Sustainable Supplier Program

PHASE 1 INSIGHTS REPORT

Executive Summary

The Music Climate Pact and the Vinyl Alliance collectively share a long-term ambition to transition the record manufacturing value chain to a sustainable model. To enable decisions to be informed by the best available data both organisations launched a sustainable supplier programme in 2025. Contracting leading carbon experts Climate Partner to deliver this piece of work against the following objectives:

1. To standardise the approach taken to quantify the product level carbon emissions.
2. To improve the specificity and accuracy of the carbon emission factors used by Music Climate Pact signatories to report their scope 3 organisational carbon emissions associated with record manufacture
3. To enable a collaborative approach to transition to sustainable methods of record manufacturing

The first phase of this programme used a life cycle accounting approach to measure the product level carbon emissions for the range of different record manufacturing options in the marketplace today. This report is based upon data that was calculated for 13 product carbon footprints that were calculated and validated from nine different suppliers representing a significant proportion of the global manufacturing supply chain.

The study found that the most significant differentiating factor for traditionally pressed PVC records is the location of the plant- this is due to variations in the carbon intensity of the electricity grid. Therefore, three average Product Carbon Footprints (PCFs) have been generated to enable more accurate and representative emissions factors to be used where supplier specific data isn't available. These are:

Global average PCF (140g PVC standard black record) = **0.93 Kg CO2e / record**
European average PCF (140g PVC standard black record) = **0.75 Kg CO2e / record**
North America average PCF (140g PVC standard black record) = **1.17 Kg CO2e / record**

These figures demonstrate that the embodied carbon within traditionally pressed PVC records is circa 50% less than previous estimates being used by record labels to report organisational emissions however the impact of record manufacturing remains a materially significant source of emissions.

An average profile for injection moulded PET records was also established- this demonstrated that the total PCF for these products is 0.54 Kg CO2e / record (140 g standard black).
A number of key recommendations were identified from the hot spot analysis of the PCF's these include transitioning away from fossil fuels in the manufacturing process, in particular natural gas for traditionally pressed products, switching to 100% renewable electricity, using bio based / bio attributed materials and increasing recycled content. These recommendations represent approximately 40-60% carbon savings at the product level.

The priority actions that are recommended within the report vary depending upon manufacturing techniques however common actions shared by both traditionally pressed record manufacturers and injection moulding record manufacturers include implementation renewable electricity, using recycled raw materials and sourcing supplier specific data to enable evidenced improvements.

This study sets a benchmark by which measurable improvement actions can be taken- however this is just the start of the process of enabling truly sustainable value chains. Building upon the data gathered in this exercise to embed lifecycle thinking in supplier and label discussions is an important priority. Immediate next steps include suppliers and labels coming together in a series of focussed workshops to agree the appropriate frameworks for sustainable record manufacturing supply chains.
Standardising the approach to quantifying the carbon emissions in the cradle to gate phase of the lifecycle is an important first step. Value chain partners are encouraged to build upon this data to understand the wider environmental impacts that exist beyond carbon emissions within the full lifecycle to enable action to be taken to address these.

1. Introduction

1.1. The importance of climate action

Our planet's climate is changing. This is a direct result of human activity. We are releasing greenhouse gases into our atmosphere, and the impacts of these carbon emissions are being felt with increasing regularity around the globe. Extreme events, including flooding, heatwaves, wildfires and droughts, are becoming more frequent. The Paris Agreement committed countries to pursue efforts to limit the planet's temperature increase to 1.5°C, thereby reducing the risks and impacts of climate change, which threaten ecosystems, human health, food security, water supply, and economic growth. The goal of every organisation, country and ultimately humanity must therefore be to reach Net Zero by a deadline of 2050[1] to keep warming below 1.5°C.

The crucial first steps for any organisation are to:
1. Measure the emissions arising from a business (corporate carbon footprint, CCF) or product (product carbon footprint, PCF)
2. Identify the carbon hotspots within, and
3. Reduce those emissions as broadly and quickly as possible.

[1] As defined by the SBTi (the de facto authority on interpreting climate science into practical business guidelines for global organisations) i.e. carbon emissions fall by 90%, with any residual carbon emissions being removed from the atmosphere (AKA neutralised) via quality carbon removal projects.

1.2. Introduction to the program sponsors

The **Music Climate Pact** is a collective commitment by record labels and music organisations to take coordinated, science-based action on the climate emergency, working across the supply chain and beyond. Its signatories, which span major and independent companies, recognise that reducing negative environmental impact is essential to safeguarding both the planet as humans know it and the future of the music industry. In 2024, the Music Pact signatories and supporters chose to focus on three priority action areas:

- Climate Training for record label staff- Equipping label employees with the necessary skills to navigate this complex topic
- Understanding and reducing the impacts of our digital products- working with Digital Service Providers and digital supply chain partners to drive carbon reductions
- Understanding and reducing the impacts of our physical products- prioritising the impacts associated with vinyl manufacturing

The impact of vinyl manufacturing is the primary focus for the physical products workstream as this as this area contributes the majority of most record labels' reported carbon footprint. This supplier programme, in proud collaboration with the Vinyl Alliance, is designed to help us understand and reduce these impacts together through life-cycle analysis that leads to actionable data. By identifying where change will have the greatest positive effect, and by supporting a just transition for suppliers, this programme can provide a clear and practical route for reducing emissions swiftly, aligning the industry with international climate goals, and ensuring that the music artists make can continue to reach the hearts and minds of fans. Our records are more than just pieces of plastic they are recordings of our cultural being- this program is helping to ensure we can continue to make and supply records into the future.

The **Vinyl Alliance** is the leading authority on vinyl's place in the 21st century. We bring together prominent players from across the vinyl value chain to exchange knowledge, gain market insight and work jointly to address issues facing the industry. Our members comprise decades of collective industry experience. Together, we work to maintain vinyl's position as the most popular premium listening experience in the streaming era.
We have three core focus areas: Education, Research and Data and Sustainability. Our goal under the sustainability workstream is to equip stakeholders with consistent, science-based impact data—using life-cycle accounting principles—to measure and communicate product-level impacts and inform sustainability decisions across the value chain. Although the genesis of this supplier programme came from our focus upon sustainability it crosses over all of our focus areas. Solutions to decarbonising the lifecycle of records will come from across the value chain which is why it is important to take a collaborative approach to quantifying, understanding and reducing our carbon emissions.

This project represents a significant first step in doing that and we are excited to be working alongside the Music Climate Pact signatories and supporters to achieve our common sustainability goals. By working together, we are helping to create a resilient supply chain that controls energy costs, stays ahead of emerging legislation, reduces carbon emissions and continues to make fantastic sounding products that will continue to be cherished items for generations.

1.3. ClimatePartner: Our partner for this project

ClimatePartner is a leading solutions provider specialising in carbon accounting, decarbonisation planning and climate project financing. For over 20 years they have supported over 6000 organizations in calculating and reducing their carbon footprints, as well as in financing certified climate projects that contribute to global climate action and sustainable development. As experts in the field of carbon footprints, Climate Partner supported the data collection and calculation of Product Carbon Footprints, or PCFs, for the record manufacturers taking part in the project. They provided the analysis of the group data and distilled the trends and recommendations in this report.

1.4. Project overview and goals

Our long-term goal is the swift and urgent transition to a more sustainable record value chain. To achieve this, we need to adopt a collaborative approach to understand the environmental impact of our industry. In this project, our focus is the product carbon footprint of common record products. In this first step, we seek to understand where the most material carbon emissions arise in the manufacturing of records, before distribution. These carbon 'hotspots' will then allow record labels and suppliers to identify opportunities where they can make changes in the pre-distribution value chain to reduce carbon emissions. These should take place as broadly and as quickly as possible, thereby contributing to global efforts to minimise the effects of climate change. This paper seeks to provide quantitative insights into record carbon hotspots alongside suggestions for actionable next steps to reduce emissions from the manufacture of records.
It is important to note this paper's goal is to focus on record manufacture, providing insights on a business-to-business level which enable data led discussions between vendors and procurement teams within labels relating to raw material choice and manufacturing impacts. Although data within this report can be used to inform end consumers about the manufacturing impacts of records it should not be presented as the full lifecycle emissions of a record.

2. Product Carbon Footprints (PCFs)

2.1. Participating suppliers

The participating suppliers represent a significant proportion of the manufacturing capacity for both traditionally pressed and injection moulded records. An important consideration of the suppliers who were selected to participate was that they should be broadly representative of the global supply chain to ensure average calculations were from statistically significant data sets. The suppliers and products that they manufacture in general represent the following scenarios

- Large volume plants located in different territories (UK, Mainland Europe and North America)
- Small to medium sized plants located in different territories (UK, Mainland Europe and North America)
- Traditional PVC products
- Bio attributed PVC products
- Injection moulded products
- Products containing recycled / recovered content

The following manufacturers participated in generating a PCF for one or more of their products:

- Optimal Media
- GZ Media (Europe)
- MPO
- Precision Pressing
- Furnace Record Pressing
- Independent Record Pressing (IRP)
- The Vinyl Factory
- Good Neighbor Music
- Sonopress

2.2. Calculation

2.2.1. What are greenhouse gases (GHGs) and carbon emissions?

Greenhouse gas (GHG) is a term used for any gas that enters the atmosphere and traps heat, preventing it from escaping into space. These gases naturally occur in the Earth's atmosphere and, in principle, are very useful to keep our planet at a habitable temperature for all species. However, since the industrial revolution humans have been increasing the concentration of these gases in the atmosphere, largely through the burning of fossil fuels, which has 'unequivocally caused global warming'[2], changing the Earth's climate.

Greenhouse gases include carbon dioxide (CO_2), methane (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF6), and nitrogen trifluoride (NF3). Each gas has a different ability to warm the earth's atmosphere (known as their global warming potential, GWP) and each remains in the atmosphere for different

[2] IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.00

lengths of time. To make their effect comparable, they are converted to CO_2 equivalents (CO_2e) as a basic unit. For example, methane has a global warming potential of 28, so the warming effect of methane is 28 times greater than CO_2 over 100 years[3]. During this project, all emissions were calculated as CO_2 equivalents (CO_2e), which may be referred to as 'CO_2' or 'carbon' in this report for simplicity.

2.2.2. Calculation framework: The Greenhouse Gas Protocol

ClimatePartner's approach is to follow the Greenhouse Gas Protocol[4] (GHG Protocol) which is the world's most widely used standard for reporting GHG emissions. For example, over 9 out of 10 Fortune 500 companies reporting their CCF to the Carbon Disclosure Project use the GHG Protocol. In preparing each record PCF, five basic principles were observed in accordance with the GHG Protocol's Product Standard:

- **Relevance:** The calculation should account for all greenhouse gas (GHG) emissions that appropriately reflect the company's carbon footprint. This report is designed to support internal and external decision-making.
- **Completeness:** The report must include all GHG emissions within the selected system boundaries. Any significant exclusions of data must be clearly documented, disclosed, and justified.
- **Consistency:** Consistent methodologies are used so that the company's emissions can be compared over time.
- **Transparency:** All important aspects of a company are recorded objectively, and any assumptions, data gaps and resulting extrapolations or data exclusions are presented clearly and openly in this report.
- **Accuracy:** The calculations of GHG emissions are designed to ensure that they are neither over nor undervalued. The report aims to be as accurate as possible and to minimise uncertainties, so that the company can make appropriate decisions.

2.2.3. Product carbon emission sources

GHGs are emitted throughout the lifecycle of physical products, from their creation (e.g. processing and transport of raw materials, manufacture) use (e.g. energy consumption during product use) and end of life disposal. This study's boundaries follow a "cradle-to-gate" approach. This was chosen to enable our key goal of providing insights pertinent to record manufacturers and the wider music industry, not to the end uses of records for whom "cradle-to-grave" PCFs might be more informative. Consequently, emissions were taken into account according to the following life-cycle stages:

- Extraction and pre-processing of raw materials and packaging
- Inbound logistics of raw materials and packaging to supplier manufacturing site
- Manufacture emissions including energy consumption and waste generated in operations up to the factory gate.

[3] Intergovernmental Panel on Climate Change, "Climate Change 2021 The Physical Science Basis", S. 1842, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf (retrieved on 31.01.2022)
[4] https://ghgprotocol.org

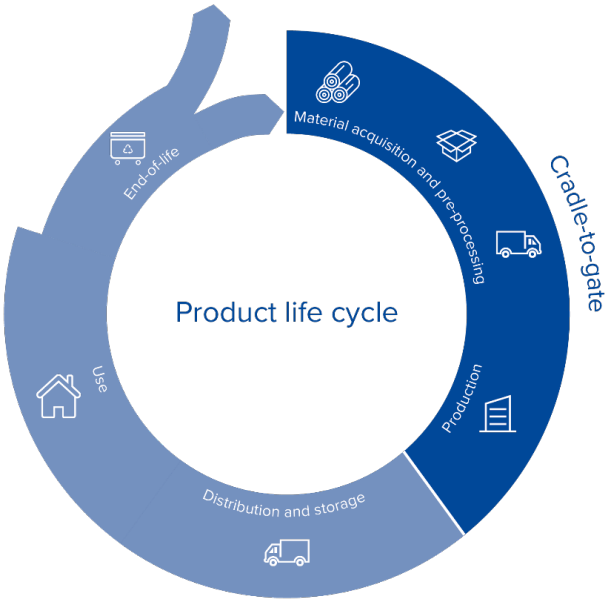


Figure 1: Cradle-to-gate product life cycle stages

Therefore, the following emissions were excluded from the boundary of this calculation:

- Transport of the finished product onwards from the factory gate to retailer and end user
- Use of sold product i.e., electricity use during the playing of the record
- Disposal of the product and packaging at end of life.

Please note that the transport of the finished product to the end user and the use of the product would remain the same regardless of the manufacturing approach taken or raw material used in the manufacturing process.

2.2.4. How data was collected

The suppliers attended a group project orientation session and then completed a data collection sheet including activity data for the following:

- Weight and description of raw materials for both the galvanics process and record manufacture process
- Logistics information (distance and mode of transport) from tier 1 supplier to the record manufacturing site
- Electricity and fuel consumption at the manufacturing site
- Details of wastage of any raw materials at the manufacturing site
- Weight and description of the packaging materials for the finished product, defined as paper sleeve, cardboard outer and shrink wrap only

All data provided was per a single reference quantity, defined as one packaged vinyl/PET[5] record. Data was submitted to ClimatePartner who processed and translated the activity into estimated emissions (see section 2.2.5 and 2.2.6).

Data protection

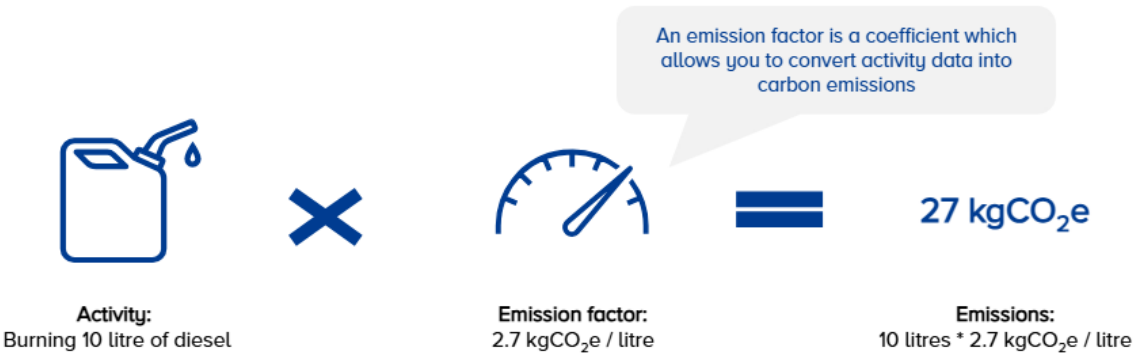
A key principle of this study was the protection of supplier data- participating suppliers are not required to publish their PCF's but are encouraged to share them with procurement and sustainability teams at labels with transparency in mind. Supplier data was only shared between individual suppliers and Climate Partner under contractual terms. There was no sharing of supplier data between suppliers or with members of the Music Climate Pact or the Vinyl Alliance to ensure compliance with anti-competitive / anti-trust requirements.

2.2.5. Data completeness approach

In the event a manufacturer was unable to provide activity data, data gaps were filled according to the GHG Protocol's basic principle of completeness (see section 2.2.2). Activity data from other manufacturers was used to calculate an average emissions per activity, which was then applied to act as a proxy for the data gap. For example, where manufacturers outsourced their galvanics, an average emissions profile for the creation of stamper discs was applied. This average was created using data from manufacturers producing their own stamper discs in-house.

2.2.6. Translating activities into carbon emissions

To translate an activity into carbon emissions, it must be multiplied by an appropriate 'emission factor'. For example, in the case of diesel combustion, we multiply the volume of fuel burnt by an emission factor that tell us how much carbon is released by the combustion of 1 L of diesel (Figure 2). ClimatePartner used the most credible and widely-used sources available, such as Ecoinvent 3.11, BEIS/DEFRA GHG Conversion Factors for Company Reporting (2024). ClimatePartner also uses white papers, industry research papers and its own research to create its own proprietary emission factors.



[5] Polyethylene terephthalate

Figure 2: Example emissions equation, converting activity data to emissions using an emission factor

3. Carbon Insights

3.1. PCFs of traditionally pressed vinyl records and injection moulded records

3.1.1. PCF of a traditionally pressed vinyl record

We used the data of several manufacturers to create an emissions profile of an 'average vinyl' record. We define an average vinyl record as:

- 140g, 12-inch vinyl record
- Raw materials consisting of 100% virgin PVC
- Manufactured with standard galvanics and pressing processes
- Packaging consisting of paper sleeve, cardboard outer and shrink wrap only

The two clear carbon hotspots of an average vinyl record (Table 1) lie in the **manufacturing process** (44.0%) and in the **raw materials** (40.2%). The third hotspot is **packaging** (6.2%).

Within raw materials, two key subcategories were included: firstly, the raw materials forming the record itself, and secondly the materials required to produce stamper discs for the pressing process. Whilst it was important to include the raw materials for the galvanics process to understand its relative contribution, this report highlights that this part of the product lifecycle does not contribute significantly to the carbon footprint of an average vinyl record (1.2%). In contrast, the raw materials of the product itself contribute a significant portion of the carbon footprint (39.0%) and therefore are a key area to target for carbon reduction initiatives (see section 4).

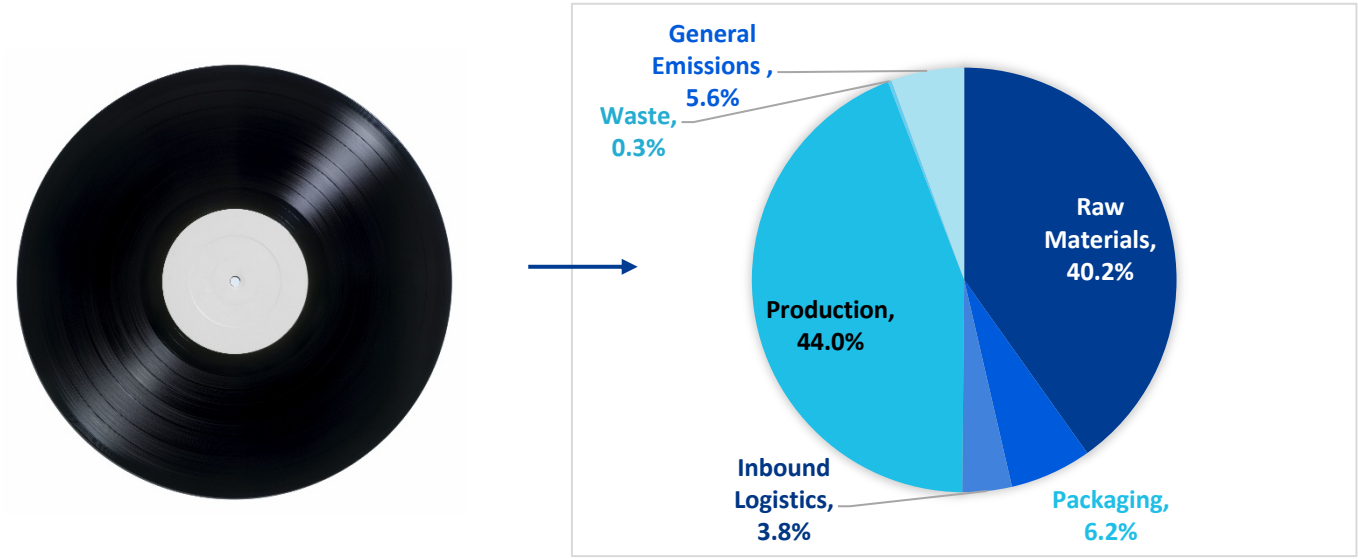


Figure 3: Emissions profile of an average 140g, 12-inch, virgin fossil fuel-derived PVC record

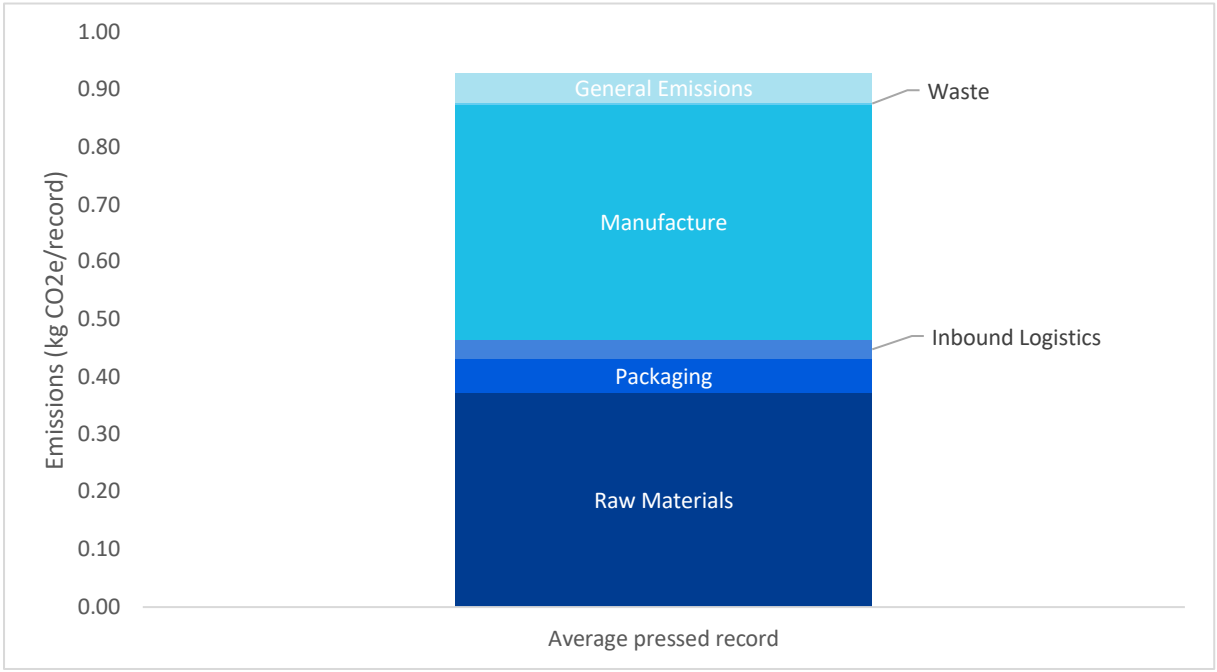
Similarly, for the manufacturing processes, the majority of emissions arise from the pressing of the record (42.8%) rather than the creation of the stamper discs (1.2%). Focus should be, therefore, on the decarbonisation of the record pressing process. It should be noted that one of the seven manufacturers contributing data to this average PCF is using 100% renewable electricity, with the remaining six manufacturers using 100% regional grid average mix electricity, during the record pressing process. This offers a significant
opportunity to reduce emissions in the manufacturing process through the switching of non-renewable electricity sources to renewable sources.

General emissions represent a material portion of the carbon footprint at 5.6%. These emissions, also described as 'non-attributable' emissions, arise from activities which cannot directly be attributed to a product but are nevertheless enablers to its manufacture. These activities, such as employee commuting or administrative functions, are allocated from a company's carbon footprint (CCF) by apportioning a fraction of these emissions to each product they make. Whilst not arising directly from the manufacture of a record, these activities nevertheless must happen to create a product and should be acknowledged. A company should consider how to reduce the emissions of the whole organisation, not just product manufacture, in order to reduce general emissions (see section 4.3).

Table 1: Breakdown of emissions (kgCO2e) per category for an average 140g, 12inch, virgin fossil fuel-derived PVC record

	140g 12 inch, virgin fossil fuel-derived PVC	
Life cycle phase	**kg CO_2e/ [1 vinyl record]**	**%**
Raw Materials	**0.37**	**40.2%**
Record pressing	0.36	39.0%
Stamper disc manufacture	0.01	1.2%
Packaging	**0.06**	**6.2%**
Paper sleeve	0.02	2.7%
Cardboard outer	0.02	2.6%
Shrink wrap	0.01	0.9%
Inbound logistics	**0.04**	**3.8%**
Manufacture	**0.41**	**44.0%**
Record pressing	0.40	42.8%
Stamper disc manufacture	0.01	1.2%
Waste	**0.00**	**0.3%**
General emissions	**0.05**	**5.6%**
Total emissions	**0.93**	**100.0%**

Figure 4: Average product carbon footprints for 140g, 12-inch, virgin fossil fuel-derived raw material based records for an average PVC pressed record



3.1.2. PCF of an injection moulded record

We used the data of two manufacturers to create an emissions profile of an 'average' injection moulded record (see Table 2). We define an average injection moulded record as:

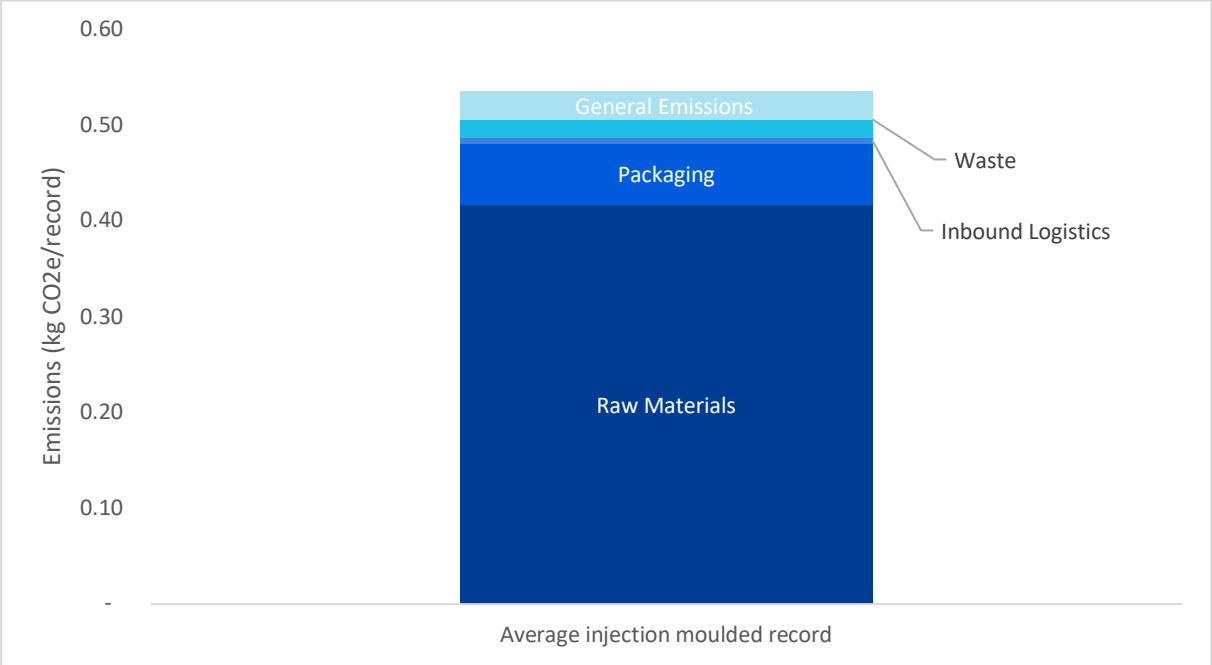
- 140g, 12-inch PET record
- Raw materials consisting of 100% virgin PET
- Manufactured with standard galvanics and injection moulding processes
- 100% renewable electricity consumption during record manufacture
- Packaging consisting of paper sleeve, cardboard outer and shrink wrap only

The two clear carbon hotspots of an average injection moulded record lie in the **raw materials** (77.8%) and in the **packaging** (11.9%). Manufacture emissions (3.6%) make up a much smaller proportion of the footprint when compared with the average pressed vinyl record. This footprint highlights the potential for energy savings when using injection moulding over traditional pressing methods (see table 4). In absolute terms, raw material emissions are higher for PET over PVC but the key difference lies in the complete electrification of the process (i.e. no fossil fuel-based heat required). The decision to source that electricity from 100% renewable sources for both suppliers has reduced the carbon footprint further. The following sections will address these points further.

Table 2: Breakdown of emissions (kgCO2e) per category for an average 140g, 12inch, injection-moulded virgin fossil fuel-derived PET record

	140g 12 inch, injection moulded, virgin fossil fuel-derived PET	
Life cycle phase	**kg CO_2e/ [1 record]**	**%**
Raw Materials	**0.42**	**77.8%**
Record pressing	0.41	77.0%
Stamper disc manufacture	0.00	0.8%
Packaging	**0.06**	**11.9%**
Paper sleeve	0.03	5.6%
Cardboard outer	0.03	4.7%
Shrink wrap	0.01	1.6%
Inbound logistics	**0.01**	**1.1%**
Manufacture	**0.02**	**3.6%**
Record pressing	0.01	1.3%
Stamper disc manufacture	0.01	2.2%
Waste	**0.00**	**0.0%**
General emissions	**0.03**	**5.6%**
Total emissions	**0.54**	**100.0%**

Figure5: Average product carbon footprints for 140g, 12-inch, virgin fossil fuel-derived raw material based records average PET injection moulded record.



3.2. Virgin raw material type

At present, records are manufactured using one of two key raw materials: PVC (polyvinylchloride) or PET (polyethylene terephthalate). Within this project, records using both materials were analysed. On average, we observed an 11.8% increase in emissions for raw materials using PET compared with PVC. However, some manufacturers were able to provide specific emission factors from their raw material manufacturers, whilst others relied on industry-average emission factors from databases, which makes it challenging to draw conclusions from such a small sample. What we can say is:

1. *We encourage all record manufacturers to seek supplier-specific emission factors for their raw materials (see section 4).* Understanding the emissions arising from supplier-specific manufacture of raw materials will allow the record manufacturer to choose which manufacturers to source from, thereby facilitating the reduction of their product carbon footprints. Eight out of the thirteen PCFs incorporated supplier-specific emission factors in this project.

2. *Databases show European sources of virgin PET are estimated to have an emission factor 10% higher than virgin PVC.* This may support decisions on choice of material where virgin materials are necessary. However, this relatively small reduction is likely to be overshadowed by the lower carbon emissions associated with the injection moulding manufacture process over traditional pressing processes (section 3.5), therefore it is important to consider potential carbon savings across raw materials and processes together.

3.3. Use of virgin vs recycled raw materials

Many record manufacturers are exploring the use of recycled raw materials[6] in favour of virgin (fossil-fuel derived) raw materials with the intention of creating a more sustainable product.

It should be noted that recycled raw materials do not come with zero carbon emissions. After their first life, the raw materials must be transported to a recycling facility, cleaned and reprocessed into a useable material: these activities generate carbon emissions. Therefore, recycled raw materials have an emission factor. This is usually lower than its virgin equivalent, but not always, depending on the processes required to repurpose it.

In this project, none of the PCFs included any post-consumer recycled PVC in their raw materials. In order to allow some comparison between virgin and recycled PVC to be drawn, a scenario was built based on publicly available industry research. Whilst there is not much available research on emissions from recycled PVC resin, a VinyLoop LCA whitepaper[7] found the reduction in emissions of recycled PVC to be 39% when compared to virgin materials. To illustrate the impact of using recycled PVC on a record footprint, this reduction was applied to the raw material emissions for record pressing for two of the PCFs only that originally sourced their raw material emission factors from databases using industry averages. This is laid out in Table 3.

When considering the impact on the total carbon footprint, this will depend on the other parts of the life-cycle. For example, the 100% recycled PVC modelled in Table 3 shows a 16% reduction compared to the virgin PVC equivalent, but a true comparison would need to create comparative PCFs where all the other life cycle stages are comparable except the raw materials.

Table 3: Comparison of emissions associated with use of virgin, blended and recycled PVC

Raw material choice	Proportion of recycled raw materials	Raw material emissions per product (kg CO2e)	Carbon reduction (% of total footprint)
Virgin PVC	0%	0.487	N/A
Blend	50%	0.393	-8.1%
Recycled PVC	100%	0.300	-16.2%

When it comes to recycled PET, two PCFs were assessed that use rPET. If a manufacturer wants to understand the impact of choosing recycled raw materials on

[6] Here we are referring to non-virgin raw materials sourced from a third-party supplier. This does not refer to the recycling of manufacturing waste within the same operations, which takes place commonly across all the manufacturers who tool part in this project.

[7] VinyLoop Eco-Footprint Study (LCA): a study conducted by Solvay and compares VinyLoop recycling vs. incinerating PVC waste and producing new PVC

their PCF, for a fair comparison then let us take the average traditional vinyl record as an example.

For injection moulded records, we estimate an average 36% reduction in raw material emissions when swapping virgin PET for 100% recycled PET[8] (rPET). It should be noted that rPET can be generated through two processes: mechanical recycling (where material is simply cleaned, melted and remoulded for reuse) and chemical recycling (where plastics are chemically broken down into their monomers and then reformed into useful polymers). When manufacturers source rPET, they should consider the two recycling types have different energy consumption demands and therefore will have different emission factors. A credible emission factor for chemically recycled PET was not available within the databases during this study, therefore all rPET emissions were calculated using a mechanically recycled factor. it should be noted some studies suggest chemically recycled PET has a higher emission factor than mechanically recycled PET[9].

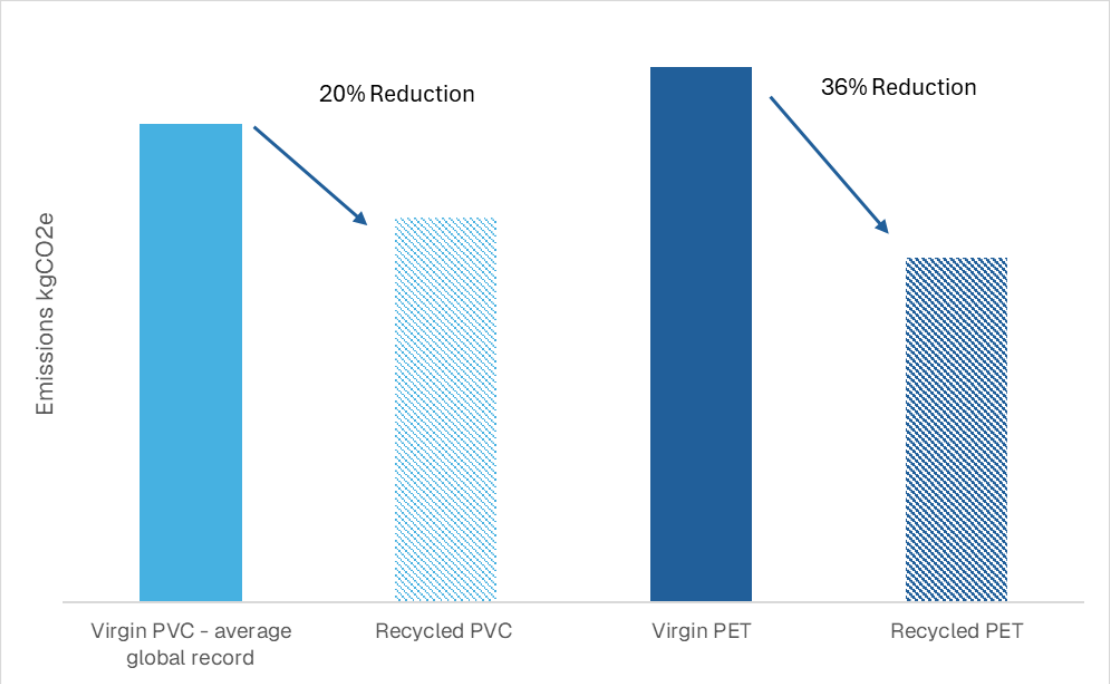


Figure 6: Raw material emissions comparison of virgin fossil fuel-derived PVC and PET records, compared with their recycled counterparts

Therefore, we recommend record manufacturers consider the following when making choices on recycled materials:

1. *Seek supplier-specific emission factors for all raw material sources wherever possible.* This will enable you to make sound data-driven decisions by comparing

[8] All analysis for recycled PET (rPET) in this analysis assumes mechanically recycled PET, not chemically recycled PET.
[9] Mechanical recycling is more climate-compatible than chemical recycling | oeko.de

virgin emission factors with their mechanically and chemically recycled counterparts.

2. *Consider the wider impact of using recycled materials, beyond the carbon impact.* Our current manufacture value chains are largely based on a linear 'take-make-waste' model, leaving the planet with limited access to finite resources and nature degraded because of the waste we discard[8]. Eliminating waste by designing products with a circular model can contribute towards building a circular economy that functions within our planetary boundaries[10]. A crucial part of this is incorporating well-recycled materials within the creation of new products.

3.4. Alternative raw materials

Traditionally, we view recycled materials as simply being reformed from the same original material. For example, in the case of recycled PVC, it may have come from post-distribution vinyl records which are simply reground into PVC granulate ready for pressing into new records. However, there are now bio-based plastics which can replace our traditional virgin, fossil-fuel origin plastics with those from plant-based sources. One example is bio-based PVC, where bioethanol (from plant biomass, such as sugar cane) or waste vegetable oils (from cooking) are used to synthesise PVC.

There are two important considerations when including bio-based materials in products:

1. *Mass balance attribution.* When sourcing bio-based materials, it is likely a manufacturer will be purchasing them using a "mass balance" approach. In reality, a manufacturer of plastic materials will be using both bio-based and fossil-based precursors, therefore the resulting raw material will be a mix of fossil-based and bio-based origins. It would be impossible to separate out the resulting raw material into bio-based and fossil-based molecules, so the manufacturer will track the input of bio-based precursors and identify the proportion of bio-based material in the final mix. Customers wishing to purchase bio-based materials will buy that proportion of the output, even though the materials themselves may be fossil in origin. Manufacturers can seek certifications of the materials they source to ensure the credibility of the attribution of bio-based materials (e.g. ISO 16620-2).

2. *Accounting for biogenic carbon.* When accounting for the carbon emissions and removals of bio-based materials used in their products, manufacturers should be careful to align to the GHG Protocol's clear guidelines[11]. These biogenic emissions and removals account for carbon that is entering and being released by living organisms, such as plants, bacteria and fungi. An example of a biogenic removal would be a plant absorbing carbon dioxide from the atmosphere through photosynthesis and locking it in its biological materials (biomass). If this were sugar cane, it may then be used to make bioethanol, then bio-based PVC and ultimately a record. Any record using this material would therefore contain

[10] Planetary boundaries - Stockholm Resilience Centre
[8] How to Build a Circular Economy | Ellen MacArthur Foundation

[11] Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf

biogenic carbon. When it comes to the end of the product's life, the record would decompose and release that carbon back to the atmosphere. This would be classified as a biogenic emission, as this is part of the natural carbon cycle of the living material. The GHG Protocol recommends that any biogenic carbon is reported separately from fossil-based carbon, to distinguish it from the fossil-based activities that are driving climate change. This ensures any biogenic removals included within raw materials don't mask fossil-based emissions arising throughout the life-cycle, especially where PCF boundaries are cradle-to-gate and therefore don't account for the ultimate release of that biogenic carbon when the product reaches end of life.

Record manufacturers do have an opportunity to explore the inclusion of bio-based materials such as bio-PVC and bio-PET. They are a good opportunity to reduce reliance on fossil fuels as raw materials, and to promote the use of waste materials with a circular economy in mind. However, great care should be taken when reporting the carbon emissions of these products. In this project, we had the opportunity to compare the footprint of a traditionally pressed record that incorporated 100% fossil-based PVC and one that used 100% bio-attributed PVC. When excluding all biogenic removals, there is a 1% difference in the carbon emissions of the raw materials in each footprint. It is only when we include the biogenic removals (carbon locked up by the plants that go on to produce the bio-PVC) that we observe an apparent 82% reduction in the carbon emissions of the raw materials, and a 40% reduction in the total PCF emissions. However, we should remind the reader that these PCFs are cradle-to-gate, and don't account for the return of the natural carbon to the atmosphere at end of life. To enable a full assessment of lifecycle impacts of bio attributed materials a full cradle to grave assessment of this product is required with biogenic carbon being reported separately as required by the GHG Protocol product standard[11].
See section 4 for our recommendations on considering bio-based plastics with a wider than carbon lens.

3.5. Manufacturing technique

This project collected data from manufacturers using traditional pressing methods as well as those using an injection moulding method. Within this sample of products, we found injection moulding reported a 62% lower consumption of electricity over the average electricity consumption for a pressed product. This presents an opportunity to reduce the carbon impact of products through reducing the energy consumption required to manufacture the product- we should note any reduction would be determined by the geographical location of the manufacturing site and the electricity grid upon which it depends (see section 3.7). See section 3.7 for details of the additional opportunities posed by utilising renewable electricity.

Energy Consumption	Average pressed record	Average injection-moulded record
Electricity (kWh)	0.41	0.15
Natural Gas (kWh)	1.16	Not required

Table 4: Average energy consumption required to manufacture a record (excluding galvanics)

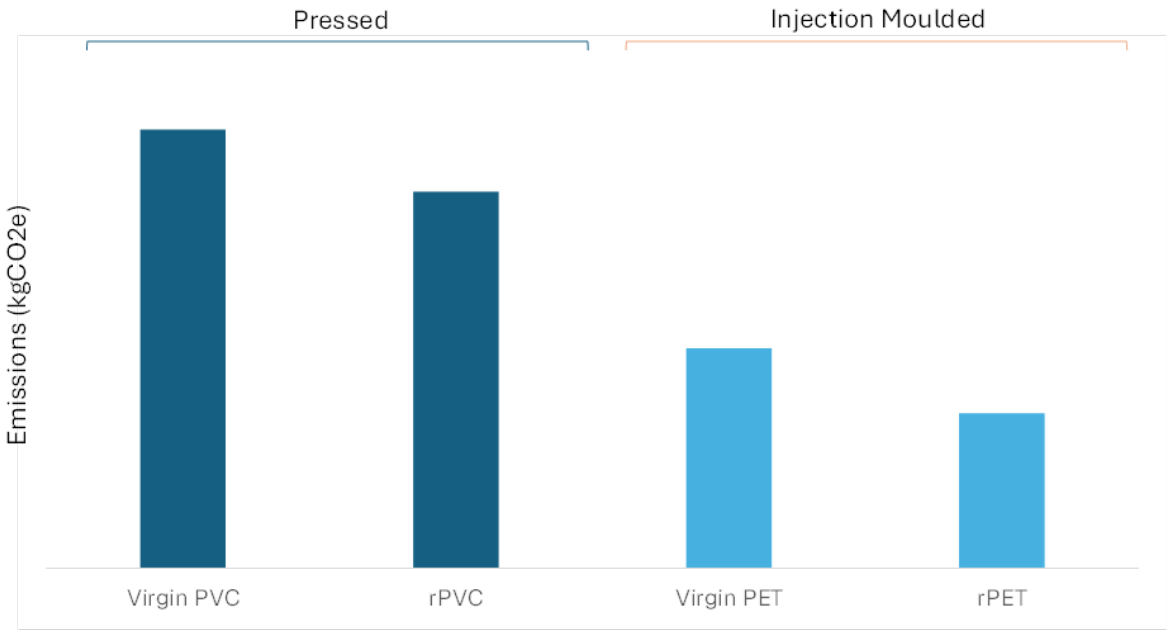


Figure 7: Comparison of combined *raw material* and *manufacture* emissions for virgin and recycled PET and PVC, using either traditional pressing or injection moulding

In addition, we noted all manufacturers using the pressing method utilised a source of fossil-based fuel to power the manufacturing process (natural gas and, in some cases, oil) whilst injection moulding plants did not require any additional energy source beyond electricity. Use of fossil fuels in the manufacturing process contributes to a significant portion of the total carbon emissions of the PCF (24-35% in the virgin PVC, pressed records) and therefore this identifies a potential target for future decarbonisation.

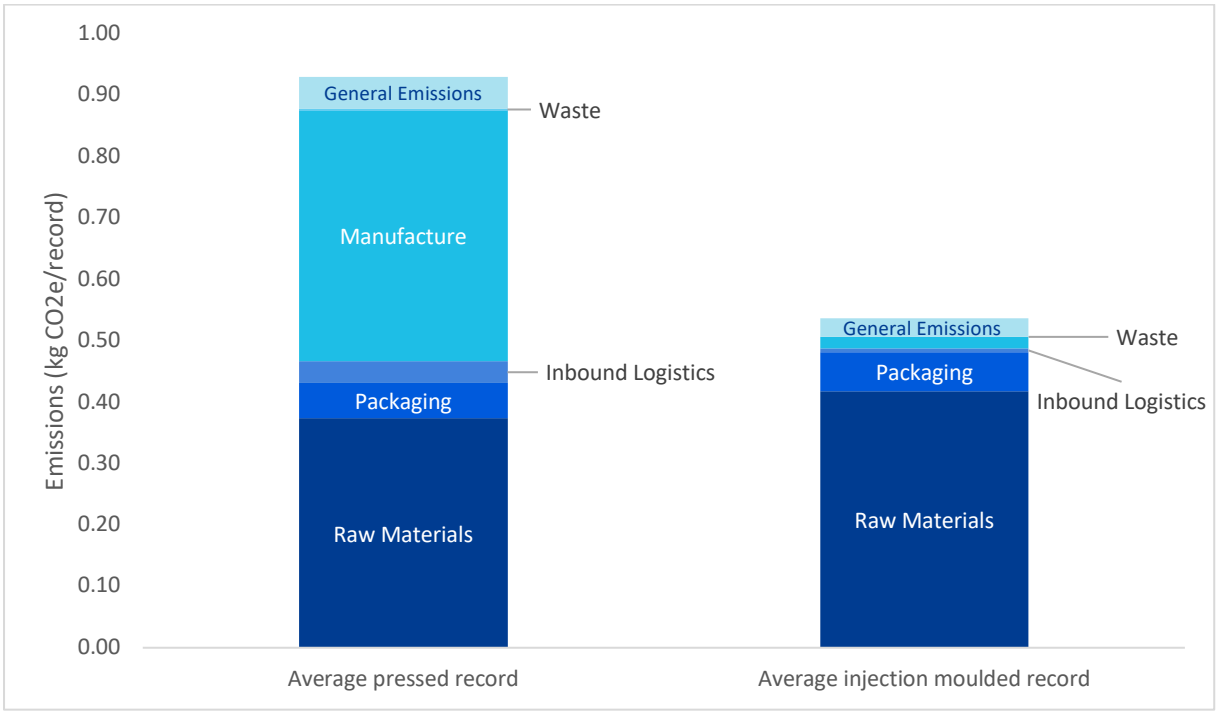


Figure 8: Average product carbon footprints for 140g, 12-inch, virgin fossil fuel-derived raw material based records for PVC pressed records and injection moulded records

3.6. Size of operations

One hypothesis put forward at the start of this project was that the size of the manufacturing operations could have an impact on the efficiency of raw material use and energy consumption. Operation size, therefore, might have an impact on the resulting carbon emissions of the records produced. This project found no significant correlation between size of operations, and raw material/energy consumption nor between size of operations and resulting carbon emissions.

3.7. Electricity source

Electricity consumption during the manufacture of a record (pressing) is a key target for decarbonisation. It accounts for 12% of an average vinyl record PCF (see section 3.1 for definition). The source of that electricity therefore has a significant impact on a record PCF.

Table 5: Breakdown of emissions (kgCO2e) per category for an average 140g, 12inch, virgin fossil fuel-derived PVC record, by geographical region

	Global		European		North American	
Life cycle phase	**kg CO_2e/ [1 vinyl record]**	**%**	**kg CO_2e/ [1 vinyl record]**	**%**	**kg CO_2e/ [1 vinyl record]**	**%**
Raw Materials	**0.37**	**40.2%**	**0.32**	**42.8%**	**0.44**	**37.9%**
Record pressing	0.36	39.0%	0.31	41.1%	0.43	37.2%
Stamper disc manufacture	0.01	1.2%	0.01	1.8%	0.01	0.7%
Packaging	**0.06**	**6.2%**	**0.06**	**8.5%**	**0.05**	**4.3%**
Paper sleeve	0.02	2.7%	0.03	3.3%	0.02	2.1%
Cardboard outer	0.02	2.6%	0.03	3.8%	0.02	1.6%
Shrink wrap	0.01	0.9%	0.01	1.3%	0.01	0.6%
Inbound logistics	**0.04**	**3.8%**	**0.03**	**3.7%**	**0.04**	**3.8%**
Manufacture	**0.41**	**44.0%**	**0.30**	**39.2%**	**0.56**	**48.1%**
Record pressing	0.40	42.8%	0.28	37.8%	0.55	47.1%
Stamper disc manufacture	0.01	1.2%	0.01	1.4%	0.01	1.0%
Waste	**0.00**	**0.3%**	**0.00**	**0.2%**	**0.00**	**0.3%**
General emissions	**0.05**	**5.6%**	**0.04**	**5.6%**	**0.06**	**5.6%**
Total emissions	**0.93**	**100.0%**	**0.75**	**100.0%**	**1.17**	**100.0%**

Geographical location of the manufacturing site is a key driver of the size of the emissions resulting from manufacture: the power sources each country uses to generate electricity differ greatly, resulting in very different emission factors between countries. For example, in a country such as France where the grid mix consists of a large proportion of renewable and low-carbon sources, (e.g. 64.3% nuclear, 11.6%

hydroelectricity and 9.8% wind in 2023[12]) then the emissions from 1 kWh of electricity are significantly lower than a country which still relies on a significant proportion of fossil fuels to generate their electricity, such as the USA (55.5% coal/oil/natural gas in 2023[13]). As a result, manufacturers with operations in countries relying on greater proportions of fossil fuels saw their electricity consumption making up a greater proportion of their PCF (18-28% of their total PCF versus 5-10% for countries with lower carbon grids).

Moving manufacturing sites is not a reasonable short-term decarbonisation strategy but sourcing renewable electricity - either by choosing a 100% renewable tariff from an energy provider, or by generating electricity on site from renewable sources, such as solar panels - is a feasible short-term option. The emissions from electricity consumption when pressing an average vinyl record would reduce by an average of 85%, if 100% renewable electricity was sourced. This translates as a reduction in total emissions of an average vinyl record of 12.5%.

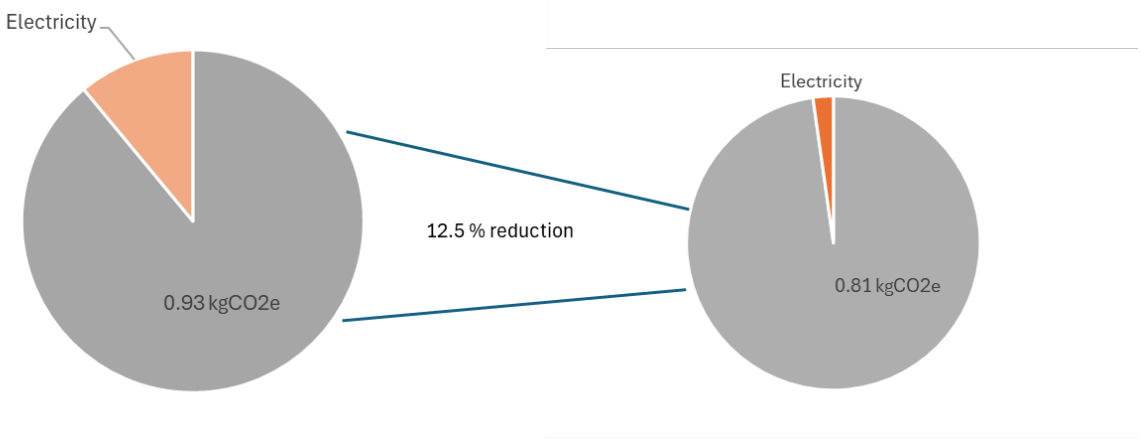


Figure 9: Proportion of emissions per average record attributable to electricity and the associated reduction of switching to a green energy tariff

It should be noted that some of the manufacturers taking part in this project have already switched to 100% renewable electricity, through self-generation and tariffs, and are already seeing the impact on their PCFs. In these cases, electricity consumption during manufacture contributes only 1-2% of the carbon emissions of these products, compared with the average of 14% for traditional vinyl pressed records using electricity from non-renewable sources.

3.8. Packaging

Packaging makes up a relatively small proportion of a record PCF. For example, 6.2% of an average pressed virgin vinyl record comes from the paper sleeve, cardboard outer and shrink wrap, which were the packaging components defined by the boundaries of this calculation. Of this 6.2%, the majority of emissions arise from the

[12] France - Countries & Regions - IEA
[13] North America – Countries & Regions - IEA

paper and card components, with only 0.9% attributed to the plastic shrink wrap. This is noteworthy as plastic materials draw focus when considering the environmental impact of a product. It is true that virgin plastic materials are derived from fossil fuels, but they are relatively low in terms of their carbon intensity per kg of material, meaning they are often immaterial in the packaging phase of PCFs.

However, if we shift our focus away from carbon and towards a wider sustainability perspective, we should appreciate the challenges associated with recycling plastic materials[14] and the impact arising from the shedding of microplastics into natural habitats, the long-term impacts of which are still not fully understood[15]. Conversely, paper and card originate from biological materials, do not release long-term breakdown products that are harmful to the environment and are readily recycled across the globe. Manufacturers should always be mindful of wider sustainability principles, such as building circularity into product design[16], when choosing materials for their packaging and not rely solely on the carbon emission analysis to make their decisions.

3.9. Manufacture waste

Wastage of raw materials was taken into account during the calculation of record PCFs from two key stages in the product life-cycle:

1. *During manufacture.* At the point of pressing/injection moulding when waste is material is removed to create the final record (e.g. sprues, flashing, trimmings). Reuse of these materials is generally high across the manufacturers, with most of the material entering the manufacture process as re-ground materials. Usually, a small proportion of the material might be contaminated/unsuitable due to repeated re-grinding and therefore cannot be recycled in this way. Most participants in the project were able to estimate the proportion of material wasted in this way, and the emissions arising from this extra material and its waste disposal were apportioned per record in this PCF.

2. *Post- manufacture.* Some records do not meet quality control and therefore do not become sold products. In many cases, much of the material from these records (i.e. the parts of the record that don't contain a label) can be recycled, either by entering the production line as re-ground material, or by being sent to a third-party recycling facility. Any plastic material in contact with the label becomes more problematic: in some cases, this material enters landfill, and in other cases is recycled but into a lower grade of material that will not be used to make new records (e.g. it becomes a construction material). Similar to manufacture waste, most manufacturers were able to estimate the proportion of post- manufacture waste they generate, describe the ultimate fate of these materials, and the emissions arising from this extra material and its waste disposal were apportioned per record in this PCF.

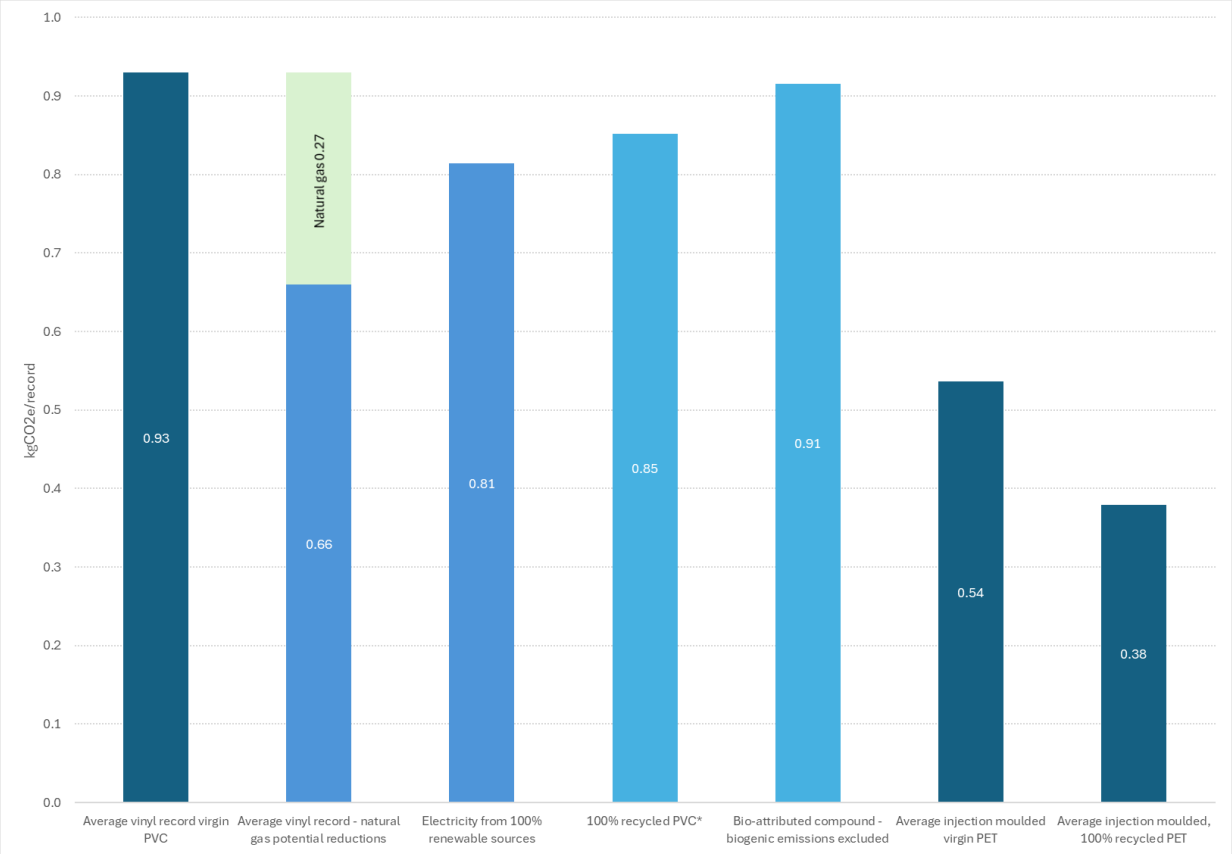
As raw material wastage is limited, and the materials wasted are largely recycled, the emissions resulting from wastage is very small (less than 1% of the PCF of an average

[14] UK facing huge recycling shortfall as household plastic film mountain grows by 55k tonnes | News | The Grocer
[15] The Lancet Countdown on health and plastics - The Lancet
[16] How to Build a Circular Economy | Ellen MacArthur Foundation

pressed vinyl record). We would recommend manufacturers to continue to minimise wastage and ensure any wasted materials enter recycling streams to keep this portion of the PCF immaterial.

4. Recommendations

In this section, we explore the opportunities record manufacturers have over the short- and mid-term to minimise the carbon emissions of their products, in order of suggested priority. These recommendations are viewed through a lens of carbon (and in some cases wider environmental sustainability) only. Therefore, manufacturers should consider costs and feasibility when creating long-term decarbonisation plans for their operations. They may find it useful to carry out a CCF (Corporate Carbon Footprint of their whole operations) in order to build their roadmap to Net Zero.



*100% recycled PVC emissions were modelled by substituting current emission factors (both supplier-specific and industry averages from databases) for the VinyLoop 100% recycled PVC factor

Figure 10 is a summary graphic designed to highlight some different scenarios and associated emissions reductions compared to an average vinyl record. These should only be used as a guide and considered in the context of all relevant variables, such as manufacturing process, raw materials etc.

4.1. Manufacturing process

1. *Eliminate use of fossil fuels by electrifying all processes.* When considering an average pressed vinyl record, use of natural gas as a fuel source is the predominant driver of high manufacture emissions and represents 26-35% of the PCF. Remove this reliance on fossil fuels through electrification of all processes where possible. This will necessitate immediate industry wide support for sustainable manufacturing techniques.

2. *Switch to 100% renewable electricity.* Emissions from electricity consumption, whilst not generally as high as natural gas and oil consumption, remain a significant portion of the average PCF of a traditional pressed vinyl record (3-28%). The good news is that these emissions are much easier to reduce in the short term. Switch to a 100% renewable electricity tariff as soon as possible. In the longer term, consider taking control of your energy security and costs by generating your own electricity through solar panels or other appropriate power sources. If considering changing the location of or expanding operations, take the proportion of renewables of the nation's grid into consideration.

In the case of both recommendations above, prioritise efforts on the processes involving record manufacture, as the emissions associated with the galvanics processes are significantly smaller.

4.2. Raw materials

1. *Source value chain-specific data.* Supplier-specific emission factors for all raw materials should be collated to facilitate informed decisions on which raw materials to source. Use of industry-wide averages from databases is a good starting point, but will not allow accurate, carbon-driven decision making in the long term. Asking for data from material manufacturers also leads to a ripple-effect of more organisations assessing their carbon footprints and enacting reduction initiatives.

2. *Source recycled materials.* Use recycled materials, either from fossil- or bio-based sources. Once materials are in our industrial value chain, keeping them in circulation minimises the carbon emissions generated through extracting and processing virgin raw materials. Always aim to source the supplier-specific emission factor for these recycled materials to ensure the energy required to recycle them is not outweighing the reduction savings from avoiding raw materials in the first place.

3. *Consider bio-based materials.* Be cognisant that using such materials might not save material amounts of carbon but do be aware they have potential wider sustainability benefits. Source LCAs for such materials to consider their wider impacts. Follow future developments on new bio-based materials with benefits such as improvements in eco-toxicity and biodegradability but be aware of challenges such as scalability of sourcing their plant-based precursors and potential land use changes. Always report two PCFs: one with biogenic removals excluded, the other with biogenic removals included, as per the guidance of the GHG Protocol.

4. *Minimise weight of all raw and packaging materials.* Any material going into a product carries a carbon burden, so minimise use of materials wherever possible. Consider the carbon impact of producing larger products (e.g. a 180g vs 140g record) alongside other business factors. Maintain low material wastage rates, prioritising immediate material reuse (re-grind) wherever possible and third-party recycling where it isn't possible. Reducing the end weight of products will have further benefits throughout the lifecycle in particular in relation to the emissions associated with distribution and shipping.

4.3. Wider impact

In addition to focussing on the PCFs of key products, record manufacturers should consider how to develop a holistic climate impact strategy where they measure and report their organisational footprint, create a decarbonisation plan, communicate their action effectively for maximum business value and support wider climate projects, thereby contributing to global Net Zero. This study has focussed upon the carbon emissions within the cradle to gate phase of the product lifecycle- value chain partners are encouraged to undertake wider assessments of environmental impacts beyond carbon emissions and throughout the wider lifecycle into distribution, usage and end of life of products. Best practice lifecycle accounting methodologies should always be followed. To ensure full transparency details of assumptions, estimations and data sources should always be provided as part of these assessments.

4.3.1. A Corporate Carbon Footprint (CCF)

Reporting your organisation's emissions (CCF) is fast becoming expected practice, even if you don't fall under any jurisdictional legislation. Consider measuring your Scope 1 and 2 emissions as a minimum to understand the direct emissions of your operations, then expand to Scope 3 to understand the carbon impact of your value chain. Report your emissions publicly for transparency and use your CCF to inform your decarbonisation plan.

4.3.2. Set Science Based Targets and a Net Zero goal

As an organisation becomes more mature in its sustainability journey, the logical next step is to set targets for carbon reductions. The Science-Based Targets Initiative (SBTi) is the de facto authority for translating climate science into practical business guidelines, therefore setting a target with the SBTi is seen as best practice. The UN Race to Zero Initiative also provides a best practice framework for setting net zero reduction pathways. Use these guidelines to set ambitious near-term and longer term (Net Zero) targets and use these to keep your organisation accountable as you measure your footprint annually.

4.3.3. Create a decarbonisation plan

Work with experts to support you in the development of a decarbonisation plan. Use the insights from your CCF and PCFs to understand your carbon hotspots, identify the key drivers that will reduce them, then prioritise reduction measures you can

implement across your business. Measure your footprints regularly to track your progress over time against your targets.

4.3.4. Beyond Value Chain Mitigation

A decarbonisation plan should always be prioritised, but this should be accompanied by investment in global climate projects that avoid, reduce or remove carbon from the atmosphere. Best practice in this respect is termed 'Beyond Value Chain Mitigation', or BVCM, and is recommended by the SBTi[17] as an alternative approach to carbon offsetting. This is a crucial part of any organisation's climate impact strategy because it contributes to wider societal decarbonisation and global Net Zero as opposed to compensating for organisational emissions. Many climate projects also offer multiple co-benefits that target the UN's Sustainable Development Goals, promoting health benefits, quality education and economic work.

[17] The Science-Based Targets Initiative. See their website for more information, e.g. https://sciencebasedtargets.org/blog/net-zero-urgent-beyond-value-chain-mitigation-is-essential and https://sciencebasedtargets.org/blog/going-above-and-beyond-to-contribute-to-societal-net-zero

Annex 1 Methodology

1. More detailed methodology for calculation of individual PCFs

All PCF's have been calculated in accordance with requirements of the Greenhouse Gas Protocol- Product lifecycle accounting and reporting standard. Specific details on the methods used in these calculations is as follows:

Life-cycle Stage	Activity data requested	Methodology & data gap completion	Emission factor sources
Raw materials – Stamper disc manufacture	Description of all raw materials included in the manufacture of 2 stamper discs, allocated to one reference unit (one record): - total weight - recycled content (%) - Supplier specific emission factor (where available)	Five manufacturers were able to provide data on the weight of nickel required to generate two stamper discs. Two manufacturers provided details of additional chemical components required during the process. These data points were used to create an average weight of nickel and process chemicals required per record. Where manufacturers were unable to provide their own data, these averages were applied to fill the data gap.	All emission factors used a 'cradle to gate' boundary. - Ecoinvent 3.11 - Ecoinvent 3.8 - Supplier-specific emission factors provided by manufacturers (checked by ClimatePartner for appropriate system boundaries and plausibility against credible databases) - ClimatePartner calculated factors based on credible sources (databases and research papers)
Raw materials – record pressing	Description of all raw materials included in the manufacture of 1 record of defined size and weight (12-inch, 140g or 180g, including any paper label), allocated to one reference unit (one record): - total weight - recycled content (%) - Supplier specific emission factor (where available)	All manufacturers were able to provide data on the weight of their primary material. Six manufacturers were able to provide supplier-specific emission factors for their virgin materials (PVC and PET.) Two manufacturers had average industry factors applied to their virgin materials (PVC.) The two manufacturers using recycled PET had average industry emission factors applied to their raw materials. One manufacturer was unable to provide data on the weight of their paper labels. In this case, the average weight of paper material required was estimated from the data provided by the other manufacturers and was applied to the data gap.	- Ecoinvent 3.11 - Supplier-specific emission factors provided by manufacturers (checked by ClimatePartner for appropriate system boundaries and plausibility against credible databases) - ClimatePartner calculated factors based on credible sources (databases and research papers)
Packaging	Description of all materials included in the packaging of one record, defined as paper sleeve, cardboard outer and shrink wrap: - total weight - recycled content (%) - Supplier specific emission factor (where available)	All manufacturers except one were able to provide data on their packaging. For the manufacturer without packaging data, an average weight of cardboard outer, paper sleeve and shrink wrap material was created and standard material types (no recycled content, paper, paperboard and LDPE film) were assumed to fill these data gaps.	- Ecoinvent 3.11 - Ecoinvent 3.8 - ClimatePartner calculated factors based on credible sources (databases and research papers)
Inbound logistics	Description of transport of all materials (raw materials for records and stamper discs, packaging) from tier 1 suppliers to the manufacturer, allocated to one reference unit (one record): - Country of origin	Most manufacturers were able to provide data on the transport of materials. For the two manufacturers where data gaps were present, conservative assumptions were applied (e.g. freight by truck with standard forecourt fuel, with a distance appropriate to the origin and destination.)	- Ecoinvent 3.11 - Smart Freight Centre (2019) - ClimatePartner calculated factors based on credible sources (databases and research papers)

	- Mode, distance and weight of material transported		
Production – Stamper disc manufacture	Description of all energy consumed during the manufacture of 2 stamper discs, allocated to one reference unit (one record): - Electricity consumption (kWh) - Renewable electricity proportion (%) - Location of manufacture - Natural gas (or other fuel/heat source) consumption (kWh)	Three manufacturers were able to provide data on the electricity and heat consumption required to manufacture stamper discs. These data were used to create average electricity and natural gas consumption values, which were then applied to fill the data gaps of manufacturers with no available data. When filling data gaps, electricity was always assumed to be 100% non-renewable. For electricity and fuel emissions, both direct and upstream emissions were included. For example, in the case of natural gas, emissions from the extraction/processing/transport of the gas to end user were included as well as the direct emissions arising from its combustion. These are also known as 'well to wheel' emissions.	- Ecoinvent 3.11 - DEFRA/UK Government Conversion Factors (2024) - Supplier-specific emission factors provided by manufacturers (checked by ClimatePartner for appropriate system boundaries and plausibility against credible databases) - ClimatePartner calculated factors based on credible sources (databases and research papers)
Production – Record manufacture	Description of all energy consumed during the manufacture of one record (one reference unit): - Electricity consumption (kWh) - Renewable electricity proportion (%) - Location of manufacture Natural gas (or other fuel/heat source) consumption (kWh)	All manufacturers were able to provide data on electricity consumption, allocated to one record. All manufacturers adopting the pressing method were able to provide data on consumption of natural gas (and other fuels, where applicable.) For electricity and fuel emissions, both direct and upstream emissions were included. For example, in the case of natural gas, emissions from the extraction/processing/transport of the gas to end user were included as well as the direct emissions arising from its combustion. These are also known as 'well to wheel' emissions.	- Ecoinvent 3.11 - DEFRA/UK Government Conversion Factors (2024) - Supplier-specific emission factors provided by manufacturers (checked by ClimatePartner for appropriate system boundaries and plausibility against credible databases) - ClimatePartner calculated factors based on credible sources (databases and research papers)
Waste	Description of production/process waste (scrap, flash/trimmings, QC rejects) as % or g per record; packaging waste (paper sleeve, cardboard outer, shrink wrap) as % or g per record; post-production (unsold/defective) waste proportion and destination; and fraction of each stream that is reground/reused, externally recycled or landfilled	Most manufacturers provided either the weight (g) of waste per record, or average % of waste per record for both raw materials and packaging materials. In the case of raw materials, the majority of the manufacturers confirmed the % of this waste that is reground and reused vs the % that is sent to waste disposal facilities (primarily for a fraction of post-production waste). If reground, this waste was treated as internal closed-loop reuse and effectively reduced the weight of raw material required to make one record. In cases where the disposal method for post-production waste was not confirmed, it was assumed to be average disposal waste streams.	- Ecoinvent 3.11 - ClimatePartner calculated factors based on credible sources (databases and research papers)

2. Calculation of the average PCFs

    a. An average 'traditionally pressed vinyl record'

We define this as:

- 140g, 12-inch vinyl record
- Raw materials consisting of 100% virgin PVC
- Manufactured with standard galvanics and pressing processes

- Packaging consisting of paper sleeve, cardboard outer and shrink wrap only

In creating this average value, we used data from 7 manufactures who provided data on products aligning with these key criteria.

Suppliers who were sampled are based in the UK, mainland Europe and North America and range from small, medium to large scale plants, collectively these plants represent an annual pressing capacity of approximately 90000 records.

Plant	**Location**	**Scale**
GZ Media	The Czech Republic (Czechia)	Large (>20 presses)
Optimal Media	Germany	Large (>20 presses)
MPO	France	Large (>20 presses)
The Vinyl Factory	U.K.	Small (<10 presses)
Precision Record Pressing	Canada	Medium (10-20 presses)
Independent Record Pressing	U.S.A.	Small (<10 presses)
Furnace Record Pressing	U.S.A.	Medium (10-20 presses)

5 of these manufacturers provided supplier-specific emission factors for their primary material (100% virgin PVC) and raw material emissions from the remaining 2 manufacturers were estimated using an industry-average emission factor from the Ecoinvent 3.11 database.

Out of the 7 manufacturers, 6 are using non-renewable electricity to power record pressing, whilst one manufacturer is using 100% renewable electricity. Market-based reporting for electricity was used throughout this project, meaning supplier-specific emissions from electricity providers were taken into account. If 100% renewable energy was sourced, zero direct emissions were attributed. Please note, electricity emissions also included indirect, or upstream emissions, as described in table 1.

Regarding the geography of the manufacturers, 4 were located in Europe and 3 in the North Americas.
Regarding the size of the operations, 2 manufacturers were considered to be large, whilst 4 were medium-sized and the remaining manufacturer small-sized.

b. An average ‘injection moulded record’

We define this as:
- 140g, 12-inch PET record
- Raw materials consisting of 100% virgin PET
- Manufactured with standard galvanics and injection-moulding processes
- Packaging consisting of paper sleeve, cardboard outer and shrink wrap only

In creating this average value, we used data from 2 manufactures who provided data on products aligning with these key criteria.

At the time of this study the Injection Moulding record manufacturing was an emergent technology. The two suppliers who participated in the study represented 100% of the capacity for this technique at the time

Plant	Location	Scale
Sonopress	Germany	Small (<10 production lines)
Good Neighbor Music	The Netherlands	Small (<10 production lines)

1 of these manufacturers provided a supplier-specific emission factor for their primary material (100% virgin PET) and raw material emissions from the remaining manufacturer were estimated using an industry-average emission factor from the Ecoinvent 3.11 database.

1 manufacturer provided data using a reference unit of one 180g, 12-inch record. In order to use this data to create an average injection moulded record (140g), the emissions of this record were adjusted using the following approach:

- It was assumed 140g PET (+ wastage rates provided) is used as a raw material
- Data for all other parts of the lifecycle per 180g record (packaging, manufacturing, galvanics, waste and logistics) were assumed to be the same for a 140g record, and were therefore used as proxies to estimate emissions

Both manufacturers reported using 100% renewable electricity during the injection moulding process, therefore the manufacturing portion of the life-cycle was low for this average footprint. Market-based reporting for electricity was used throughout this project, meaning supplier-specific emissions from electricity providers were taken into account. If 100% renewable energy was sourced, zero direct emissions were attributed. Please note, electricity emissions also included indirect, or upstream emissions, as described in table 1.

Both manufacturers were located in Europe and were considered to be small-scale operations.

Data completeness

The only notable omission from the average PCF's detailed in this report is the emissions associated with print finishing of external cardboard sleeves.
When using these PCF's for the generation of representative emissions factors for record manufacturing appropriate data should be sourced relating to print impacts to ensure that the emissions factors are representative of the finished product.