materials, or material recycling capabilities, might influence the environmental impacts of LightSpray™ technology in the future.
- Adaptation to future environmental standards: Analyse how changes in environmental regulations and standards could impact the deployment of LightSpray™ technology. This should include an assessment of potential adjustments needed to comply with future sustainability criteria.

5. Long-term environmental impact monitoring

- Continuous impact assessment: Establish a framework for ongoing monitoring of the climate and other environmental impacts of LightSpray™

technology throughout its life cycle. This should involve periodic updates to the life cycle assessment based on real-world operational data, including live energy-consumption measurements on the production line, as the technology matures.

- End-of-life management: Research into the end-of-life phase of products made with LightSpray™, focusing on the recyclability and disposability of the materials used, to ensure the technology adheres to circular-economy principles.

These recommendations aim to address the current analyses' limitations by broadening the scope of research, enhancing data reliability, and ensuring that the environmental benefits of LightSpray™ technology can be accurately quantified and realised at scale.

By implementing these suggestions, On can better position LightSpray™ as a sustainable solution in the athletic footwear industry.



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Appendix A: Product System Input Parameters

Appendix B: Transportation Assumptions

Appendix C: IPCC 2021 Characterisation Factors

Appendix A

Product System Input Parameters

Placement Footwear	Net Material Weight Per Piece (g)	Material Composition
Upper		
Vamp	27	26% Polyester (Virgin) - PES, 26% Polyester (Mechanical Recycled) - rPES, 24% Thermoplastic Polyurethane (Bio-Based), 24% Bio-Based TPU - bTPU
Eyrow TPU	4.2	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Foxing Lateral	4.7	45% Thermoplastic Polyurethane - TPU, 30% Thermoplastic Polyurethane (Recycled) - rTPU, 25% Polyurethane (Resin) - PU
Foxing Medial	3.1	45% Thermoplastic Polyurethane - TPU, 30% Thermoplastic Polyurethane (Recycled) - rTPU, 25% Polyurethane (Resin) - PU
Heel Logo	0.1	55% Thermoplastic Polyurethane (Virgin) - TPU, 30% Glass, 10% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM, 5% Ink (Water Based)
Top Tongue	2.6	100% Polyester (Mechanical Recycled) - rPET
Top Tongue	0.6	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Tongue Bottom	4	100% Polyester (Mechanical Recycled) - rPES
Tongue Foam	1.2	100% Polyurethane (Foam) - PU
Tongue Bottom Nasa	0.1	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Vamp Lining	11.2	100% Polyester (Mechanical Recycled) - rPES
Collar Lining	7.2	100% Polyester (Mechanical Recycled - Bottle) - rPET
Collar Foam	5.2	100% Polyurethane (Foam) - PU
Eyrow Lining	5.6	100% Polyester (Mechanical Recycled - T2T) - rPET
Eyrow Lining	1.4	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Collar Reinforcement Lateral	4.5	100% Polyester (Recycled) - rPES
Collar Reinforcement Lateral	1.1	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Collar Reinforcement Medial	4.3	100% Polyester (Recycled) - rPES
Collar Reinforcement Medial	1.08	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM

Placement Footwear	Net Material Weight Per Piece (g)	Material Composition
Lateral Foxing Reinforcement	2.6	100% Polyester (Recycled) - rPES
Lateral Foxing Reinforcement	0.7	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Medial Foxing Reinforcement	2.3	100% Polyester (Recycled) - rPES
Medial Foxing Reinforcement	0.6	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Toe Box	7.4	100% Polyester (Recycled) - rPES
Toe Box	1.0	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Toe Box	1.0	100% Thermoplastic Polyurethane (Hot Melt - Virgin) - TPU HM
Counter	6.5	52% Polyester (recycled), 26% TPU, 19% HM, 3% Polyester
Add-Ons		
Tip Reinforcement Tape	0.1	100% Polyester (Chemical Recycled - T2T) - rPET
Collar Reinforcement Tape	0.1	100% Polyester (Chemical Recycled - T2T) - rPET
Lace	3.5	100% Polyester (recycled)
Sockliner		
Moulded Sockliner	20.3	100% EVA
Insole		
Insole	4.3	100% Polyester (Mechanical Recycled - T2T) - rPET
Bottom		
Outsole	41.3	100% Synthetic Rubber
Top Midsole	67.4	56% Polyether Block Amide (Pebax), 44% Bio-based Polyether Block Amide (Pebax)
Bottom Midsole	58	50% EVA, 50% Olefin Block Copolymer (Infuse)

Appendix B

Transportation Assumptions

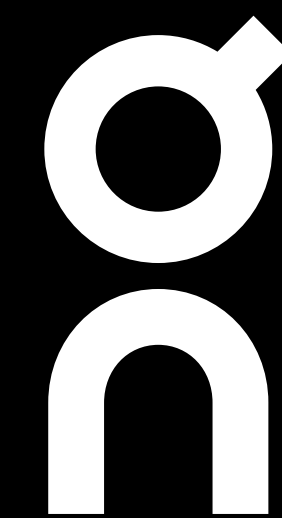
Placement Footwear	Country of Origin	Country of Destination	Transport Mode	Transport Distance (km)
Upper				
Vamp	China	Vietnam	Road	3307
Eyrow TPU	Vietnam	Vietnam	Road	1000
Foxing Lateral	Vietnam	Vietnam	Road	1000
Foxing Medial	Vietnam	Vietnam	Road	1000
Heel Logo	Taiwan	Vietnam	Sea	2076
Top Tongue	Vietnam	Vietnam	Road	1000
Top Tongue	Vietnam	Vietnam	Road	1000
Tongue Bottom	Vietnam	Vietnam	Road	1000
Tongue Foam	Vietnam	Vietnam	Road	1000
Tongue Bottom Nasa	Vietnam	Vietnam	Road	1000
Vamp Lining	Vietnam	Vietnam	Road	1000
Collar Lining	Vietnam	Vietnam	Road	1000
Collar Foam	Vietnam	Vietnam	Road	1000
Eyrow Lining	Vietnam	Vietnam	Road	1000
Eyrow Lining	Vietnam	Vietnam	Road	1000
Collar Reinforcement Lateral	Vietnam	Vietnam	Road	1000
Collar Reinforcement Lateral	Vietnam	Vietnam	Road	1000
Collar Reinforcement Medial	Vietnam	Vietnam	Road	1000
Collar Reinforcement Medial	Vietnam	Vietnam	Road	1000

Placement Footwear	Country of Origin	Country of Destination	Transport Mode	Transport Distance (km)
Lateral Foxing Reinforcement	Vietnam	Vietnam	Road	1000
Lateral Foxing Reinforcement	Vietnam	Vietnam	Road	1000
Medial Foxing Reinforcement	Vietnam	Vietnam	Road	1000
Medial Foxing Reinforcement	Vietnam	Vietnam	Road	1000
Toe Box	Vietnam	Vietnam	Road	1000
Toe Box	Vietnam	Vietnam	Road	1000
Toe Box	Vietnam	Vietnam	Road	1000
Counter	Spain	Vietnam	Sea	13573
Add-Ons				
Tip Reinforcement Tape	Vietnam	Vietnam	Road	1000
Collar Reinforcement Tape	Vietnam	Vietnam	Road	1000
Lace	Vietnam	Vietnam	Road	1000
Sockliner				
Moulded Sockliner	Vietnam	Vietnam	Road	1000
Insole				
Insole	Vietnam	Vietnam	Road	1000
Bottom				
Outsole	Vietnam	Vietnam	Road	1000
Top Midsole	China	Vietnam	Road	3307
Bottom Midsole	Vietnam	Vietnam	Road	1000

Appendix C

IPCC 2021 Characterisation Factors

Greenhouse Gas (GHG)	IPCC 2021 Characterisation Factor
Carbon Dioxide	1
Methane	29.8
Nitrous Oxide	273
Pentafluoroethane	3740
1,1,1,2-Tetrafluoroethane	1530



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