eppendorf

WHITE PAPER No. 114

# Small Tips – Big Impact: The Carbon Footprint of Biobased Pipette Tips

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Research is gathering data on the climate crisis, working on solutions to mitigate its effects – and at the same time, research itself has a major impact on the environment. Single-use plastics items are a major concern for researchers, even though they are often indispensable in the daily laboratory work. One solution is to shift from fossil-sourced to biobased products. This White Paper compares the carbon footprints of fossil-sourced and biobased pipette tips and shows how much greenhouse gas emissions can be saved and what other ways there are to reduce the carbon impact of these products.

Sustainability in the laboratory has become an important issue in recent years and more and more people are taking measures to make their laboratory work more sustainable. Obviously, one major issue that concerns almost everyone working in the laboratory is the large amount of plastics waste generated by the use of disposable plastics consumables. On top of this comes the carbon footprint of the production and disposal of the plastics. On the other hand, it is simply not possible to avoid plastics completely. Single-use items help to avoid contamination (which may occur if they are re-used), they ensure the quality of scientific results by providing reliable product quality, and they often simply save valuable time. The question is: how to tackle this issue? Any optimization of the product carbon footprint by reducing the usage of plasticware in laboratories is currently challenging. One solution to reduce carbon emissions of single-use plastics is to change the material from which they are made. Switching from primary fossil oil-sourced plastics (hereinafter shortly referred to as "fossil-sourced") to biobased resources can reduce greenhouse gas emissions and offers potential for a (more) circular economy.

The first biobased products arrived in the laboratories. Since 2022, Eppendorf has introduced three product groups: biobased tubes, biobased PCR plates, and biobased pipette tips (see Figure 1). More will follow. However, the question remains: how much greenhouse gas emissions can be saved by switching to a biobased alternative? And which lessons can be learned for future products? This White Paper takes a closer look at biobased tips, compares their carbon footprint with that of their fossil-sourced counterparts, and identifies further levers to reduce the carbon footprint.


**Figure 1:** Biobased consumables (tubes, tips, and plates) made of recycled oils from the food industry

### Life cycle analysis and carbon footprint

Every product has multiple environmental impacts throughout its life cycle, from the sourcing of its raw materials, through its manufacture and use, to the end of its life, whether through incineration, landfill or, in the best case, recycling. Greenhouse gases such as $CO_2$, methane, or nitrous oxide contribute to global warming. Other components such as $SO_2$ generated from combustion of fossil fuels contribute to acidification, while the extraction of resources are in most cases associated with negative impacts on planetary boundaries such as biodiversity, while being lost to future generations. A Life Cycle Assessment (LCA) examines these environmental impacts (use of soil, biodiversity, water, $SO_2$, etc.) over the entire life cycle of a product (or a service or a process). It provides a very detailed picture that helps to identify opportunities for improvement or to compare different products and their environmental performance. which requires a similar calculation approach and similar data quality.
Eppendorf conducted an LCA for its biobased 5 mL tubes which revealed valuable insights (see also our White Paper 93 [1]). However, it is important to note that conducting an LCA requires a lot of data, is very complex and also expensive. It is therefore not feasible for every product in a portfolio as large as Eppendorf's. Nevertheless, this LCA provided valuable insights and one of the key findings was that greenhouse gas emissions are one of the biggest environmental impacts in the production of biobased tubes [1].

This led to the decision to focus on the Product Carbon Footprint (PCF) and calculate it for other products. This also fulfills the needs of many customers and stakeholders who mainly ask for the carbon footprint and the carbon savings of a product rather than a full life cycle analysis.

A first calculation has now been carried out for biobased pipette tips. But before we get into detail, let's take a closer look at how a carbon footprint is calculated and what assumptions and limitations need to be taken into account.

### Explained: What is a Product Carbon Footprint?

The PCF is calculated according to similar mathematical rules and data methodologies as an LCA. The chosen standard, scope, and boundaries influence the final results of the PCF. In addition, the LCA focuses on several environmental impact categories, whereas a PCF is focused on the climate change impact category only. Therefore, the PCF only includes greenhouse gas emissions [Table 1]. A detailed and well-accepted guideline for the calculation of a PCF is "The Greenhouse Gas Product Life Cycle Accounting and Reporting Standard". [2] This document outlines in detail how to calculate the carbon footprint of a product and the steps to be followed.

**Table 1:** Relevant greenhouse gas emissions and their impact for a Product Carbon Footprint [3]

| **Type of greenhouse gas** | **GWP** (based on $5^{th}$ Assessment Report) |
|---|---|
| $CO_2$ | 1 |
| $CH_4$ | 28 |
| $N_2O$ | 265 |
| Fluorinated gases (HFC, PFC, $SF_6$, $NF_3$) | Broad mix of substances with very diverse range of GWP, up to 23,500 |

To begin with, you need to answer a number of questions: What is the goal/ purpose of your PCF? Do you want to determine the greenhouse gas emissions of your product or compare two or more products?  Secondly, you need to define in detail the product for which you want to calculate the PCF. Is it a box of pipette tips or a packaging unit with several boxes? It is also necessary to include all auxiliary material such as packaging. This is now your functional unit and the basis for all further calculations.

There are other assumptions that need to be considered or decided upon: What pre-products, ancillary-products, and other processes, such as transportation, need to be included in your analysis? What are your geographical boundaries – are you focusing on one country, one region (such as Europe, the USA, or Asia), or the whole world? Last, but not least, it is crucial to outline any exclusions due to data gaps or data deemed insignificant.

You must decide between two life cycle scenarios: Depending on the selected standard, there are two scenarios possible:

> Cradle-to-grave scenario where the greenhouse gas emissions are calculated over the entire life cycle.
> Cradle-to-gate scenario where you focus on the sourcing of materials, pre-processing, and manufacturing of your product. Such a scenario can be selected if the focus is on the early stages of the life cycle or if data on the use phase and/ or end-of-life are missing.

Once you have defined your functional unit, scenario, geographical boundaries, and further assumptions in detail, you need to collect all the data. This step involves a detailed analysis of the energy flows, services, and material inputs and outputs of your process: How much electricity is used to manufacture your product? Which materials are used in the production process and how much? How long are the transportation routes and which types of transport (truck, train, ship, plane) are used? All this data must be obtained either from the manufacturer, suppliers or, if this is not possible, from databases. It is essential to specify whether original data were used in the analysis or whether data had to be modelled using proxy data from databases. Data quality must also be assured and it is recommended that “companies shall report a descriptive statement on the data sources, the data quality, and any efforts taken to improve data quality”. [4] Once all the data has been collected, the greenhouse gas impact can be calculated using emission factors and converted into $CO_2$-equivalents. Emission factors are specific to a service, material, or energy flow. The emissions indicate, for example, how much greenhouse gas is emitted when a particular energy source (gas, coal) is burned. The emission factors are either available directly from suppliers for a specific material or can be retrieved from databases. These results are then used to identify potential improvements and reduction levers.

**The carbon footprint of fossil-sourced and biobased pipette tips**

Pipette tips are one of the most single-used products in the lab. Due to their enormous quantities used in the global scientific world, switching to a biobased product can represent a great lever to reduce the product carbon footprint of a pipette tip. For example, in a 6-month student internship at the University of Groningen (Netherlands), 18,000 pipette tips with a volume of 250 µL volume were used. [5] This figure gives an idea of the scale and why it makes sense to focus on pipette tips, but in the end, you need data to know how big the potential savings are when switching to biobased plastics compared to a fossil-sourced product. To answer the question about carbon savings, the carbon footprints of two Eppendorf products were calculated by an external party:

**Product 1:**
The ep Dualfilter T.I.P.S.® BioBased Reload 0.1-10 µL M, 960 tips, PCR clean and sterile (#0030081030) that contains biobased pipette tips while filter, container, tray, lid, and membrane are still fossil-sourced.


**Figure 2:** ep Dualfilter T.I.P.S.® BioBased Reload 0.1-10 µL M, reload-system that contains biobased pipette tips while filter, box, tray, lid, and membrane are still fossil-sourced

**Product 2:**
The ep Dualfilter T.I.P.S.® Rack 0.1-10 µL M, 960 Tips, PCR clean and sterile (#0030078519) that contains only fossil-sourced components including fossil-sourced pipette tips.


**Figure 3:** ep Dualfilter T.I.P.S.® Rack 0.1-10 µL M, single use system, containing only fossil-sourced components including fossil-sourced pipette tips

The sourcing of the biobased material is based on second generation material such as plant oil waste from the food industries (= recycling of previously used material).
The supply chain of the biobased material is checked and verified by ISCC PLUS. The biobased tip material has a 100% biobased share, based on the mass-balance-approach. The biobased tips as products are checked and validated by the ACT® label of My Green Lab®.

The carbon footprint was calculated according to the guidelines of "The Greenhouse Gas Product Life Cycle Accounting and Reporting Standard". The functional unit on which the PCF calculation is based is defined as follows:

**a) Functional Unit: epT.I.P.S.® BioBased Sterile Reloads (#0030081030)**
- > 960 ep Dualfilter T.I.P.S.® BioBased PCR clean/ Sterile with a volume of 0.1-10 µL (10 x 96 tips = 960 tips in total)
- > Ten (10) containers with bottom, lid, and tray
- > Packaging Material including the primary plastics and secondary cardboard packaging for the individual containers and tertiary packaging cardboard box

**b) Functional Unit: epT.I.P.S.® Racks (#0030078519)**
- > 960 Functional Unit: epT.I.P.S.® BioBased Sterile Reloads (#0030081030)
- > 960 ep Dualfilter T.I.P.S.® BioBased PCR clean/ Sterile with a volume of 0.1-10 µL (10 x 96 tips = 960 tips in total)
- > Ten (10) containers with bottom, lid, and tray
- > Packaging Material including the primary plastics and secondary cardboard packaging for the individual containers and tertiary packaging cardboard box

The carbon footprint was calculated based on a cradle-to-grave concept. In this White Paper, we focus on the cradle-to-gate scenario which is a part of the complete calculation but ending at the gate of Eppendorf.
The cradle-to-gate scenario included raw material sourcing, manufacturing, and a sterilization step as well as transportation between different sites. [Graph 1]

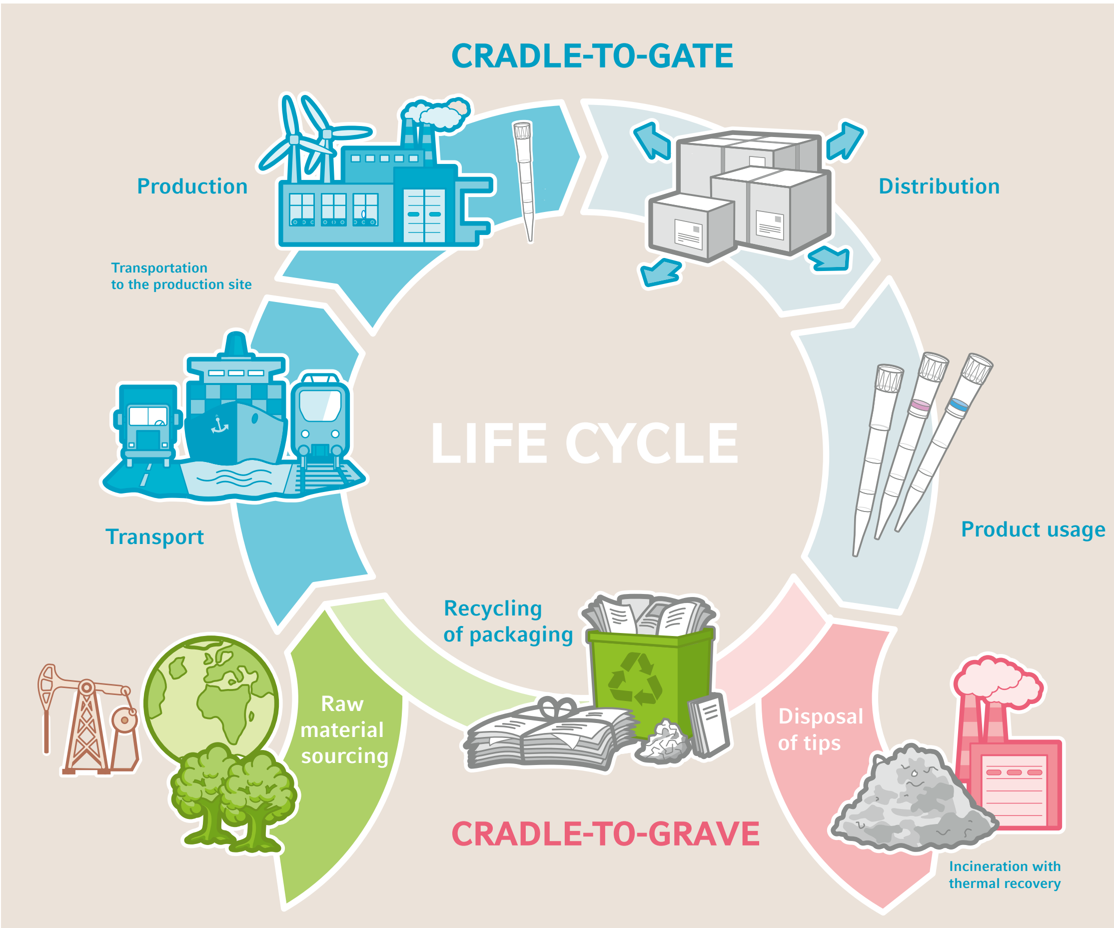


**Figure 4:** ep Dualfilter T.I.P.S.® BioBased Reload 0.1-10 µL M, reload-system that contains biobased pipette tips while filter, box, tray, lid, and membrane are still fossil-sourced

In detail, the PCF is based on the following data:
All raw materials were listed in a detailed Bill of Materials (BoM) with all parts required to manufacture the product, the material, and weight of each component. The BoM included detailed information on the transport routes to the production site.
The manufacturing process was monitored in detail and the electricity consumption was measured directly at the injection molding machines.
The final sterilization process was carried out in an external facility. Only the transport to and from the sterilization side was considered. The total energy for sterilization was known, but could not be broken down to the energy for sterilization of each tip. However, since the total energy for sterilization was small compared to the injection molding process, it was considered insignificant.
Once all the data was collected, emission factors were assigned or estimated. Some suppliers were already able to provide a PCF for their specific raw material or component, but most of the raw material data still had to be researched in databases. However, compared to the provision of carbon emission data for the LCA of bio-based tubes, improvements can be seen and the overall quality of data is considered high. Emission factors for the energy mix or truck transportation were also obtained from specific databases. Based on these emission factors, the product carbon footprints were calculated. The scale-up calculation from single tips to complete functional units and vice versa can lead to rounding errors, as many values are very small.

Due to the different sterilization locations for fossil-sourced versus biobased tips as well as the different packaging systems (single-use Racks for fossil-sourced tips and Reloads for biobased tips), the comparison of both tip types is challenging. But as these two products are the most similar ones, we decided to go for a comparison. To clearly mark the fundamental differences between both products, we split the carbon data into two groups:
> Analyzing the raw material impact only to show the real impact of the biobased material.
> Analyzing the complete product: This value is important for your own calculation in the laboratory as the total product value represents the real $CO_2$e savings compared to the fossil-sourced material.

**Raw material only**

Based on these results, it is possible to calculate and compare the carbon footprint of a pipette tip based on the raw material, as the tips in both products are exactly the same and only differ in the feedstock:

> A single pipette tip with a volume of 0.1–10 µL M made from fossil-sourced material has a carbon footprint of 0.22 g $CO_2$e (fossil-sourced).
> A single tip with a volume of 0.1-10 µL M made from biobased material has a carbon footprint of 0.07 g $CO_2$e. Switching from fossil-sourced to biobased material saves 0.15 g $CO_2$e emission per pipette tip (0.1 – 10 µL M). Extrapolated, these are 14.4 g $CO_2$e savings per tray (96x) and 144 g $CO_2$e savings for a package of 960 pipette tips (0.1 – 10 µL M)

Biogenic carbon emissions are not included in this calculation. Biogenic carbon emissions take into account the fact that plant material absorbs $CO_2$ as it grows and releases exactly the same amount when it burns or decomposes. This results in net zero emissions - no additional $CO_2$ is released into the atmosphere. In contrast, non-biogenic fossil materials release $CO_2$ during combustion, increasing the total amount of $CO_2$ in the atmosphere. If you compare fossil-based materials to plant-based materials, you save exactly this amount of $CO_2$ emissions by using the plant-based material. These so-called biogenic emissions have not been included in this calculation - but they would significantly increase the $CO_2$ savings until the "Gate". The inclusion of biogenic carbon in the calculation of the carbon footprint is still under discussion in the community.

**Total product**

The functional unit requires 2.962 kg $CO_2$e for fossil-sourced tips and 2.129 kg $CO_2$e for biobased tips. This is a difference of ca. -28%.

> A single tip with a volume of 0.1–10 µL M made from fossil-sourced material has a carbon footprint of 3.09 g $CO_2$e (fossil-sourced).
> A single tip with a volume of 0.1-10 µL M made from biobased material has a carbon footprint of 2.22 g $CO_2$e.

Switching from fossil-sourced to biobased material saves 0.87 g $CO_2$e emissions per pipette tip (0.1–10 µL M). Extrapolated, these are 83.5 g $CO_2$e savings per tray (96x) and 835 g $CO_2$e savings for a package of 960 pipette tips (0.1–10 µL M)

**Learnings**

1) The biobased total product has a 28% lower carbon footprint.
The ep Dualfilter T.I.P.S.® BioBased Reloads have an overall 28% lower carbon footprint than the fossil-sourced ep Dualfilter T.I.P.S.® when comparing the raw material and tip production process.
These savings are not only due to the change from fossil-sourced to biobased pipette tips which results in a 68% reduction in carbon emissions for the tip material, but also due to other changes made during the redesign of the product. As mentioned above, the design of the box and packaging of the Reloads (biobased tips) were optimized resulting in a 35% reduction in $CO_2$e-emissions for the container material and a 15% reduction in $CO_2$e emissions for the packaging material.
In addition, the change in the sterilization unit has resulted in far fewer transportation routes, resulting in a 72% reduction in carbon emissions.
Be aware, the single savings in percentage cannot be directly summed up to get the final 28% saving value.

2) The absolute numbers help to calculate your carbon footprint.
The absolute numbers in carbon emissions have also been calculated. These absolute numbers describe the carbon emissions of the total product (cradle-to-gate). This includes raw material, Dualfilter®, Racks, packaging material, sterilization logistics, production of tips, and production of the container.

The results are as follows:
The functional unit consisting of one package of Reloads for biobased pipette tips containing 10 boxes of 96 pipette tips with a volume of 0.1–10 µL M generates 2.13 kg $CO_2$e while the Rack for fossil-sourced one generates 2.96 kg $CO_2$e. By choosing the option with biobased pipette tips, 0.83 kg $CO_2$e can be saved.
On a per container basis, the Reload for biobased pipette tips generates 213 g of $CO_2$e whereas the fossil-sourced pipette tip container generates 296 g $CO_2$e which leads to a saving of 83 g $CO_2$e.

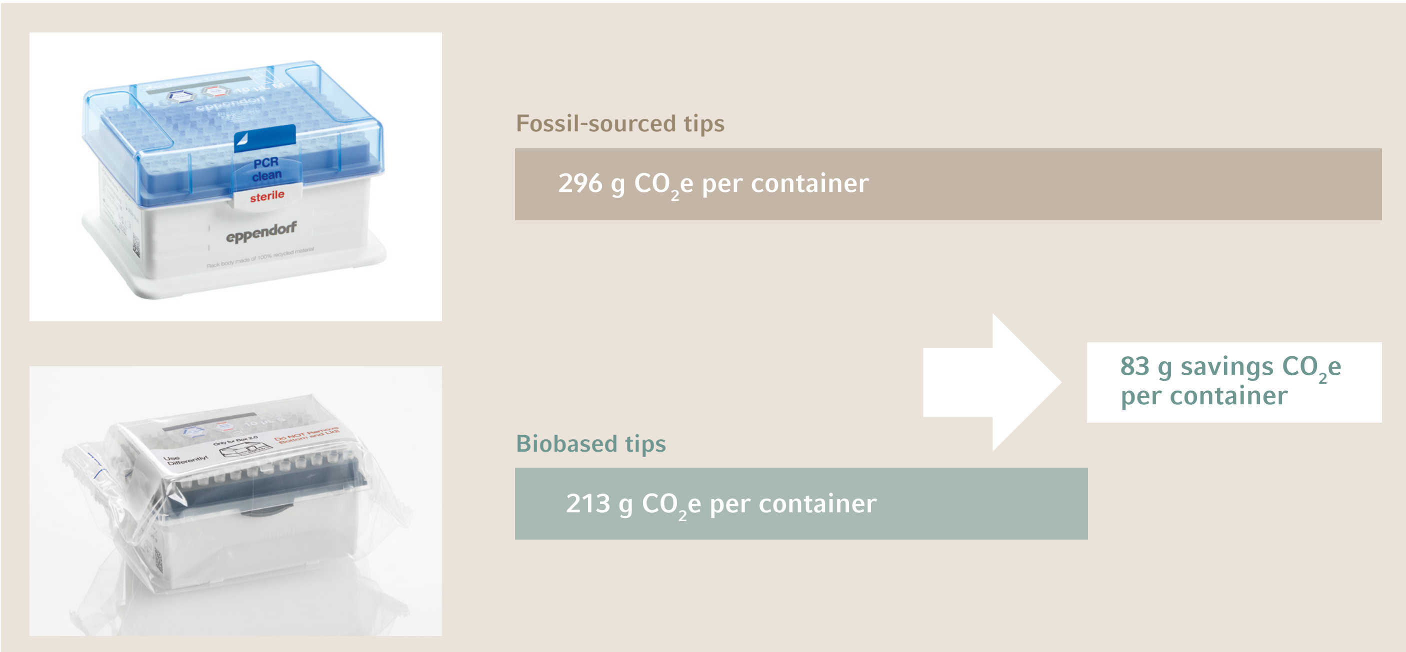


**Figure 5:** Carbon saving of biobased tips 0.1-10 µL M (savings per container) compared to equivalent tips made of fossil oil

Both absolute values (raw material as well as total product) seem to be marginal when checking the single tip.
The emission savings are increasing when being upscaled to real laboratory scale. Here is one example: A group at the Technical University of Dresden (Germany) used eleven boxes of pipette tips with a volume of 0.1 – 10 µL in one week. [6] Switching to bio-based tips would have saved 918.7 g of $CO_2$e-savings in one week, 3.675 g in one month and 42.3 kg of $CO_2$e savings in a typical working year of 46 weeks.

How many pipette tips do you use per week, per month, or per year? In addition, you probably use pipette tips with a volume of 100 µL, 250 µL, or 1,000 µL as well as those with such a small volume. Based on the $CO_2$e emissions of the raw material for the 0.1-10 µL M tips, Eppendorf has extrapolated the carbon emissions and carbon savings for other tip sizes in relation to the weight. This means that every lab can now get an idea of the carbon emissions associated with the use of these pipette tips.

**Lessons learned and outlook**

We need to reduce carbon emissions, and we need to know our impact reduction potential. The first step is to have reliable data on the carbon footprint of a product. Based on this data, laboratories can calculate their carbon impact and carbon reduction potential related to a specific product.
This use case clearly shows the major levers in product design and logistics that lead to a 28% reduction in carbon emissions for the ep Dualfilter T.I.P.S.® BioBased pipette tips in Reloads compared to the fossil-sourced pipette tips in Racks. This was achieved by changing to a biobased material, redesigning the Reload containers to reduce material consumption and by reducing transport distances. These tips are now available as Reload variant for epT.I.P.S. BioBased Biopur, ep Dualfilter T.I.P.S. BioBased PCR clean/Sterile, and ep Dualfilter T.I.P.S. SealMax Biopur. However, the aim of a PCF for a company is not to stop at the result, but to draw conclusions for the future. In this case, additional optimization levers were identified. These include further regionalization for materials and services as well as further reduction of fossil-sourced materials. Such a reduction does not only include the switch to biobased materials but also the switch to other materials with a lower carbon footprint, such as recycled polymers for containers and packaging materials.
What are the prospects for the future? These two PCFs are just the beginning and many more product carbon footprints must and will follow.
The ecodesign regulation (EU) 2024/1781, also known as ESPR, will request many product data to be published, not limited to carbon emissions. With the product carbon information, laboratories will be able to choose the most ecological product in terms of carbon emissions – and companies can identify the biggest levers to improve their manufacturing and product design.

**Table 2:** Carbon emissions and emission savings for different tip sizes based on PCF of 0.1-10 µL M tips

| Tip size | Emission per fossil-based tip – Cradle to Gate [g-$CO_2$-equ] | Emission per biobased tip – Cradle to Gate [g-$CO_2$-equ] | Relative emission saving per tip – Cradle to Gate [%] | Absolute emission saving per tip [g-$CO_2$-equ] | Absolute emission saving per package [g-$CO_2$-equ] |
|---|---|---|---|---|---|
| 0.1-10 µL M | 3.09 | 2.22 | 28 | 0.87 | 833 |
| **epT.I.P.S.® BioBased** | | | | | |
| 0.1-20 µL M | N/A | N/A | N/A | 0.87 | 417 |
| 2-200 µL | N/A | N/A | N/A | 2.27 | 1090 |
| 20-300 µL | N/A | N/A | N/A | 2.34 | 1122 |
| 50-1,000 µL | N/A | N/A | N/A | 4.41 | 2115 |
| 50-1,250 µL | N/A | N/A | N/A | 5.07 | 2436 |
| 50-1,250 µL L | N/A | N/A | N/A | 6.41 | 3076 |
| **ep Dualfilter T.I.P.S.® BioBased** | | | | | |
| 0.1-10 µL M | N/A | N/A | N/A | 0.87 | 833 |
| 0.5-20 µL L | N/A | N/A | N/A | 1.00 | 961 |
| 2-20 µL | N/A | N/A | N/A | 2.27 | 2,179 |
| 2-100 µL | N/A | N/A | N/A | 2.27 | 2,179 |
| 2-200 µL | N/A | N/A | N/A | 2.34 | 2,243 |
| 20-300 µL | N/A | N/A | N/A | 2.34 | 2,243 |
| 50-1,000 µL | N/A | N/A | N/A | 5.07 | 4,871 |
| 50-1,250 µL L | N/A | N/A | N/A | 6.41 | 6,153 |
| **ep Dualfilter T.I.P.S.® SealMax® BioBased** | | | | | |
| 0.5-20 µL L | N/A | N/A | N/A | 1.00 | 961 |
| 2-100 µL | N/A | N/A | N/A | 2.27 | 2,179 |
| 2-200 µL | N/A | N/A | N/A | 2.34 | 2,243 |
| 20-300 µL | N/A | N/A | N/A | 2.34 | 2,243 |
| 50-1,000 µL | N/A | N/A | N/A | 5.07 | 4,871 |

epT.I.P.S.: 100% biobased polypropylene

1 This data set is the result of the comprehensive Product Carbon Footprint conducted for the 0.1-10 µL M epT.I.P.S. (biobased + fossil-based). The critical review was performed by independent external experts.

2 Absolute amount of emissions saved when using a 0.1-10 µL M epT.I.P.S. BioBased instead of a fossil-based 0.1-10 µL M epT.I.P.S..

3 **Validated by 3rd party**

The data is depending on the boundaries set for the analysed system. Cradle to Gate: The emissions generated, starting from the collection of the raw material and ending with the final product leaving the warehouse. Distribution + end of life are excluded. As a Life Cycle or Carbon Footprint Analysis required, there are no values for other tip sizes available.

4 These values have been internally computed for the other tip sizes. These values are not validated by an independent 3rd party.

## References

[1] Whitepaper No. 093: Life Cycle Analysis of a 5 mL tube – Insights into environmental impacts and learnings: https://www.eppendorf.com/product-media/doc/en/11622498/Sustainability_White-Paper_093_Sustainability_Tubes-5-mL-LCA_Life-Cycle-Analysis5-mL-Tube-Insights-into-Environmental-Impacts-Learnings.pdf
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## About Eppendorf

Since 1945, the Eppendorf brand has been synonymous with customer-oriented processes and innovative products, such as laboratory devices and consumables for liquid handling, cell handling and sample handling. Today, Eppendorf and its approximately 5,000 employees serve as experts and advisors, using their unique knowledge and experience to support laboratories and research institutions around the world. The foundation of the company's expertise is its focus on its customers. Eppendorf's exchange of ideas with its customers results in comprehensive solutions that in turn become industry standards. Eppendorf will continue on this path in the future, true to the standard set by the company's founders: that of sustainably improving people's living conditions.

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