footwear innovation FOUNDATION

Understanding & Mitigating the Modern Footprint of the Footwear Industry

From Manufacturing Energy Use to Total Emissions

The footwear industry's carbon emissions comprise **0.45%** of total global emissions. Manufacturing a typical shoe emits **1.5 kg** of CO_2 while the total cradle-to-grave carbon footprint per pair is **6.7 kg** of CO_2-eq.

About the footwear Innovation Foundation

The Footwear Innovation Foundation (FIF) is a scientific 501(c)(3) non-profit organization. Our mission is to be an ideas broker, innovation accelerator, and knowledge center for the future of footwear. We theorize about the future of footwear, conducting and funding critical research that produces better footwear products, a stronger workforce, and new business models that will benefit consumers and companies in the coming years.

Learn more at **footwearinnovation.com**

About the Author

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Author's Foreword

When I sat down to work on this project, I had no intention of writing a research paper. Instead, I wished merely to explore innovative ideas that might help shoe companies reduce their environmental impacts at the factory level. Yet, what my team and I found surprised me, gave me much food for thought, and inspired me to compile this report.

The existing literature on the impact of shoe manufacturing on carbon emissions is old and flawed. Much of it is grounded upon questionable data and poor assumptions or filled with misunderstandings. However, this same literature remains authoritative in the eyes of many and continues to shape popular and industry perspectives.

To give but one example: during our research we reached out to a Business Insider reporter to make them aware that a story they had published on shoe emissions was misleading. In response, they cited a 2013 MIT press release on a sneaker Lifecycle Assessment (LCA) study, which had been conducted by MIT professors, on a shoe manufactured in 2010. Even though this data is nearly 15 years old, it remains the data most cited by researchers and journalists today; data that this report will show is not accurate for today's shoes.

The response to our asking for the addition of a simple notation to the article that would date the data, so readers would at least be aware of its provenance, was telling:

> *I haven't covered a lot of footwear stories, so I'm less versed in the industry research. That said, I just so happen to have previously worked for the MIT News Office…so I'm inclined to trust her [the press release's author] reporting and characterizations even if they are a decade or so old.*

This was far from an isolated example of the way in which flawed data retains a position of unwarranted preeminence. Elsewhere, we found citations in articles and reports on shoe emissions that were not drawn from primary source material. Numerous news articles – as well as group websites and releases – merely cite other news articles' data, rather than the original research itself. The gap between data and reportage creates spaces which can be (and have been) filled with errors.

It is self-evident to anyone researching shoe emissions that most reporters and groups are so overly focused on apparel that they fail to discern how shoes are more like a Tesla than a T-shirt; footwear is often reduced to a side note. As you will see, apparel tunnel vision is blinding researchers and reporters to the unique science of shoes.

Clearly, the shoe industry has environmental issues it must address, but it must have modern, scientifically accurate, shoe-specific data to help it produce an appropriate response. Consumers should likewise have access to current and accurate information. The purpose of this report is to begin the process of meeting that need.

My hope is that this report serves as a foundation for additional research that is footwear specific and helps companies further minimize their environmental impacts.

Andy Polk
Executive Director
Footwear Innovation Foundation

Executive Summary

A Modern Footwear Footprint Analysis

- Manufacturing a typical shoe today emits 1.5 kg of CO_2, while the total cradle-to-grave carbon footprint is 6.7 kg CO_2-eq per pair.
- The entire global footwear industry contributes approximately 0.45% of total global carbon emissions, significantly lower than previous estimates.
- Footwear accounts for less than 0.3% of total U.S. carbon emissions.

Insights from Modern Footwear Production

- Footwear manufacturing has greatly improved energy efficiency and has all but eliminated coal as a direct energy source inside factories.
- Looking at 54 million pairs of shoes, the average electricity consumption to produce a pair of shoes is 1.17 kWh, significantly lower than older estimates.
- Examining the total energy required—including electricity and previously unaccounted-for sources—reveals basic injection-molded footwear needs 0.5 kWh per pair on average, whereas boots require more than 5 kWh per pair.

Distinguishing Footwear from Apparel for Accurate Research

- Apparel tunnel vision continues to blind researchers and reporters to the distinct science of footwear—sidelining shoes in ways that lead to flawed and incomplete environmental analysis.
- Unlike apparel, footwear factories require specialized energy-intensive processes, such as molding, adhesives, and high-temperature assembly techniques.
- Textiles account for less than 20% of the total materials used in footwear.
- Footwear production can involve 200+ manufacturing processes.
- Shoes incorporate an average of 60 different materials and components, whereas apparel typically consists of just a few.

Pressing Onward—Today's Opportunities for Further (Targeted) Emission Reduction

- Better material choices—such as using recycled, renewable, regenerative or natural components—represent the greatest opportunity for reducing carbon emissions per pair.
- Supply chain and logistics optimization, including reduced air freight and more localized production, can further cut carbon emissions.

Beyond Emissions

While this report focuses on emissions, and there is much more work to be done to reduce emissions, the footwear industry's environmental work extends well beyond carbon. A growing concern is post-consumer waste—what happens to footwear at the end of its life. The industry must grapple with how disposal methods, recycling limitations, and landfill accumulation affect long-term sustainability and impact ecosystems. Equally pressing are water-related issues, both in the manufacturing process and in how footwear is used and ultimately discarded. These topics are future challenges we believe deserve the same rigor, transparency, and research that this emissions-focused report represents.

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I. Introduction – Lack of Primary Data on Energy Used in Footwear Manufacturing + Defunct Footwear Emission Data

It is essential to have both accurate and up-to-date data when calculating the environmental impact of a product or an entire industry. Scientifically precise carbon calculations enable companies to focus on key areas to address and reduce their environmental impact. This data also helps consumers make informed choices about what is, or is not, truly 'sustainable,' and assists policymakers in crafting appropriate standards. Unfortunately, there is a major shortfall in this area in relation to footwear emissions.

At present, there is no single report that examines the footwear industry's overall, global, environmental impact, while including primary source data on energy consumption in shoe factories. This absence is a critical flaw.

Instead, nearly every report uses data from the apparel industry to estimate footwear manufacturing impacts, even though footwear involves at least 200 more manufacturing processes than apparel and uses at least 30 additional material types.

Furthermore, major reports on footwear carbon emissions – both at the individual product and total industry level – cited in media articles, by advocacy groups, and by policymakers, are more than a decade old. Yet, this occludes key recent developments, notably: advances in factory production and energy efficiency over the last decade.

Today's factories use completely different energy sources compared to those accounted for in earlier analyses of carbon emissions. For example, coal is no longer burned inside footwear factories as a direct energy source, yet coal use was factored into a widely cited Lifecycle Assessment (LCA) on sneaker carbon emissions. This LCA has been used in subsequent reports to partially calculate overall industry emissions, despite its data being outdated. The absence of coal combustion in modern footwear factories significantly affects current carbon emissions data.

Reports based on outdated data mislead companies, consumers, and policymakers. **Just as we should avoid 'greenwashing,' we must also prevent the acceptance of obsolete, inaccurate data without scrutiny and noting the data age.**

This report aims to address these shortcomings by drawing on current, primary source data on the energy used by Tier 1 footwear factories in Asia today. The use of such data is crucial for gaining an accurate picture of the carbon emissions situation, as there are numerous public claims that between 60-80% of a shoe's emissions can come from manufacturing and the process of materials development. Is that actually accurate? New data and analysis will help clear this up and provide companies with insights to strategically target carbon emissions reductions.

This report also aims to establish a more accurate baseline for the footwear industry's total carbon emissions. This will assist companies, consumers, and policymakers, and contribute to the development of future emissions analyses. With new energy sources, new machinery, and new energy powering footwear factories, we need fresh perspectives on these issues.

Finally, this report will demonstrate that future analyses of the footwear industry's environmental impacts must distinguish between footwear and apparel due to the fundamental differences that exist between the two industries, whether in relation to the materials used, or the nature of factories, supply chains, and end-of-life processes. Shoes are more like a Tesla than a T-shirt, yet nearly everyone continues to erroneously lump them together save a few who understand 'fashion' is no monolith.[1]

1 see footnote 2, "excludes footwear": Ellen MacArthur Foundation, *Redesigning Fashion*, 2020, 2, **https://www.ellenmacarthurfoundation.org/publications/redesigning-fashion**.

II. Study Objectives

Numerous earlier LCAs and reports were reviewed to identify both gaps and those areas where this study could contribute new data and insights. Dozens of footwear production experts and sourcing executives were interviewed. This study gathered a large sample of Tier 1 footwear factory data to gain a detailed understanding of modern energy usage. It augmented the factory data by compiling new footwear data sets from a range of trusted primary sources. Finally, new LCA tools were used to measure the modern environmental impacts of footwear – with a view toward establishing a new industry impact baseline that could assist future operations, as companies continue to target and reduce impacts.

This study aims to first assess the energy inputs required for modern footwear manufacturing (Tier 1). Our goal is to identify power sources, benchmark energy usage, and evaluate how this impacts carbon emissions calculations at the individual product level. Additionally, we will provide a more detailed explanation of shoe development and manufacturing processes to aid future research.

The second part of this study will focus on reviewing calculations for overall footwear industry carbon emissions. Two research reports are most frequently cited by journalists and industry groups regarding the industry's total carbon emissions: One by Quantis in 2018[2], and another by Global Fashion Agenda and McKinsey in 2020[3]. While these reports offer valuable insights into various aspects of emissions measurement and calculation, they lack primary data specific to footwear and were produced several years ago. Here, we will examine the data sets used in these reports to assess whether they are outdated or missing crucial information on footwear-specific processes and materials. The aim is to identify what can better inform future studies.

The third and final part of this study seeks to define the carbon emissions generated by a 'typical shoe', to provide a foundation for new emissions' calculations in the footwear industry. While there are 436 different ways to classify a shoe in the U.S. Harmonized Tariff System (HTS), and we do not claim to establish a definitive average, we aim to offer a guidepost for understanding impacts, generating insights for new studies, and assisting companies in benchmarking. This effort may also lead to deeper exploration in future studies of various footwear product types.

2 Quantis, *Measuring Fashion: Environmental Impact of the Global Apparel and Footwear Industries Study,* 2018. (**https://quantis.com/wp-content/uploads/2018/03/measuringfashion_globalimpactstudy_full-report_quantis_cwf_2018a.pdf**)
3 Global Fashion Agenda and McKinsey, Fashion on Climate: *How the Fashion Industry Can Urgently Act to Reduce Its Greenhouse Gas Emissions*, 2020. (**https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/fashion%20on%20climate/fashion-on-climate-full-report.pdf**)

III. Footwear Insights Critical for Accurate Future Research: *Shoes are Not Shirts*

The first finding of our research is that many researchers, journalists, and organizations do not fully understand the complexities of footwear production, processes, or materials. This leads to erroneous assumptions, such as using apparel data and applying generalizations that do not accurately reflect footwear manufacturing. To properly understand energy usage and environmental impacts, it is crucial to examine footwear materials and processes on their own terms.

Key Terms and Nuances

Before proceeding it is useful to lay out some key foundational premises and terminology, as used later in this study:

- **Nomenclature:** "Footwear factories" refer to Tier 1 factories where the final assembly of shoes takes place. Tier 2 and Tier 3 "suppliers" are responsible for providing materials and components to Tier 1 factories for final assembly.
- **Types:** Footwear factories often specialize in producing specific types of shoes. A facility designed to manufacture athletic shoes, for example, may not have the machinery, material supply chains, or skilled labor necessary to produce leather fashion shoes.
- **Uniqueness:** Footwear production requires a robust infrastructure to support specialized machinery and labor, which is why production cannot easily shift from one location to another. Building a new footwear factory and supporting infrastructure requires tens, if not hundreds of millions of dollars. Footwear factories also utilize processes and tools that are significantly different than those used in apparel manufacturing.
- **Ownership:** Most small and midsized factories in Asia are privately owned, while larger factories are typically operated by corporations overseeing multiple facilities. Shoe brands do not own these factories and therefore lack control over production decisions, such as what products are made and when, as well as the flexibility to make real-time adjustments based on demand. While shoe brands are responsible for accounting for their emissions and environmental footprint, they may not have enough influence over factory owners to prompt investments in technologies that would reduce carbon emissions. This is similar to a retail store leasing space in a mall where the mall owner controls infrastructure upgrades.

We turn now to consider key aspects of the shoe manufacturing process.

Where are shoes made?

Data collected from the *World Footwear Yearbook 2023*, USITC, and Eurostat show that global footwear production reached an estimated 23.8 billion pairs in 2023. In the largest markets, U.S. footwear imports totaled 2.0 billion pairs, while EU imports in 2023 reached 2.5 billion kilograms (European trade agencies do not publish data in pairs). Table 1 below provides a breakdown of the top three footwear production locations, with China remaining the dominant producer.

China produces a wide variety of shoe types made from a number of different materials. Many companies manufacture private label footwear, as well as "brown" comfort or fashion footwear, in China. The provinces of Guangdong and Fujian have the highest concentration of footwear factories and material suppliers. Factories in China employ large numbers of workers for hands-on assembly, with some machinery used; they are almost entirely powered by electricity taken from the local grid. Larger factories can employ as many as 40,000 workers, though there are also numerous midsized and smaller factories scattered across southeastern China. Midsized factories tend to be less automated and are typically owned by independent operators, while larger factories are often owned by companies managing multiple production sites.

The largest growth in footwear production in recent years has been in Vietnam, which is now the leading producer of athletic footwear for the U.S. market. This shift is significant when considering product types. On average, factories in Vietnam are newer and use more automation than those in China, increasing their efficiency. However, even with high levels of automation, these factories still employ tens of thousands of workers to operate machinery, reflecting the enduringly artisanal character of production lines.

Vietnamese factories also benefit from a more diverse energy mix, which goes beyond the main electric grid, as compared to China. There is a growing trend toward using solar power, as many factories have installed solar panels on their roofs, leading to cost savings and a reduced environmental impact.

TABLE 1: GLOBAL FOOTWEAR PRODUCTION STATS (2023)

Key Global Footwear Producers		
Country	**Volume (Bln. Pairs)**	**World Share (%)**
China	12.3	56.1
India	2.6	8.7
Vietnam	1.4	5.8
Key Footwear Suppliers to the U.S.		
Country	**Volume (Bln. Pairs)**	**Volume Share of US Imports (%)**
China	1.203	60.2
Vietnam	0.464	23.2
Indonesia	0.129	6.5
Key Footwear Suppliers to the E.U.		
Country	**Volume (Bln. Kgs.)**	**Volume Share of EU Imports (%)**
China	0.571	22.8
Vietnam	0.233	9.3
Germany*	0.218	8.7

*The data on Germany may be transshipments—that is a company importing shoes and then distributing them across borders in Europe. European data here is not fully transparent, especially considering the World Footwear Yearbook pegs German shoe production at just 58 million pairs, well short of what this data portrays.

In contemplating this data and thinking about future trends, it is worth highlighting an obvious omission. India is a powerhouse in leather footwear production, serving both its domestic market and, notably, the European market. Recently, athletic brands like NIKE and Adidas have begun working with partners to establish new factories in India for athletic shoe production[4]. These factories are being constructed with advanced water management systems, in line with government regulations and cultural norms and will incorporate new manufacturing innovations. This makes India a promising area for future studies on footwear manufacturing impacts.

4 "Taiwanese manufacturer of Nike, Adidas shoes commits $280M for first factory in India," *Manufacturing Asia*. (2024). (**https://www.manufacturing.asia/manufacturing/news/taiwanese-manufacturer-nike-adidas-shoes-commits-280m-first-factory-in-india**)

What materials are in shoes?

As has been described, footwear is often grouped into textile or apparel categories, even though textiles make up a small percent of all materials used in footwear globally. Furthermore, to compare footwear and apparel is really a case of comparing apples and oranges, in terms of the complexity of the products.

"Shoes have 10 times the number of materials and components, all intertwined, compared to clothing. This results in very different (and larger) traceability challenges and sustainability complexities not seen in apparel."[5] In fact, footwear averages 60 different materials and components[6] and this number can increase to as many as 120 different materials for performance footwear.

Global footwear trade data classifies shoes typically by the majority material of the upper. In that way, 47% of shoes are classified as being made of rubber/plastic, 33% textile (22% for the U.S. and E.U. Markets respectively), 15% leather, and 5% as "other" (waterproof, high performance, etc.).[7]

However, in actual practice, less than 20% of all materials used in a shoe, globally, are textiles. If the shoe is classified as a textile, it just means the majority of the shoe upper is textile. You still must calculate the midsole and insole foams, backings, and outsole. A quick math example: If 33% of global production is textile upper (and that makes up 50% of the shoe's volume due to other materials) then that would be around just 16.5% of textiles used in shoes globally.

In previous reports, little attempt was made to offer a deep impact assessment of the materials used in footwear beyond textiles, leathers, and synthetic materials; the complexity of footwear materials has rarely been fully addressed. Footwear can incorporate more than 30 unique materials in various product models. These materials include many that are typically overlooked but are important to account for, such as glues, foams, steel, cork, wood, brass, aluminum, and/or PVC.[8]

Analysis must also consider the constant evolution of products and materials. A brand may produce 30 different types of shoes per season, each using a different range of materials sourced from multiple suppliers, across different countries.[9] Additionally, new environmentally preferred materials are being introduced each season at an accelerating pace, continuously altering the impact calculations.

How are shoes made?

Footwear factories vary in size based on several factors, including location, product type, capacity, and ownership. Larger factories in China and Vietnam may employ tens of thousands of workers, run up to 25 production lines simultaneously, and produce millions of pairs annually.

Today, most Tier 1 footwear production in Asia follows a similar pattern. Depending on the product type, there can be anywhere from 100 to over 300 processes involved in the manufacturing of a single pair of shoes. The production of high-quality footwear requires a combination of manual labor and machinery, and the process more closely resembles that of an auto factory than an apparel factory.

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5 "Shoe Sustainability: Right-Sized Standards," *Shoe Sustainability*, (**shoesustainability.com/right-sized-standards**).
6 L. Cheah, C.N. Duque, E. Olivetti, S. Matsumura, D. Forterre, R. Roth, and R. Kirchain, "Manufacturing-Focused Emissions Reductions in Footwear Production," *Journal of Cleaner Production* 44 (2013): 18–29. (**https://www.sciencedirect.com/science/article/abs/pii/S0959652612006300**)
7 APICCAPS. (2023). *World Footwear Yearbook* 2023. **https://www.worldfootwear.com/news/the-world-footwear-2023-yearbook/8981.html**
8 "Shoe Sustainability: Right-Sized Standards," *Shoe Sustainability*, accessed October 2024, (**shoesustainability.com/right-sized-standards**).
9 Ibid.

These factories typically have material storage warehouses on-site where inputs from Tier 2 and Tier 3 suppliers – such as foams, leathers, and glues – are stored. In these areas, trucks unload materials, and forklifts transport them throughout the factory.

In other areas of the factory, upper materials are cut and stitched together by hundreds of workers operating machines. The completed uppers are then sent to the assembly line, where shoes move along a conveyor belt. Along the way, workers perform various tasks, such as gluing or welting the shoe uppers to the soles, finishing the shoes, inspecting and packaging them. Forklifts are often used to transport pallets of packaged shoes to trucks bound for shipping by sea or air.

This is the basic process, but there are many complexities on the factory floor. As one expert noted, "…materials can be cut and sewn conventionally, but they can also be laser cut, RF welded, hot pressed, cold pressed, co-molded, perforated, and over-molded—all on one shoe!"[10] To give but one example of what this means in practice: Affixing the upper to the midsole and outsole of most sneakers requires glue to be placed in twelve different areas across the shoe. This process adds to the complexity and demands careful attention to detail.[11] Depending on the size and efficiency of the factory, as well as the type of footwear being made, it generally takes 20 to 30 minutes to produce a pair of shoes, if timed from the start of the first material process down to the finished shoe being placed in a box.

What are the key performance standards for shoes?

Shoes are made the way they are because, unlike clothing, they cannot simply drape. They must be durable enough to perform on the feet, flexing and rebounding with every step. The materials and construction vary greatly depending on intended use, as safety standards for work boots are quite different from consumer expectations for beach sandals. While there have been advancements in reducing material use where possible, much more work remains to be done.

Regulatory standards for footwear are also far more complex than those for apparel or other soft goods. Consider the needs of firefighters, nurses, or construction workers, who require footwear that provides protection against slips, twisted ankles, or other health risks. Shoes must be designed to meet multiple performance requirements that are not present in apparel, such as slip resistance, traction, flexibility, durability, chemical resistance and weight support.[12]

What are the important modern manufacturing considerations?

Over the last decade, factories have adopted several innovations to improve the speed and quality of production, including laser cutting; machines that knit entire uppers; and robots that trim and finish footwear. While these advancements increase efficiency, they may also lead to higher energy consumption, altering carbon emissions calculations, year over year.

Manufacturing innovation continues with the rise of additive manufacturing, which allows for faster prototyping, increased customization, and more modular construction. One effect of recent changes has been the rise of more disjointed manufacturing processes, where shoe uppers are made in one location and shipped elsewhere for assembly, depending on efficiencies. Such changes again impact emissions calculations.

10 Wade and Andrea Motawi, *Shoe Material Design Guide* (2017), 32. (**https://shoemakersacademy.com/product/shoe-material-design-guide-softcover/?srsltid=AfmBOopCB3PXyyg9fp80IWdQsNSsMUsm9seF_CoVy3BdYpZNDj5DmwGG**)
11 "Shoe Sustainability: Right-Sized Standards," *Shoe Sustainability*, accessed October 2024, (**shoesustainability.com/right-sized-standards**).
12 Ibid

IV. Modern Shoe Factory Energy Sources

Existing studies that analyze the carbon emissions of the footwear industry have rarely used primary source data drawn from factory floors. Almost all reports, with one exception, have relied on energy-to-emission calculations taken from databases (see Table 5). By contrast, here we aim to provide primary source data that might help other researchers and analysts more accurately assess carbon emissions across the footwear supply chain.

The most comprehensive data gathered to-date on energy use in footwear production comes from a LCA study conducted by MIT professors on shoes manufactured in 2010–2011. The study was published in 2013 under the title "Manufacturing-Focused Emissions Reductions in Footwear Production."[13] This groundbreaking analysis of shoe manufacturing energy use and its impacts remains a crucial resource for companies and researchers seeking to understand and measure the environmental impacts of shoe materials and manufacturing processes.

It was one of the few studies to use primary data taken directly from a factory, analyzing energy sources and then calculating the likely carbon emissions. The report found "electricity use was the greatest in the Assembly and Midsole buildings, with a total of 23 GWh across all buildings." Additionally, coal was reported to be used in the Outsole and Midsole buildings for heating purposes during manufacturing. This finding is significant, as the burning of coal was identified as the largest emissions factor for the shoe, surpassing nearly all other lifecycle aspects.

Nevertheless, the MIT-led study was built on factory data collected between August 2010 and January 2011. Since then, energy sources and efficiencies in footwear factories have changed significantly. In addition, the study drew on highly specific data, calculating energy use and emissions for a "size 9 men's ASICS GEL KAYANO 17 shoe, manufactured in 2010 by a major contract manufacturer in China." To be clear, the authors of the study were entirely scientific and transparent in their approach. They made it clear that their calculations applied solely to this particular shoe and did not claim it as an industry benchmark. Others, however, have not been so careful in caveatting the data and clarifying its limits. And it is this reality that means we need to revisit certain important assumptions on which the report was based.

Having visited numerous shoe factories, we have never seen coal being used as a direct energy source. Further, interviews with ten shoe-sourcing executives living in Asia, who collectively work with several hundred factories across the region, further confirm that coal is not combusted for energy in any typical factory today. Many of those executives added that they have not seen coal used directly in shoe factories for many years. This shift is partly due to government mandates in China restricting the burning of coal, as well as improvements in the consistency of electricity supply. As a result, factories no longer need to rely on in-house energy generation to guard against blackouts, as they did in the past. As several respondents told us:

"Coal is not used in any of our factories."

"…the power now is not coal feedstock anymore, and more are going full solar."

"I've never seen coal used in a factory, and it would be obvious."

"…not in a long time."

Could coal be used in a footwear factory today for energy generation? Yes, but based on our extensive interviews it would be out of the ordinary.

Additionally, it is worth noting, as described above, that the factory used in the MIT-led LCA study consumed 23 GWh of electricity over just a six-month period to produce the sneakers. This is an exceptionally high figure for typical footwear manufacturing facilities today, which also warrants closer examination.

13 L. Cheah, C.N. Duque, E. Olivetti, S. Matsumura, D. Forterre, R. Roth, and R. Kirchain, "Manufacturing-Focused Emissions Reductions in Footwear Production," *Journal of Cleaner Production* 44 (2013): 18–29. (**https://www.sciencedirect.com/science/article/abs/pii/S0959652612006300**)

Modern Energy Sources for Shoe Manufacturing

To determine modern energy sources and requirements for shoe manufacturing, we collected and analyzed data from 33 shoe factories, located across China and Vietnam. This primary source data was gathered by professionals working directly in the factories.

The factories represent a variety of sizes, energy mixes, and shoe types, providing greater insight and accuracy – as compared to relying on a single data source. Collectively, these factories produced over 54 million pairs of shoes. The data was collected over the period between April 1, 2023, and March 31, 2024. We converted the various energy sources into BTU for consistency.

TABLE 2: ENERGY USED IN T1 FOOTWEAR FACTORIES

Sample of 33 factories in China and Vietnam (date: 4/1/23 – 3/31/24)

Energy Source (54,708,123 pairs)	Energy use total (BTU)	Percent energy type per pair
Solar (kWh)	6,533,041,700	2.60
Electricity (kWh)	218,305,485,336	86.76
Gasoline (Liter)	6,842,820,366	2.72
Diesel Fuel (Liter)	5,976,075,037	2.38
Liquified Petroleum Gas (Kg)	1,277,062,467	0.51
Liquified Natural Gas Cubic meters (m3)	12,682,031,147	5.04
TOTALS	**251,616,516,053.10**	**100**

We identified a range of energy inputs not specifically accounted for in previous reports or LCAs, including gasoline (for trucks and machinery), diesel fuel (for backup generators), and natural gas. While these inputs represent a small portion of the overall energy mix, they are still important for enhancing the accuracy of measurements for footwear carbon emissions.

Importantly, as described above, no coal was used as an energy source in any of the factories we studied.

By contrast, we observed a growing trend for factories, particularly in Vietnam, to utilize solar panels on their roofs. This shift is significantly reducing other energy consumption, and consequently, carbon emissions. It's remarkable to see the progression over the past 15 years—from a reliance on partial coal, to nearly all-electric, and now a push towards solar—and how this movement is poised to further reduce environmental impacts.

Energy Efficiency Shifts in Modern Shoe Manufacturing

We also found the total energy used to manufacture shoes today is significantly lower than in the past. The MIT-led LCA study noted that their observed factory used 23 GWh of electricity to produce 3.6 million pairs of shoes over a six-month period, equating to over 6 kWh per pair. Of note: This calculation does not include the coal use, just the electricity used in the factory studied.

In contrast, our data shows that today's factories average just over 1 kWh of electricity usage per pair. See Table 3 for the like-for-like electricity comparison. Again, the 33 factories from which we collected data make nearly every type of shoe in the market (see Table 4), which allows us to be confident in our estimation of this average. A number of shoe companies we consulted also confirmed similar energy data levels were applicable to their factories.

TABLE 3: ASSESSING GRID ELECTRICITY NEEDED TO PRODUCE SHOES IN FACTORIES

33 Factories Sampled (Combined) Production in 2023–2024	'Manufacturing-focused emissions reductions' study Production in 2010
54,708,123 pairs	3,600,000 pairs
63.98 GWh	23 GWh
12 month period	6 month period
1.17 kWh of electricity per pair	6.39 kWh of electricity per pair

Research by others has revealed that numerous factories are investing in energy efficiency measures. One such report is from 2021: "ISO 50001 Energy Management System Implementation: Case Study."[14] The report examined the PT. KMK Global Sports factory in Indonesia, which was a supplier to NIKE at the time. The factory had implemented a new energy program to lower both costs and its carbon footprint, with the report serving as a case study for other factories.

According to the ISO 50001 report, at the start of the program, the factory produced 7.5 million pairs of shoes per year and used 24 GWh of energy. By 2020, production had increased by 100%, reaching 15 million pairs, while energy consumption increased by only 25%, to 30 GWh. In 2007, the energy index was 3.2 kWh per pair, and by 2018, they had reduced energy consumption to 2.09 kWh per pair.

The fact that factories are publicly reporting energy usage as low as 2 kWh per pair further confirms that energy efficiencies are playing a significant role in reducing both energy use and emissions.

Moreover, we extended our analysis by calculating the kWh per pair of shoes by type from our data sets from the 33 factories. This involved analyzing each factory's energy consumption, the types of shoes they were producing, and the number of pairs produced. See Table 4 below for a detailed breakdown.

TABLE 4: ASSESSING ENERGY NEEDED TO PRODUCE SHOES BY TYPE IN TIER 1 FACTORIES

Calculated from ALL energy types in Table 2

Type of shoe	kWh per pair needed (average)	BTU per pair needed (on average)
Injection molded footwear/sandals	0.49	1682.12
Casual/lifestyle basic shoe	1.00	3412.00
Leather casual shoe	2.49	8495.88
Athletic shoe	3.32	11327.84
Leather boot	5.25	17913.00

Previous reports have indicated that the production of sneakers required over 6 kWh of energy per pair. Today, the equivalent figure is nearly half that amount, representing a significant improvement in energy efficiency. Additionally, we should reassess whether the commonly cited figure—that 60% of a shoe's carbon emissions come from manufacturing—still holds true. Given recent advancements in energy efficiency, this reduction in energy consumption could lead to a significant decrease in the carbon footprint of modern footwear compared to the past.

14 "ISO 50001 Energy Management System Implementation: Case Study PT. KMK Global Sports," *Clean Energy Ministerial*, (**https://www.cleanenergyministerial.org/content/uploads/2022/03/cem-em-casestudy-kmk-indonesia.pdf**).

V. Exploring Footwear Carbon Emissions at the Individual Product Level

To better understand carbon emissions at the individual product level, we examined numerous Life Cycle Assessments (LCAs). Table 5 below lists several public LCAs on footwear that we gathered as part of our efforts to build a holistic understanding of footwear emissions. Each assessment evaluates distinct types of shoes, manufactured in different locations, and applies unique research parameters. These parameters include specific supply chain segments and underlying assumptions that shape the assessment's scope.

Rather than treating the data from each LCA as a baseline or average for specific product types, this list serves as informative guidance for companies.

TABLE 5: SUMMARY STATISTICS OF PUBLIC LCA STUDIES ON ENVIRONMENTAL IMPACTS OF FOOTWEAR MANUFACTURING AND OTHER FACTORS

Study year	Location	Footwear type	System boundary	Functional unit	Global Warming Potential (kg CO_2-eq)	Reference / Link
2008	China	Casual Shoe	Cradle-to-grave	4 different styles of shoes + packaging	Range of 1.672 to 7.51 (variations based on materials, etc.)	K. Albers, P. Canepa, J. Miller. "Analyzing the Environmental Impacts of Simple Shoes," Bren School of Environmental Science & Management (2018)
2012	China	Sneaker	Cradle-to-grave	One shoe + packaging	14	L. Cheah, C.N. Duque, E. Olivetti, S. Matsumura, D. Forterre, R. Roth, and R. Kirchain, "Manufacturing-Focused Emissions Reductions in Footwear Production," Journal of Cleaner Production 44 (2013): 18–29)
2013	Mexico	Leather shoe	Cradle-to-gate	One shoe, with a lifetime of 3650 hours	3.31	Rivera Muñoz, Z., "Water, energy and carbon footprints of a pair of leather shoes." 2013, Universitat Politècnica de Catalunya
2015	Sweden	5 shoe types (textile, leather, waterproof, rubber/plastic and others)	Cradle-to-grave	5 various types of shoes.	2.35 for textile, 5.39 for waterproof and 11.0 for leather	Gottfridsson, M. and Y. Zhang, "Environmental impacts of shoe consumption, Combining product flow analysis with an LCA model for Sweden." 2015
2019	Poland	7 shoe types for children, women and men	Cradle-to-grave	7 types of shoes using weight	Top level of 8.04, others less (significant variation by shoe type and weight)	Serweta, W., et al., "Carbon footprint of different kinds of footwear–a comparative study." Fibres & Textiles in Eastern Europe, 2019(5 (137): p. 94-99
2021	Italy	Leather shoe	Cradle-to-gate	One shoe + packaging	11.63	Rossi, M., et al., "Life cycle assessment of a leather shoe supply chain." International Journal of Sustainable Engineering, 2021. 14(4): p. 686-703.
2024	Romania	safety boots	Cradle-to-grave	One Shoe	18.65	A. Bodoga, A. Nistorac, M. C. Loghin, D. N. Isopescu, "Environmental Impact of Footwear Using Life Cycle Assessment—Case Study of Professional Footwear" Sustainability 2024, 16(14), 6094

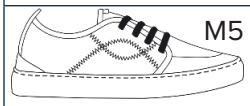
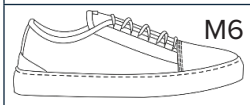
As can be seen, carbon emissions vary based on the product type. Each shoe differs by the materials involved, construction, supply chain, use, and end of life calculus. Depending on the data and boundaries, there is a range of carbon emission data.

New 'sustainable' material's impact on product level emissions calculations

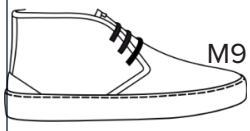
One angle we found interesting (and on which much more research is needed), was provided by a study that examined shoes made with sustainable materials and construction for disassembly (circularity). "The Environmental Impact of Sustainable Footwear" was produced by a leather and footwear research institute in Romania.[15] This was one of the only reports we found that tried seriously to compare the carbon emissions generated by supposedly 'sustainable' footwear versus emissions produced by the production of more traditional shoes. In particular, the report explored the question of how much impact reduction occurs when environmentally preferred materials (EPMs) are used, as well as when the life of the product can be extended or recycled. It drew on data received from the shoe producers and analyzed the data through GaBi software and the ecoinvent database to calculate the models.

We put the report's findings in Table 6 below to display the various carbon footprints for sustainable footwear models they calculated, ranging between 3.04 and 6.25 Kg CO_2-eq per pair. The materials used for the upper parts of these shoes are mainly recycled cotton, rPET, PET and linen, reflecting a strong focus on sustainability. The outsoles are primarily composed of a mix of natural and synthetic materials, with some models using bio-based or recycled content.

TABLE 6: SUMMARY OF THE CO_2 DATA FOR VARIOUS SUSTAINABLE FOOTWEAR MODELS IN *THE ENVIRONMENTAL IMPACT OF SUSTAINABLE FOOTWEAR REPORT*[16]

Footwear Model	Upper Part Materials	Outsole Materials	Carbon Footprint (Kg CO_2-eq/pair)
 M1	50% R-pet, 50% recycled cotton	80% natural rubber, 20% synthetic rubber vulcanized	3.04
 M2	50% pet, 50% recycled cotton	30% preconsumer recycled, 70% synthetic TR rubber injected	3.56
 M3	50% recycled cotton, 47% R-pet, 3% other fibers	100% bio eco TPU injected	4.23
 M4	50% pet, 50% recycled cotton	100% bio eco TPU injected	6.25
 M5	50% pet, 50% recycled cotton	50% natural rubber, 50% synthetic vulcanized rubber	4.95
 M6	50% pet, 50% recycled cotton	50% natural rubber, 50% synthetic vulcanized rubber	5.12
 M7	100% recycled cotton	25% recycled EVA, 75% synthetic conventional EVA	3.04

15 T. Sârbu, "The Environmental Impact of Sustainable Footwear." *Proceedings of the 11th International Conference TEXTEH* P. 171-177. (**https://sciendo.com/chapter/9788367405386/10.2478/9788367405386-fm**).
16 Ibid

Footwear Model	Upper Part Materials	Outsole Materials	Carbon Footprint (Kg CO_2-eq/pair)
 M8	50% recycled cotton, 50% pet	100% bio eco TPU injected	4.50
 M9	50% pet, 50% recycled cotton	100% bio eco TPU injected	5.25
 M10	100% linen	50% natural rubber, 50% synthetic vulcanized rubber	4.75
 M11	50% linen, 50% R-EARTH	50% natural rubber, 50% synthetic vulcanized rubber	4.85

This is important because this analysis suggests that the use of better materials led to a significant reduction in the carbon footprint of these sustainable models, when compared to conventional footwear. Another thing to note is that we know many major biomaterial T2 providers are increasingly producing their materials in facilities that may be newer, and/or using solar and new energy methods.

This area of research seems particularly interesting, and requires more exploration, because most LCAs have not zeroed in on shoes with EPMs. In the last 5 years, nearly every major shoe company has utilized recycled and/or bio-based materials and components in their various product categories. Many follow the Environmentally Preferred Material Guide produced by the Footwear Distributors and Retailers of America (FDRA), which helps companies choose better materials and operationalize work in this area.[17] The materials used in studies published before 2020 usually do not account for these materials and their reduced impacts. As shoe companies can better balance costs and performance, the use of EPMs will increase a great deal.

Today's manufacturing impact on product level emissions calculations

Among the key findings from the "Manufacturing-Focused Emissions Reductions in Footwear Production" study were the following:

- 68% of carbon emissions were due to manufacturing sneakers
- The emission from manufacturing was estimated as being "9.5 ± 2.7 (coefficient of variation = 28%) kg CO_2-eq per pair of shoes produced."[18]
- Of the 9.5 kg it calculated from manufacturing impacts,
  - 5 kg was due to coal combustion.
  - 4.4 kg was due to electricity use
  - And 0.1kg for emissions from waste disposal.

Again, this study looked at shoes manufactured nearly 15 years ago. If the LCA was revised today, electricity would likely displace all the coal combustion for factory energy needs since we know coal is no longer a direct energy source inside factories. Further, as seen in Table 4, the efficiencies of modern factories have decreased by half the energy needs of shoe production.

17 "Footwear Environmentally Preferred Material Guide (EPM)," *Shoe Sustainability*, October 2024, (**shoesustainability.com/epm**).
18 Ibid

What this means in turn is that: if coal is eliminated from the study (amounting to one-third of the calculated shoe's total carbon emissions), one accounts for modern energy efficiency at factories reducing electric needs by half, and one uses new EPMs seen in modern shoes… the emissions of sneakers today are significantly lower than those reported by journalists, cited by organizations, and used by some companies in marketing campaigns.

What then is the carbon emission from a pair of shoes today?

To establish a new baseline figure for researchers, we developed a concept of what we considered to be the typical shoe in the global marketplace.

(We note and caution researchers there are 436 different ways to classify footwear according to chapter 64 of the U.S. Government's Harmonized Tariff Schedule. There is, therefore, no such thing as a definitive 'average' shoe, but we can get close.)

We used global shoe trade data (production volume, type, weight, and marketplace) and input from industry leaders to try to get at this idea of a baseline typical shoe. Based on extensive research, we concluded that the global typical shoe is a women's basic, minimally constructed, walking/running shoe, size 7, and generally sold at a large retail store for $25–$30. It has a synthetic upper (PU and polyester), a high-density foam insole, PU lining foam, a low-density EVA midsole, and a TPR outsole.

IMAGE 1: WOMEN'S SYNTHETIC RUNNING SHOE (TYPICAL GLOBAL SHOE*)

*This shoe may exceed the global average. We opted for a more liberal example rather than a conservative one to ensure greater accuracy in the emissions data.

When judged by weight and volume, this shoe represents a mid-point between, on the one hand, mold injected sandals and basic shoes, and on the other hand, heavy outdoor waterproof work boots. Materially, it deploys a balance between cotton, synthetics, leather and foams. And viewed in terms of affordability, it is commensurable with where most consumers are in the world. In fact, even then, by global standards, this will be overconstructed and a higher price than most people in the world may be able to pay.

We took this conceptualization of the typical shoe and ran it through The Footwear Impact Calculator, a footwear specific LCA-like tool created by Eurofins.[19] This tool is unique in that its sole purpose (pun intended!) is for footwear environmental calculations. This does not displace a full meticulous LCA, but it provides the most clear real-time analysis possible for our purposes.

19 The Footwear Impact Calculator can be found here: **https://simapro.com/products/footwear-impact-calculator/**

It is meticulous in looking at the total impact of a shoe, from the material to transit and consumer use. It breaks the shoe down into specific component parts, in terms of material type, weight, and location to help increase accuracy. The tool computes the shoe inputs provided and then runs it through the SimaPro database to calculate each individual part's impact, before producing a final report on carbon overall emission, water use, and land impact. It follows the technical rules described in the draft E.U. Product Environmental Footprint Category Rules that will eventually dictate how LCAs are to be conducted, as well as follows IS0 14040 and ISO 14044 guiding current LCAs.

We were very specific in deciding on inputs for the various parts of this shoe and the production process. We used no EPMs, all virgin materials. We established the shoe as manufactured in China. We shipped it only to the US and split it between ecommerce and in-store sales. (Of note, through testing various scenarios, there is a slightly lower carbon footprint for shipping to Europe than the U.S.) All these inputs were chosen to not conservatively skew the emissions data in any way.

For full transparency, inputs to the tool it meticulously calculated included:

- **Synthetic Upper:** Mix of PU (19.58 grams) and polyester (26.8 grams)
- **Lining:** polyester (16.02 grams) and PU foam (30 grams)
- **Insole:** polyester scrim high density foam (80 grams)
- **Midsole:** low density EVA foam (120 grams)
- **Toe Puff:** Non-woven 1.2mm. (40 grams)
- **Accessories:** polyester laces (30 grams) and a silicone logo (10 grams)
- **Packaging:** Virgin cardboard box with PVC skin. Wrap tissue (virgin). Polybag (virgin).
- **All materials** came from China
- **The shoe was manufactured** in China
- **The shoe was shipped** from China to the U.S.
- **The shoe was sold** online (50%) and in stores (50%)
- **The use** of the shoe by a consumer was 'moderate'

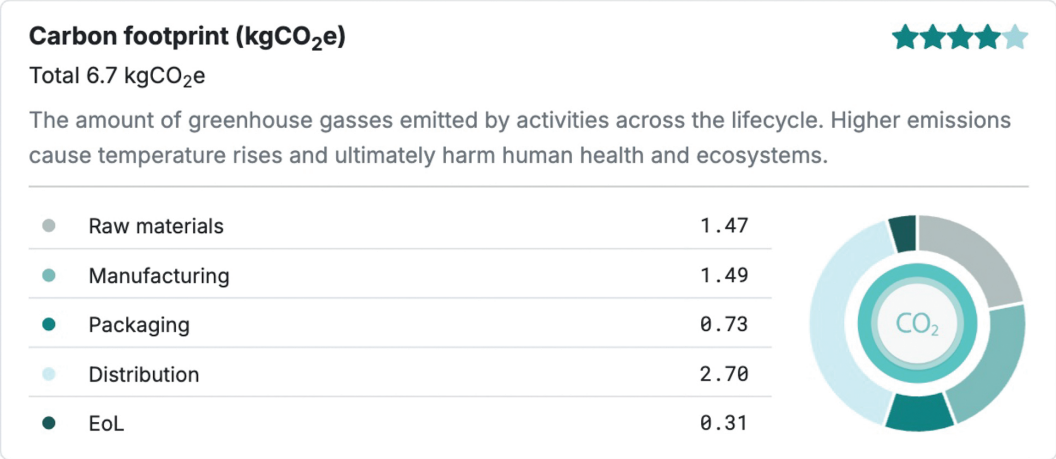
The tool reported the typical shoe emits 6.7 kg CO_2-eq throughout its entire life, "from cradle to grave" (see image 2). Manufacturing the finished shoe represents 1.5 kg of that total, just under 25% of the total impact. This would challenge the prevailing narrative that the overwhelming majority of a shoe's carbon emissions comes from manufacturing.

Our researched typical shoe is not a like-for-like with the ASICS running shoe assessed in the MIT-led study. As a reminder, the Asics shoe in the study is well above industry averages for materials, construction, has outdated energy sources like coal used in direct production, and doesn't have the modern calculations for energy efficiency at the factory. Most importantly, the 2013 study authors did not claim they were calculating emissions for the average shoe – journalists and marketers created that narrative.

The report we received (see image 2) on our typical shoe broke down the various areas that created carbon emissions and calculated their impacts. The results were surprising.

Most notably, manufacturing is no longer the oversized cause of shoe emissions it once was, for the many reasons mentioned previously. Interestingly, the decisions on logistics and channel (e-comm versus in-store) are just as impactful to reducing emission as materials and manufacturing. Perhaps the most important finding here is that better materials do in fact represent the greatest opportunity today for companies to reduce the impact per pair of shoes.

IMAGE 2: A DIRECT SNAPSHOT FROM THE FOOTWEAR IMPACT CALCULATOR'S REPORT ON THE MODERN WOMEN'S RUNNING SHOE



More research is needed

Not every company uses the same databases, consultants, or methodologies to calculate product emissions, leading to variations in reported figures. Additionally, emissions vary significantly by product type. For example, we have seen emissions data ranging from 1 kg CO_2-eq for sandals to approximately 15 kg CO_2-eq for a robustly constructed leather boot.

Data from various brands' own calculations indicate that raw material extraction and processing contribute more to emissions than final manufacturing in Tier 1 factories, regardless of whether the material is leather or cotton. In fact, most of the data we've seen shows finished manufacturing (Tier 1) consistently produces low carbon emissions—often lower than what we have reported here.

Furthermore, the transportation emissions in our calculations appear significantly higher than those seen in other studies. This discrepancy is likely due to our assumption that 50% of these shoes are sold via direct-to-consumer (DTC) channels. This assumption increases air freight emissions compared to the more typical scenario where shoes are shipped via ocean freight and then trucked to brick-and-mortar stores.

Our goal is to establish a new baseline. We are comfortable presenting higher emissions figures than others if it means ensuring transparency and avoiding any perception of skewed data.

To refine our understanding, new peer-reviewed life cycle assessments (LCAs) on modern footwear—including sneakers—are needed. We advocate for a new generation of detailed LCAs that adhere to consistent boundaries and methodologies across all shoe categories, including work boots, dress shoes, sandals, slippers, walking shoes, running shoes, and children's footwear.

We also encourage the development of methods to distribute carbon emissions over a shoe's lifespan. A shoe with a 6.7 kg CO_2-eq footprint that lasts one year should not be considered more 'sustainable' than a well-made 15 kg CO_2-eq shoe that lasts five years and reduces the need for multiple replacements within that timeframe.

A more precise breakdown of emissions across each tier of production for every shoe type would provide invaluable insights. This would help companies better address their environmental impact while also giving consumers clearer benchmarks for making sustainable choices.

VI. Exploring the Footwear Industry's Total Carbon Emissions

There are two reports, which are invariably cited in academic literature and news articles, that attempt to quantify the total global carbon emissions produced by the global footwear industry. The first of these is Fashion on Climate report by McKinsey and GFA (2020).[20] This study sought to baseline the 'fashion' industry's GHG Emissions. It calculated a combined apparel and footwear total of 2,106 Mn tonnes CO_2-eq, or 4% of total GHG emissions.[21]

It is striking that while Fashion on Climate mentions garments, textiles, cotton, weaving, knitting and spinning, it provides no in-depth analysis of footwear specifically. There are no references to footwear-specific materials like foams, or synthetics. As stated previously, textiles make up less than 20% of all materials in footwear. Yet there is no attempt to reflect this fact in the McKinsey report. It provides no calculated footwear metrics. Further, it lacks any data on total global footwear production. Instead, the report only calculated the volume of garments produced and disposed of, in order to suggest an emissions baseline.[22]

Indeed, to produce numbers for footwear, it appears to have calculated apparel industry carbon emissions and then merely 'scaled up' to 'combined apparel and footwear industry emissions based on 2018 emissions split between the two segments.'[23] Its 'shoe math' can be seen in endnote 88: "Apparel assumed to represent ~82% combined apparel and footwear industry carbon emissions based on Quantis: Measuring Fashion Report 2018",[24] What the authors did was use a past report on footwear emissions to calculate the breakdowns – but again, there was no use of any footwear data.

By only using textile data to 'triangulate' calculations, this report therefore misses the critical data that applies to the majority of shoe materials; it fails to account for the much more complex manufacturing processes of footwear; and it does not account for the use or end of life of shoes.

Despite this, the McKinsey report has been highly influential. It is cited in the U.N. report Sustainability and Circularity in the Textile Value Chain: A Global Roadmap.[25] It is also discussed on countless websites and articles as somehow representative of total shoe carbon emissions.

The second report, which enjoys similarly canonical status, is Measuring Fashion by Quantis (2018).[26] This study was much more meticulous in its methodology for trying to calculate the carbon emissions of footwear, removing calculations for apparel for accuracy. It drew on several fiber databases and data taken from the 2012 World Footwear Yearbook (we are uncertain why they did not use 2017 data from the yearbook). Quantis also relied heavily – as per the report's methodology – on the MIT-led study "Manufacturing-Focused Emissions Reductions in Footwear Production."[27] Of note, the shoe emissions data in the MIT-led LCA study was already over 7 years old by the time of Quantis' publication.

Measuring Fashion examined the entire lifecycle of a shoe except consumer use. It zeroed in on three globally produced shoe types: leather (25%), synthetic (57%), and textile (18%). It stated that the global footwear industry generates 700 million metric tons CO_2-eq, which was quantified as representing 1.4% of global impacts. Notably, the authors claimed that the global footwear industry produces one-fifth the impact of the apparel industry.

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20 Global Fashion Agenda and McKinsey, *Fashion on Climate: How the Fashion Industry Can Urgently Act to Reduce Its Greenhouse Gas Emissions,* 2020. (**https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/fashion%20on%20climate/fashion-on-climate-full-report.pdf**)
21 Ibid., 5
22 Ibid., 28
23 Ibid., 28
24 Ibid., 52
25 United Nations, *Sustainability and Circularity in the Textile Value Chain: A Global Roadmap*, 2023, (**https://www.unep.org/resources/publication/sustainability-and-circularity-textile-value-chain-global-roadmap**).
26 Quantis, *Measuring Fashion: Environmental Impact of the Global Apparel and Footwear Industries Study*, 2018. (**https://quantis.com/measuring-fashion-report-2018**)
27 L. Cheah, C.N. Duque, E. Olivetti, S. Matsumura, D. Forterre, R. Roth, and R. Kirchain, "Manufacturing-Focused Emissions Reductions in Footwear Production," *Journal of Cleaner Production* 44 (2013): 18–29.

How they came to the figure of 700 million metric tons is unknown. The report did not provide a detailed breakdown of its mathematical working. It merely listed the sources used to break shoes down for measurement within the three categories. The methodology section does provide some detail on the materials captured within each category. But reveals a major flaw in understanding footwear: it did not appear to appreciate that each shoe type does not use the same materials – leather shoes, for example, were calculated with just EVA foam. In reality, leather shoes rarely contain foams.

Again, the Quantis report appears to draw its math almost exclusively from the calculations originally made in the MIT-led study "Manufacturing-focused emissions reductions in footwear production." We reiterate this because as we have pointed out, the figures for footwear emissions produced in this study are higher than would be accurate today.

Of course, we know no data and analysis will be perfect, but there are major red flags in both highly influential reports presently in circulation. The numbers they produce for industry carbon emissions are built on bad assumptions and data sets. A better understanding of the true picture of carbon emissions requires a new look at total global shoe emissions, with far greater detail on shoe breakdowns, materials, and the manufacturing process.

The Global Footwear Industry's Total Carbon Emission Today

We seek to calculate the industry's modern carbon footprint in a more logical, accurate manner that can be used as a benchmark until additional robust research is conducted.

What is the industry's carbon emission at the highest end of the spectrum?

First, we identified the total global emission baseline. There are numerous global organizations that calculate total global carbon emissions, and they all have varying numbers based on their scope. According to the Global Carbon Project, the total global carbon emissions (including fossil fuels and land use change) for 2023 were estimated to be around 40.9 billion tonnes.[28] The World Resource Institute (WRI) quantified there was 47.4 billion tonnes of carbon emissions globally in 2020.[29]

We then took the carbon emissions data from the MIT-led LCA study on a pair of Asics manufactured in 2010–2011. As dissected above, the study's emission data is well outdated and overstated based on modern factory energy uses and efficiencies. It is also a shoe that is well above an industry average in terms of construction, materials, and overall emissions. However, we wanted to calculate a worse-than-average scenario to ensure our analysis remains balanced. This approach demonstrates our commitment to avoiding selective reporting and provides a comprehensive understanding of the potential environmental impact.

From the study, we know the Asics sneakers emitted 13.8 kg CO_2-eq per pair. We know there are 23.3 billion pairs of shoes manufactured annually across the globe (all types) per the World Footwear Yearbook 2023. That equals 321.54 billion kgs of annual carbon emissions.

TABLE 7: CALCULATING TOTAL GLOBAL FOOTWEAR CARBON EMISSIONS (HIGH)

At the high end of the spectrum, emissions significantly exceed those of modern shoes, using the 2010-2011 Asics Shoe LCA (13.8 kg CO_2-eq)

Global Shoe Industry: 23.3 billion pairs x 13.8kg = 321.54 billion kgs of annual CO_2 emissions	
Carbon Project: 40.9 billion tonnes of total CO_2	**WRI: 47.4 billion tonnes of total CO_2**
Shoe industry global emissions percent of total: **0.786%**	Shoe's industry global emissions percent of total: **0.678%**

28 **https://globalcarbonbudget.org/fossil-co2-emissions-at-record-high-in-2023/#:~:text=The%20report%20projects%20that%20total,to%20meet%20global%20climate%20targets**.

29 **https://www.wri.org/data/world-greenhouse-gas-emissions-2020**, Source: **Climate Watch**, based on raw data from IEA (2022), GHG Emissions from Fuel Combustion, **www.iea.org/statistics**; modified by WRI.

When running the calculations, using a worse than average shoe, we see an industry that is – at its highest point on the spectrum – responsible for between 0.68% – 0.78% of all C02 gas emitted globally across all economic activities each year. That is half of Quantis' 1.4% estimation. Again, these are the highest case calculations.

What is the industry's emission level according to the modern footwear analysis?

We used the same numbers from the Carbon Project and WRI, and the 23.3 billion pairs of shoes manufactured globally. We then used the 6.7 kg CO_2-eq our average shoe emitted (see image 2) to calculate impacts. The result is 156.11 billion kg of annual carbon emissions by the footwear industry – from cradle to grave.

Compared against total global carbon emissions by all industries the modern global footwear industry emits between 0.38% and 0.33% of total global emissions. That is 75% less than Quantis' 1.4% estimation – Again, their 1.4% was based on outdated data and erroneous assumptions.

TABLE 8: CALCULATING TOTAL GLOBAL FOOTWEAR CARBON EMISSIONS (NEW MATH)

Finding the Medium Using the modern 2024 Women's Running Shoe Calculation of (6.7 kg CO_2-eq)

Global Shoe Industry: 23.3 billion pairs x 6.7 kg = 156.11 billion kilograms of annual CO_2 emissions	
Carbon Project: 40.9 billion tonnes of total CO_2	**WRI: 47.4 billion tonnes of total CO_2**
Shoe industry global emissions percent of total: **0.38%**	Shoe's industry global emissions percent of total: **0.33%**

What would that number be if we just looked at the U.S. and E.U. markets?

There were 1.998 billion pairs imported into the U.S. in 2023 and roughly 20 million pairs produced domestically, for 2.018 billion total shoes in the marketplace.[30] Total carbon emissions from the U.S. in 2022 was 5.057 billion tonnes of CO_2.[31] There were 2.849 billion pairs of shoes consumed in European Union states in 2023.[32] Total carbon emissions from the E.U. in 2022 was 2.762 billion tonnes of CO_2.[33]

TABLE 9: CALCULATING U.S. AND E.U. TOTAL FOOTWEAR CARBON EMISSIONS

Calculus Using the 2024 Women's Running Shoe Calculation (6.7 kg CO_2-eq)

U.S. Shoe Market	**E.U. Shoe Market**
2.018 billion pairs (2023) x 6.7kg = 13.52 billion kgs of annual CO_2 shoe emissions	2.849 billion pairs (2023) x 6.7kg = 19.2923 billion kgs of annual CO_2 shoe emissions
5.057 billion tonnes of total CO_2 emitted in the U.S.	2.762 billion tonnes of total CO_2 emitted in the E.U.
Shoes' percent of total U.S. emissions: 0.27%	**Shoes' percent of total E.U. emissions: 0.7%**

We wanted to test that U.S. figure to see if it passed muster. Annual U.S. shoe consumption of ($112.7 billion[34]) is roughly 0.4% of annual U.S. GDP (~$28.87 trillion). That is, the ratio of U.S. shoe demand divided by GDP is comparable to CO_2 output from U.S. shoe demand divided by CO_2 output from total U.S. economic output. So, it passes a rough accuracy measure.

30 USITC and FDRA data **domesticfootwear.com**
31 Our World in Data (Oxford) **https://ourworldindata.org**
32 *World Footwear Yearbook* 2024. **https://www.worldfootwear.com/yearbook/the-world-footwear-2024-Yearbook/232.html**
33 Our World in Data (Oxford) **https://ourworldindata.org**
34 U.S. Bureau of Economic Analysis. Full year 2023. Assessments by FDRA staff.

For an additional comparison perspective, the U.S. Pentagon alone accounts for 1% of total U.S. emissions. It encompasses a vast network of facilities, oversees immense logistical operations, and is one of the largest U.S. employers and energy consumers.[35] It is implausible to suggest that footwear carbon emissions could exceed those of the magnitude and complexity of the world's largest military institution. This comparison further reinforces the validity of the figure in Table 9.

Again, we feel this analysis is more accurate than anything previously calculated, because of the modern data used, coupled with a more detailed and accurate look at shoe components and breakdowns. It would be our hope that others might run closer analysis of various product types to then combine and get at even more detailed calculations.

Bottom Line: What then, is the shoe industry's total global carbon emissions today?

Crucially, we know it is not 10%, 8%, or 4% of total emissions as past reports and groups have tried to claim, often by lumping shoes in with 'fashion', instead of scientifically breaking it out. We know it is not 1.4% as the Quantis report claimed.

Instead, we can state with a high level of confidence that the figure is below 1%. We cannot determine whether it is exactly 0.33% or 0.38% per Table 8. What we do know is that the trend line is moving downward, and it is highly unlikely to exceed 0.5%, even when accounting for a 25% upward variance on 0.38%.

Forced to give a bottom-line number today when this report is published, we would put the global footwear industry's carbon emissions at 0.45% of total global emissions.

Global carbon emissions have continued to grow, making it essential to assess the footwear industry's emissions within the broader context of this increase. However, unlike many industries, footwear production has remained relatively stable over the past decade. In 2014, global footwear production was nearly 24 billion pairs, and in 2023, it stood at around 22 billion pairs. **This stability contrasts sharply with the expansion seen in other sectors. Absolute emissions within the industry still matter and must be reduced. However, a stable production baseline offers a valuable advantage—it allows us to isolate emissions trends and better understand where reductions can have the greatest impact.**

The most accurate look at total footwear carbon emissions would be to conduct LCAs for each of the 436 different types of shoes, as classified by chapter 64 of the U.S. Customs code, run the math on production and emissions per type, and then combine into one data set. Due to multiple challenges beyond the millions of research dollars needed, including collecting accurate country-by-country production data and the granularity of each shoe type's materials and construction, this is nearly impossible at the global level.

What could be done in the future is paired back research following the same logic. Running a LCA for each selected average shoe (size, weight, materials, etc.) from each major category of footwear (sandals, slippers, heels, oxfords, casual, athletic, boots); then use global production data of each type to calculate each category's emissions and combine them into one data set. This was in part what Quantis was attempting to do, but did not go far enough in product types and did not have the right data for footwear.

35 "How hard is it to run the Pentagon," *The Economist*. (2025). **https://www.economist.com/united-states/2025/01/12/how-hard-is-it-to-run-the-pentagon**; Crawford, N. C. (2019). "Pentagon fuel use, climate change, and the costs of war." *Brown University Costs of War Project*. **https://watson.brown.edu/costsofwar/files/cow/imce/papers/Pentagon%20Fuel%20Use%2C%20Climate%20Change%20and%20the%20Costs%20of%20War%20Revised%20November%202019%20Crawford.pdf**

VII. Key Emerging Issues in a Changing Landscape

There are some key areas of note that will impact our understanding of emissions, and there are some areas that require further in-depth study to help with industry alignment and clarifications.

Grid Emissions Updates

Emission calculations by energy type for shoe manufacturing are constantly changing. Grid electricity varies based on location due to the upstream sources. In the past, there may have been more coal used to generate electricity than is the case today, where there may be a greater mix of hydro, wind, and solar in certain areas of Asia. This would significantly reduce the carbon emissions calculations for grid electricity. However, we must be careful as this is a shifting landscape.

An example of this changing calculus is in the debate over how much carbon emissions comes from the Guangdong China power industry. Within the existing literature some have suggested that power drawn from this region's electricity grid could have an impact of .87 kg CO_2 per kWh, if a high amount of coal is used as a power source.[36] By contrast, others have noted that the region now has a large amount of hydro power fueling electricity production and as a result, concludes that the new calculation should be .404 kg CO_2 per kWh.[37]

The International Energy Agency (IEA) is also bullish on China's energy transformation. Their World Energy Outlook for 2024 stated that China was becoming a world leader in the new age of electricity. China accounted for 60% of all new renewable energy, globally, in 2023. As it incorporates more renewables into its grid, the emissions per kWh will continue to fall. However, China is also constructing new coal powered plants to feed its electric grids making this an ever-changing carbon emission landscape to quantify.[38]

The various electricity emission datasets provide even greater difficulty for assessing footwear both because of the enormous material inputs, but also because of a growing geographic divide among suppliers. The MIT-led LCA study looked at a shoe whose T1 and T2 suppliers were seemingly in the same geographic location, perhaps even in the same factory. This was common in China in 2010. Today, industry sourcing is proliferating where a company's T1 factories may be in multiple countries, while some of the T2 suppliers to those factories are in yet another country. That is added to the fact T3 suppliers of various inputs for a single shoe may be located across several different continents.

Grid emissions outside China are also changing. Vietnam has approved a plan to phase out coal-fired electricity by 2050. That, combined with increased renewable energy being used in factories, would have a further significant reduction in emissions for Tier 1 and Tier 2 manufacturing in Vietnam.

The Acceptable Age of Data

How long does carbon emissions data remain accurate? This is important for measuring impacts across products and companies, but it matters to consumers as well. Emission factors are changing on almost an annual basis. It is, in fact, a legal issue raised with the Federal Trade Commission (FTC) as part of feedback on their efforts to update the U.S. "Green Guides". The FDRA issued a letter to the FTC on this very topic. Speaking for the footwear industry, it raised this as an issue for accurate marketing and consumer facing information generally:

> We find companies using 10+ year-old environmental impact data to compare their current efforts and products. We would encourage the Commission to look at this issue and seriously consider rules around the age of comparative data being used for marketing.

36 J. Zuo, et al., "Analysis of Carbon Emission, Carbon Displacement and Heterogeneity of Guangdong Power Industry," *Energy Reports*, 2022, (**https://www.sciencedirect.com/science/article/pii/S2352484722006709**).
37 Chen, H., et al., "Monitoring the enterprise carbon emissions using electricity big data: A case study of Beijing." *Journal of Cleaner Production*, 2023, (**http://ae.ruc.edu.cn/docs/2023-05/f0acefb399ed495e9c7b0a66189b6749.pdf**)
38 CREA, "When Coal Won't Step Aside: The Challenge of Scaling Clean Energy in China," 2025, (**https://energyandcleanair.org/publication/when-coal-wont-step-aside-the-challenge-of-scaling-clean-energy-in-china/**)

> Using data that is perhaps even three years old against rapid product innovations can make a company's product look better for the environment than other like products in the marketplace. This directly confuses consumers over benefits and options. Not only should the comparison be in the same exact category, but it should also be using impact assessments within only the last few years.

LCAs and impact assessments can be valuable for measuring and mitigating impacts even if they are outdated. However, the data becomes obsolete after several years and new studies are needed. Researchers may consider a series of assessments on the same company, factory, or shoe every year to measure adjustments and observe changes.

Shoe Lifespan

One important thing to consider is whether LCAs calculate the accurate life span of the shoe. Often, boots are much more durable and can provide ten times more days of use for consumers than a simple walking shoe. Currently, we've seen European government bodies consider listing ALL close-toed shoes as delivering 100 days of consumer use under their Product Environmental Footprint discussions.[39] Is this accurate?

Technical footwear testing – flex tests, etc. – is often not informative for our understanding of actual consumer use. **We need more data derived from actual consumers, such as how many uses, on average, can one get out of basic shoes.**

We should also agree that a shoe's carbon footprint should be spread out over its life – doing so may help consumers think more about buying higher quality items and donating/selling/disposing of shoes after they are finished with them. Some private LCAs we have seen score in this manner to help show designers and development teams the difference that materials and construction techniques have on the shoe's total score. A work boot may have a large impact score from cradle to grave, but it should get credit for lasting 3-4 years and have that impact spread out each year it is in use.

Research is also needed to help calculate the impact of refurbishing shoes – the impacts for shipping to a cobbler; deconstruction/disposal of old materials; use of new materials; rework and return to the customer; as well as how extending the life of a shoe impacts its total emissions. Likewise, we need data on emissions and benefits from resale as well as donations.

Finally, we need a scientific study on the actual end of life of footwear. We need data on the carbon emissions from putting shoes in a landfill, recycling shoes (both upcycle and downcycle), and burning shoes for energy recovery. We lack a clear understanding of the carbon impacts of these final stages in the lifespan.

39 European Footwear Confederation Joint Statement: **http://cec-footwearindustry.eu/new-co-signatories-of-the-joint-statement-on-durability-in-af-pefcr/**

VII. Quick Conclusions and Thoughts

Footwear is a labor-intensive, highly-developed product that must perform for consumers with every step they take. Researchers, policymakers, and groups need to separate footwear from apparel if their reports are to be accurate for consumers, as well as help companies better focus their efforts, and help produce appropriate policy responses against real-world data.

The footwear industry has achieved significant reductions in its carbon impact over the last decade. Of course, the footwear industry must – and will – do more to further reduce its carbon emissions, but already, contrary to conventional wisdom, shoes do not have a high impact on global emissions. In fact, if a running shoe used even 10–20% of the environmentally preferred materials which are standard today in an average factory in Asia, the environmental impact would be half of that which was calculated a decade ago.

More scientific research is needed on the carbon emission of footwear to continue to help companies further improve their performance. We hope this report has provided a first step towards a new, realistic appraisal of where the footwear industry is and areas companies can target to further advance their efforts.

Building on the progress made over the last decade, factories can continue to optimize and reduce their carbon emissions across the shoe lifecycle as they continue to adopt renewable energy sources. Factories can do more to reduce waste and can adopt better water management systems. Optimizing and using programs such as FDRA's ZERO Factory Waste Program can reduce carbon impacts and boost profits. Water is another critical issue that requires attention, even though it is often overlooked due to carbon tunnel vision. Currently, we have good data on this issue, but it remains an area for future research.

Brands can continue to choose better materials. There are a range of new plant-based materials in the market. Even displacing 5, 10 or 20% of fossil fuels in components and materials can provide meaningful reductions in emissions. Companies can also continue to optimize how they ship and deliver shoes to consumers – providing consumers a choice or incentive to deliver product to their homes in a more sustainable manner is an easy one to adopt.

Consumers equally have a role to play. Consumers can choose shoes with bio, recycled, or regenerative to support footwear's transformation. They can choose shoes that last longer and are repairable. They can make a choice to donate their footwear to others, to ensure the shoe's full potential life is met. There is also an opportunity for future research into the gap between consumers' perception that their shoe's useful life has ended and the actual remaining life it may have, particularly for individuals at the lower end of the socio-economic spectrum.

Finally, beyond looking at emissions, we need more scientific data on the impact that shoes have on biodiversity at both raw material extraction and the end of life.. What impacts do shoes in landfills, for example, have on the soil and animals? What better materials may help mitigate that impact? Few have ventured into the space of considering questions about the relationship between footwear and biodiversity – yet it too will be crucial. And as discussed here, when we do explore these issues, it is vital we do so with accuracy and up-to-date data assumptions.