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"The Environmental Impact of The Music Industry"

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Introduction

Music is more than just an art form — it is a powerful cultural force that shapes economies, influences societies, and connects people across the world. As an artist actively working within the industry, I have experienced firsthand both the incredible potential of music and the pressing need for systemic change. While music has long been a vehicle for creativity, community, and activism, it is also an industry deeply intertwined with commercialism and environmental impact. From the excessive production of physical albums to the energy-intensive nature of digital streaming, the ways in which we create, distribute, and consume music today come with significant consequences — many of which remain overlooked.

This thesis explores the complex relationship between the music industry and sustainability, examining its economic, social, and environmental implications. The industry is an undeniable economic powerhouse, contributing billions of dollars to global markets and providing employment for millions of people. Yet, its economic growth often comes at a cost — whether through exploitative labor practices, inequitable access to resources, or unsustainable production and distribution models. At the same time, music serves as a catalyst for social change, shaping cultural movements, giving voice to marginalized communities, and fostering global solidarity. However, for music to continue serving as a force for good, we must also confront the ways in which its current practices contribute to environmental harm.

As an artist, I feel a deep responsibility not only to create music but to also advocate for a more ethical and sustainable industry. Whether through eco-conscious touring practices, sustainable merchandising, or pushing for greener music production, I am committed to making a tangible difference. This research not only investigates the industry's impact but also seeks to highlight practical solutions that artists, record labels, and consumers can adopt to create a more responsible and environmentally conscious music ecosystem.

By analyzing the economic structures that drive the industry, the environmental footprint of both physical and digital media, and the social influence of music, this thesis aims to provide a comprehensive understanding of the challenges we face and the opportunities for change. The music industry stands at a pivotal moment, where innovation, responsibility, and sustainability must intersect. The question is not whether music can drive change, but whether those within the industry, including myself, are willing to take the necessary steps to ensure that the art we create today does not compromise the world of tomorrow.

1. The Hidden Costs of Music Production

1.1 Environmental Impact of Music Instruments and Equipment

The Guide to Greener Electronics, periodically published by Greenpeace¹, is an analysis of the environmental impact of major electronics manufacturers and IT companies like Apple, Google and Samsung. The last report, published in 2017, found that the supply chain – including manufacturing – accounted for 70 to 80% of the carbon footprint generated during the lifetime of a product. While there is no similar report for electronic musical instruments and studio gear, we can assume that the data would be similar. I want to bring attention to this data to highlight what concerns its repercussions on the environment.

Scopes. The most significant environmental impact of the music industry stems from the manufacturing process. To better understand these effects, we shall categorize emissions into three distinct categories. The three scopes are a way of categorizing the different kinds of emissions a company creates in its own operations and in its wider value chain (its suppliers and customers).

It is not clear why they are called 'scopes' rather than 'groups' or 'types' but the name comes from the Greenhouse Gas Protocol², which is the world's most widely used greenhouse gas accounting standard. As the Greenhouse Gas Protocol itself puts it: "*Developing a full* [greenhouse gas] *emissions inventory – incorporating Scope 1, Scope 2 and Scope 3 emissions – enables companies to understand their full value chain emissions and focus their efforts on the greatest reduction opportunities*".

Scope 1 emissions refer to those directly produced by a company's own operations, such as emissions from on-site power generation, manufacturing facilities, and company-owned vehicles. Scope 2 emissions encompass indirect emissions resulting from the electricity, heat, or steam that a company purchases from external providers. These emissions, while not produced on-site, are essential to the manufacturing process and contribute significantly to its carbon footprint. The most complex category, however, is Scope 3 emissions, which are the most challenging to quantify. These emissions originate from sources that are not owned or directly controlled by the company but are nevertheless a consequence of their activities. This includes emissions from suppliers

¹ Greenpeace is a global network of independent campaigning organizations that use peaceful protest and creative confrontation to expose global environmental problems and promote solutions that are essential to a green, just, and joyful future.

² GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions.

Building on a 20-year partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), GHG Protocol works with governments, industry associations, NGOs, businesses and other organizations.

involved in material extraction, transportation, and component production, as well as the broader supply chain network.

Because Scope 3 emissions extend beyond a company's immediate operations, they require more intricate calculations and a deeper commitment to sustainability to mitigate their impact effectively. Unlike Scope 1 emissions, which businesses can actively mitigate by optimizing their internal operations and adopting more sustainable practices, Scope 3 emissions present a far greater challenge.

This complexity arises from the fact that much of these emissions fall outside a company's direct control, making them difficult to manage and reduce. A significant portion stems from the broader supply chain, including the extraction and processing of raw materials, the production methods of third-party suppliers, and the transportation of goods.

Additionally, emissions generated during the product's use and eventual disposal contribute to the overall carbon footprint, further complicating efforts to track and minimize their impact. As a result, companies seeking to address Scope 3 emissions must collaborate closely with suppliers, consumers, and policymakers to implement meaningful and lasting reductions.

One of the most effective ways for companies to reduce CO_2 emissions is by making sustainable choices during the manufacturing process, such as incorporating recycled materials in place of newly sourced ones. For instance, recycling aluminum from existing products requires significantly less energy than extracting raw aluminum through mining, which is both resource-intensive and environmentally damaging.

Amid growing concerns over the ecological impact of music equipment production, certain companies have taken proactive steps toward sustainability. Focusrite, a renowned name in the audio equipment industry, stands out as a leader in adopting environmentally responsible manufacturing practices. Focusrite has made a concrete effort to integrate recycled materials into its production wherever possible, opting for recycled aluminum, polycarbonates (a type of durable plastic commonly used in engineering), and other sustainable alternatives.

However, working with high-percentage post-consumer recycled plastic presents challenges. Each time plastic is recycled, its structural integrity deteriorates, causing it to become brittle and prone to breaking. As a result, while Focusrite and other manufacturers strive to maximize the use of recycled plastics, achieving 100% post-consumer recycled content remains an elusive goal. Nevertheless, companies are actively researching and developing new solutions to push these limits.

Unlike plastic, aluminum is infinitely recyclable without losing its quality. Yet, as Andy³ from Focusrite points out, securing a steady supply of recycled aluminum is not without obstacles. Demand is exceptionally high, with massive corporations such as Coca-Cola competing for the same materials to produce their beverage cans. While the electronics industry is still small in comparison to other sectors, its demand for recycled aluminum is dwarfed by the scale of global consumer brands, making sourcing a persistent challenge.

Despite these hurdles, Focusrite has taken significant strides toward sustainability with its newly released fourth-generation Scarlett Audio Interface for instance, a milestone for the company in sustainable product design. This latest model integrates post-industrial recycled aluminum for the chassis across all units, along with an impressive 85% post-consumer recycled ABS⁴ plastic. While there is still progress to be made, this represents a substantial step forward in reducing environmental impact while maintaining high product quality.

Packaging also plays a crucial role in assessing the overall environmental impact of a product, and companies are increasingly looking for ways to make it more sustainable. Focusrite, for instance, has implemented several eco-conscious changes, such as replacing traditional polyethylene plastic product bags with starch-based alternatives, switching from plastic tape to paper tape, and optimizing the internal arrangement of packaging to minimize volume. This seemingly small adjustment allows for more units to fit onto a pallet or into a shipping container, ultimately improving shipping efficiency and reducing carbon emissions associated with transportation. The goal is simple: designing packaging to be as efficient as possible while maintaining product protection.

Another key consideration in reducing environmental impact is the shift away from printed manuals. While some customers may lament their removal from hardware boxes, digital PDF versions offer a far more sustainable alternative, significantly reducing paper waste and the resources required for production and distribution.

Beyond packaging and logistics, another crucial aspect of Scope 3 emissions reduction is the endof-life cycle of a product. Ideally, consumers would seek to repair, recycle, or repurpose their

³ Andy Land, Head of Sustainability for the Focusrite Group

⁴ Acrylonitrile butadiene styrene (ABS) (chemical formula $(C_8H_8)_x \cdot (C_4H_6)_y \cdot (C_3H_3N)_z$) is a

common thermoplastic polymer. Its glass transition temperature is approximately 105 °C (221 °F). ABS is amorphous and therefore has no true melting point.

ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15% to 35% acrylonitrile, 5% to 30% butadiene and 40% to 60% styrene. The result is a long chain of polybutadiene crisscrossed with shorter chains of poly(styrene-co-acrylonitrile).

musical equipment rather than discard it. However, the growing consumer culture surrounding musical instruments may be fostering a disposable mindset, where products are quickly replaced rather than maintained.

Greenpeace⁵ highlights this concern, noting that although electronic take-back and recycling programs are expanding, the rate at which products are discarded far outpaces the ability to collect and process them. One of the most effective ways to extend a product's lifespan is through regular software and content updates, which keep hardware relevant and delay obsolescence.

By continuously improving functionality, companies can encourage consumers to use their devices for longer, thereby reducing overall electronic waste. To truly drive sustainability efforts forward, collaboration across the industry is essential. However, many companies remain reluctant to share data, often citing competitive concerns.

While this hesitation is understandable from a business standpoint, an exception should be made when it comes to environmental sustainability. Greater transparency and shared innovation would allow industry to collectively set and achieve meaningful sustainability goals, ultimately benefiting both businesses and the planet.

1.2 Merchandise and Its Environmental Toll

A band T-shirt may not be a financial game-changer for an artist, but in the challenging economic landscape of the indie music industry, it can provide a much-needed source of revenue. At the same time, the world is already overwhelmed by excess clothing, with the fashion industry contributing to 2% - 10% of global carbon emissions, as estimated by UNFCCC⁶.

Some experts argue that the only truly sustainable solution is to reduce overall consumption and scale back manufacturing. So, where does that leave an eco-conscious musician hoping to fund their next tour through T-shirt sales? Much like ongoing efforts to make vinyl production more sustainable, switching to environmentally friendly band merchandise will not single-handedly combat climate change, but it is certainly a step in the right direction.

However, sustainable merch comes at a higher cost — a significant challenge for independent artists operating on razor-thin margins. Choosing between manufacturers with different pricing models and

⁵ Global Network of Independent Campaigning Organizations

⁶ United Nations Framework Convention on Climate Change. The UNFCCC entered into force on 21 March 1994. Today, it has universal membership. The 198 countries that have ratified the Convention are called Parties to the Convention. Preventing "dangerous" human interference with the climate system is the aim of the UNFCCC.

environmental commitments can ultimately mean the difference between a financially viable tour and one that barely breaks even.

But how long will your favorite band T-shirt last? The answer — like most discussions surrounding sustainable fashion — is complex. In ethical consumerism, "sustainability" is often reduced to a buzzword, but in this context, it refers to clothing with minimal environmental impact and ethical labor practices.

Most band shirts are made from 100% cotton, a natural fiber that is technically biodegradable under the right conditions. However, cotton farming is notoriously resource-intensive, requiring vast amounts of water, land, and energy, making it environmentally unsustainable on scale. An ecofriendlier alternative is organic cotton, which reduces its footprint by eliminating synthetic chemicals from the production process. Even better is recycled cotton, which repurposes postconsumer and post-industrial waste to create new textiles. Though it is widely regarded as the most sustainable option, its higher production costs make it less accessible for smaller artists.

Beyond the fabric itself, the printing process also plays a role in sustainability. The ink used to transform a blank T-shirt into a statement of fan loyalty comes in two primary forms: water-based or plastic-based (plastisol). While water-based inks may seem like the cleaner, more eco-friendly choice, improper disposal can still cause environmental harm.

Figure 1 [The Impact of Fast Fashion]



source: Codogirl [2019, The Impact of Fast Fashion]

Every stage of production, from raw materials to finishing touches, has an ecological impact, making it crucial for artists and consumers alike to make informed, responsible choices in the pursuit of more sustainable music merchandise. Navigating the many factors that influence sustainability in the music industry requires time, effort, and discernment, and the reality is often far more complex than statistics alone suggest.

Many companies engage in greenwashing, a deceptive marketing practice that prioritizes a sustainable image over meaningful environmental action. The problem extends beyond misleading advertisements; systemic issues within certification processes further muddy the waters. A recent New York Times investigation⁷, for example, revealed widespread corruption in India's organic cotton certification, raising concerns about transparency and accountability.

For both consumers and musicians, understanding which products are genuinely sustainable — and which merely claim to be — can be an uphill battle. At the same time, climate responsibility is frequently framed as an individual burden, while corporations and governments continue to resist the large-scale systemic changes necessary to curb environmental damage. Artists should not feel eco-guilt over choosing to sell 100% cotton shirts instead of pricier recycled alternatives.

"I don't think anybody should feel guilty about whether they can [make sustainable merch] if it's not affordable for them," explains Rachel Dispenza⁸. "Being in a band does not guarantee you any money to begin with. You can do as much as you can to make the most environmentally friendly shirt, but if people aren't willing or able to pay that cost, then you just have a box of T-shirts sitting there. Is that really doing any service to the environment either?".

Beyond cost, practical challenges, many of which have been exacerbated by the pandemic and global supply chain crisis, can interfere with even the best of intentions. "*For our most recent tour, we had to switch to a big brand we would never normally use because all our regular options had no stock*". says Christine Mackie⁹. Thanks to material shortages and rising shipping costs, oncereliable sustainable options are no longer as accessible or affordable as they once were.

The harsh reality is that only well-established artists with a strong fanbase and financial resources can effectively produce and sell sustainable merchandise and even face logistical hurdles. Ironically, many top-tier musicians, who have the means to invest in high-quality, eco-friendly merch, often do little more than offer standard 100% cotton shirts.

⁷ That Organic Cotton T-Shirt May Not Be as Organic as You Think. By Alden Wicker, Emily Schmall, Suhasini Raj and Elizabeth Paton. Published Feb. 13, 2022Updated April 12, 2022. Available at:

https://www.nytimes.com/2022/02/13/world/asia/organic-cotton-fraud-india.html # organic-cotton-fraud-india.html # organic-cotton-fraud-india

⁸ Merch Manager for Japanese Breakfast.

⁹ Rosenstock's partner and manager

However, some artists are rethinking their entire environmental footprint rather than just making incremental changes. Coldplay, for example, has implemented an extensive sustainability strategy, incorporating kinetic flooring at concerts — where audience movement is converted into energy — alongside ethically sourced merchandise.

These efforts, while ambitious, highlight the ongoing challenge of balancing sustainability with economic feasibility in the music industry.

1.3 Green Supply Chains in the Music Industry

The music merchandise industry has evolved into a multi-billion-dollar global market, valued at approximately 3.48 billion \$ in 2018. Over the years, merchandise has grown from a simple means of fan engagement into an essential financial pillar for musicians. As the rise of digital streaming services continues to erode traditional album sales, physical merch, including T-shirts, hoodies, vinyl records, and other collectibles, has become one of the few remaining ways for artists to generate meaningful income.

For independent musicians selling merch can mean the difference between financial stability and struggling to make ends meet. However, the significance of music merchandise extends far beyond individual artists. It plays a crucial role for record labels, music festivals, radio stations, and other industry players who use merch not only as a revenue stream but also as a powerful branding tool.

Wearing a band T-shirt, for example, is more than just a fashion choice — it is a statement of identity, a way for fans to express their loyalty while also promoting the artist in a highly visible, organic manner. The cultural importance of merch cannot be overstated, it allows fans to connect with artists in a tangible way, reinforcing the sense of community and shared experience that music fosters.

Yet, for all its economic and cultural significance, the music merch industry comes with a hidden cost — its devastating impact on the environment. The fashion and textile industry are one of the largest polluters in the world, contributing enormously to waste, water consumption, carbon emissions, and toxic pollution. Since music merchandise is often produced cheaply and in large volumes, it directly contributes to the worsening climate crisis.

The scale of this issue is staggering, as demonstrated by the following facts:

• The average American consumer discards roughly 82 pounds [41 kgs] of post-consumer textile wastes every year. This waste accounts for over 5.2% of all municipal solid waste in the U.S.A., much of which ends up in landfills or incinerators (Igini, 2023).

- Synthetic and blended textiles, commonly used in music merch, can take centuries to decompose — some materials remaining in landfills for over 200 years, slowly releasing microplastics and toxic dyes into the environment (Baloyi, 2023).
- On a global scale, more than 2 billion T-shirts are manufactured and sold every year, many of which are worn only a handful of times before being discarded (Igini, 2023).
- The carbon footprint of a single cotton T-shirt, as estimated by Carbon Trust¹⁰, is around 15 kg of CO₂e over its lifetime. When considering the sheer volume of T-shirts produced worldwide, the total emissions introduced through T-shirt production each year are comparable to the total annual emissions of an entire country, such as France (Saunders, 2018).
- The textile industry accounts for roughly 6% of all global greenhouse gas emissions, making it one of the biggest contributors to climate change. Additionally, the industry is responsible for 10% to 20% of pesticide use worldwide, due to the high demand for conventionally grown cotton (Filho, 2024).
- The production of a single cotton T-shirt requires approximately 2,700 liters of water an amount equivalent to what a single average person would need for 900 days of drinking water. Given the world's increasing water scarcity, this level of consumption is unsustainable (Garcia, 2024).
- Clothing production, in general, is responsible for nearly 10% of the world's total carbon emissions, further accelerating the climate crisis (Maiti, 2025).

Despite these overwhelming environmental costs, music merchandise production continues at an unsustainable pace, with little regard for its long-term impact on the planet. Most merch is produced as part of the fast fashion cycle, meaning that many of the items sold at concerts, festivals, and online stores are not designed for longevity. Instead, they are cheaply made, mass-produced, and often end up discarded within a few years.

For the music industry to mitigate its environmental footprint, it is crucial to rethink how merchandise is produced and consumed. Some artists and labels are already exploring more sustainable alternatives, including organic cotton, recycled fabrics, water-based inks, and ethical supply chains. Others are considering circular economy models, where merchandise is designed for reuse, resale, or upcycling rather than ending up in landfills.

¹⁰ an expert partner for businesses, governments and organizations around the world – helping them decarbonize and accelerate to Net Zero.

While merch remains an essential financial pillar for the music industry, the time has come for artists, businesses, and consumers alike to acknowledge its ecological impact and actively seek more sustainable solutions. Only by shifting towards responsible manufacturing practices and mindful consumption habits can the industry continue to thrive without compromising the health of the planet.

2. Technology and Environmental Innovation in Music Consumption

The landscape of music consumption has undergone a dramatic transformation, propelled by relentless technological advancements. What once required physical formats — vinyl records, cassette tapes, and compact discs — has evolved into a realm of intangible digital experiences.

The arrival of downloadable music was a milestone, but it was the advent of streaming platforms that truly redefined accessibility, convenience, and immediacy in how audiences engage with music. However, beneath this seamless digital transition lies an often-overlooked consequence: the shifting patterns of energy consumption within the music industry.

While traditional formats relied on tangible production materials and distribution networks, the digital era has introduced its own ecological footprint, one dominated by vast server farms, high-powered data centers, and continuous internet connectivity. Streaming services, which now dominate the global music market, depend on complex infrastructures such as Content Delivery Networks (CDNs)¹¹ to facilitate the instant transmission of millions of songs across the world. These networks ensure smooth and efficient streaming, but they also contribute to rising energy demands.

This raises pressing questions: What are the environmental costs of maintaining a digital music ecosystem? Can technological innovations mitigate the carbon footprint of streaming? And how do emerging business models — ranging from blockchain-powered music ownership to evolving digital access frameworks — shape sustainability in the industry?

As we explore the intersection of technology and environmental innovation in music consumption, this chapter will examine how digital platforms are adapting to energy-efficient solutions, assess the ecological implications of blockchain technologies like NFTs, and critically analyze whether digital ownership models can truly be sustainable. By understanding these dynamics, we can better navigate the future of music in a way that harmonizes both technological progress and ecological responsibility.

¹¹ A content delivery network (CDN) is a network of interconnected servers that speeds up webpage loading for dataheavy applications. CDN can stand for content delivery network or content distribution network.

2.1 Digital Music Platforms and Energy Efficiency

Unlike physical music formats, which required the production and distribution of tangible materials, digital streaming relies on an invisible yet energy-intensive infrastructure. Every song streamed in real time involves complex processes, from encoding and transmitting data across vast networks to storing music files in power-hungry data centers.

With billions of people worldwide streaming music at any given moment, the cumulative energy consumption of this industry is staggering. The environmental cost of music streaming is not limited to personal device usage; it extends to the massive cloud computing systems, server farms, and content delivery networks (CDNs) that facilitate seamless listening experiences across different platforms.

At the heart of this discussion lies the role of Content Delivery Networks (CDNs), a crucial yet often unrecognized component of digital music infrastructure. CDNs work by distributing streaming data across a network of servers strategically placed in different geographic locations. Rather than relying on a single, centralized server to process millions of song requests simultaneously, CDNs balance the load by directing traffic to the nearest and most efficient data center. This reduces latency¹², minimizes buffering¹³, and improves user experience. More importantly, CDNs play a vital role in reducing overall energy consumption, as they allow data to be delivered more efficiently, decreasing the need for excessive data transfers across long distances.

Figure 2: [The Music Streaming Service Design]



source: Medium [2024, System design: Music Streaming Service]

Yet, despite their efficiency, CDNs and data centers remain significant energy consumers, operating 24/7 to ensure uninterrupted access to music worldwide. The challenge, then, is how to make

¹² Network latency is the delay in network communication. It shows the time that data takes to transfer across the network. Networks with a longer delay or lag have high latency, while those with fast response times have low latency. ¹³ Buffering is the practice of preloading and storing a portion of a media file in the buffer or temporary memory of a device. This process enables video, audio, gaming, or other media files to be played smoothly and without jitter or stuttering.

streaming more sustainable by optimizing digital infrastructure and integrating environmentally friendly solutions. A growing number of companies are tackling this challenge by embracing "green CDN" initiatives, which focus on minimizing the carbon footprint of streaming services. These initiatives include implementing advanced caching mechanisms¹⁴, optimizing data compression techniques¹⁵, and refining streaming protocols to ensure that music files are delivered with minimal energy waste.

One of the most effective ways to reduce the environmental impact of streaming is through improvements in audio compression¹⁶ and encoding¹⁷ technologies. High-quality audio files typically require significant amounts of data to be transferred across networks, consuming large amounts of bandwidth and energy. However, advancements in energy-efficient audio codecs — such as the Opus codec¹⁸ and other next-generation adaptive bitrate¹⁹ streaming technologies — allow platforms to deliver the same level of audio quality while reducing the file size, thereby decreasing the amount of energy needed for transmission.

Additionally, major streaming platforms are exploring ways to integrate artificial intelligence (AI) and machine learning into their CDN operations. AI-powered predictive caching can anticipate user behavior and pre-load frequently accessed tracks on nearby servers, significantly reducing unnecessary data transfers. By optimizing when and where songs are stored and streamed, AI-driven infrastructure can help streaming services lower their energy footprint while maintaining smooth, uninterrupted playback.

Beyond software-level optimizations, the transition toward renewable energy-powered data centers represents another crucial step in making digital music consumption more sustainable. Traditionally,

¹⁴ Caching is a buffering technique where we store the frequently accessed data in temporary memory or space to make it readily available and reduce the workload for our application, server, or database. It can be implemented on different levels in a web application depending on the use case.

¹⁵ Data compression is defined as the process whereby information is encoded in less bits than it had originally occupied.

¹⁶ Audio compression allows the dynamic range to be controlled — the difference between the loudest and the quietest moments of a signal

¹⁷ Encode refers to the process of converting information or data into a specific format for various purposes. It is a crucial concept in technology and computing.

¹⁸ Opus is a totally open, royalty-free, highly versatile audio codec. Opus is unmatched for interactive speech and music transmission over the Internet but is also intended for storage and streaming applications. It is standardized by the Internet Engineering Task Force (IETF) as RFC 6716 which incorporated technology from Skype's SILK codec and Xiph.Org's CELT codec.

¹⁹ Adaptive bitrate streaming is an advanced technique used by most major media platforms today, including Netflix and Amazon Prime Video. It allows users with fast connections (upwards of 15 Mbps) to get higher resolutions while those with slower connections get lower resolutions – all without buffering or interruptions.

data centers have relied on electricity from conventional power grids²⁰, consuming vast amounts of energy to maintain operations and keep their high-performance hardware cool. However, leading technology firms — including those behind major streaming services — are now investing in carbon-neutral data centers that are powered by solar, wind, and hydroelectric energy.

In September 2021, Spotify joined the Exponential Roadmap Initiative and the United Nations' Race to Zero, which is a network of companies, scientists and non-governmental organizations committing to halve emissions by 2030 (Spotify, 2021). The company has also shifted from traditional data centers to the Google Cloud platform, which Google states is a carbon-neutral platform that intends to power all its data centers with clean energy by 2030. Amazon Web Services, home to services including Apple Music, also powers 65 per cent of its operations with renewable energy (Tachev, 2024). These sustainable initiatives help offset the environmental costs of continuous music streaming and push the industry toward a more responsible energy model.

Another strategy for reducing the energy demands of streaming is the adoption of multi-CDN architecture²¹. Rather than relying on a single CDN provider to handle all traffic, streaming services can distribute content delivery across multiple CDNs, allowing them to dynamically root traffic to the most efficient and environmentally friendly servers at any given time. This multi-CDN approach not only improves reliability and reduces the risk of service outages but also ensures that data is delivered through the shortest and most energy-efficient pathways available.

A prime example of this strategy in action is Spotify's multi-CDN infrastructure, which allows the platform to optimize energy consumption while maintaining its industry-leading streaming speeds. By leveraging load balancing techniques and regional caching, Spotify minimizes unnecessary data transfers and ensures that music is streamed from the closest and least energy-intensive data source.

While improving the efficiency of streaming infrastructure is essential, a broader question arises: Can alternative models of digital music consumption be more sustainable than streaming? The current industry trend overwhelmingly favors streaming subscriptions, where users pay for unlimited access rather than owning digital or physical copies of music. However, this model inadvertently increases ongoing energy consumption, as users frequently re-stream the same tracks rather than downloading them for offline use.

 $^{^{20}}$ An electrical grid (or power grid) is a complex power generation, transmission, and distribution network. Grid operators — the entities that manage energy production and delivery — are regional entities that control electrical energy as it travels through a fixed infrastructure.

²¹ Multi-Content Delivery Network (CDN) uses multiple content delivery networks to deliver content to end-users. A CDN is a network of geographically distributed servers that work together to deliver web content, such as videos, images and other static or dynamic content, to users around the globe. (Digicert, 2023)

It is more than arguable that alternative digital ownership models — such as downloadable purchases, pay-per-play models, or hybrid streaming-download options — could offer a more sustainable approach. For instance, if users were encouraged to download frequently played tracks rather than streaming them repeatedly, overall bandwidth consumption and energy use could decrease significantly.

Achieving sustainability in digital music consumption is not solely the responsibility of streaming platforms; it requires collaboration across multiple stakeholders, including technology developers, policymakers, artists, and consumers. Music streaming companies must prioritize transparency by publicly disclosing their energy usage statistics and outlining their commitments to sustainability. Consumers, in turn, can influence the industry by choosing services that demonstrate a clear commitment to green initiatives and responsible energy practices.

Regulatory bodies and policymakers also have a crucial role to play in shaping the future of ecofriendly digital consumption. Implementing industry-wide sustainability standards, offering incentives for green technology adoption, and enforcing stricter environmental regulations for data center operations could accelerate the transition toward a more energy-conscious music industry.

Furthermore, fostering partnerships between streaming services and environmental organizations can drive positive changes. By collaborating with sustainability advocates, music companies can develop the best practices, invest in research on energy-efficient technologies, and contribute to carbon offset initiatives that mitigate their environmental impact.

As we move deeper into the digital age, the challenge of balancing technological convenience with environmental responsibility becomes increasingly urgent. The music industry's transition toward digital streaming has undeniably transformed the way we listen, but it has also introduced new sustainability concerns that must be addressed proactively. Through advancements in green CDN practices, energy-efficient data centers, AI-driven optimization, and alternative ownership models, the industry has the potential to significantly reduce its carbon footprint while continuing to deliver high-quality music experiences.

The path toward sustainability in music streaming is a shared responsibility — one that requires innovation, commitment, and conscious decision-making from both industry leaders and consumers alike. The future of music should not come at the expense of the planet. By embracing environmentally friendly solutions today, we can ensure that future generations will continue to enjoy the beauty of music without leaving an irreversible ecological impact on its wake.

2.2 NFTs, Blockchain, and Their Ecological Consequences

The rise of non-fungible tokens (NFTs)²² has been nothing short of meteoric, reshaping the landscape of digital ownership and creative monetization. Closely intertwined with cryptocurrencies like Bitcoin and Ethereum, NFTs have captured the imagination of artists, collectors, and investors alike. This surge in popularity has extended into the music industry, where musicians and producers are exploring NFTs as a new means of revenue generation, artistic expression, and fan engagement.

But does this technological evolution truly serve the interests of musicians, or does it introduce more challenges than solutions? To answer this, we must first understand the fundamental nature of NFTs and how they apply to the world of music.

At its core, an NFT is a unique, blockchain-based digital certificate that verifies ownership of a digital asset. Unlike cryptocurrencies, which are fungible (meaning one Bitcoin is interchangeable with another), NFTs are one-of-a-kind — each token is distinct and cannot be replicated or exchanged on a one-to-one basis.

This exclusivity is what drives the demand for NFTs. In the traditional art world, collectors assign value to original paintings despite the availability of countless prints or reproductions. Similarly, an NFT grants its owner a verifiable claim over a specific digital asset, whether it be a piece of artwork, a music track, an album, or even a virtual concert ticket.

However, this raises an important philosophical and practical question: If digital content can be copied infinitely, does the ownership of an NFT truly confer special status, or is it simply an illusion of exclusivity? Despite this ambiguity, NFTs have established a strong foothold in the music industry, providing new opportunities for both artists and fans.

How Do NFTs Function in the Music Industry?

For musicians, NFTs represent an entirely new economic model, one that bypasses traditional gatekeepers such as record labels, streaming platforms, and ticketing agencies. Instead of relying on album sales, concert tours, or streaming royalties (which are often fractional and inconsistent), artists can sell exclusive digital assets directly to their audience.

NFTs can take many forms within the music industry, including:

• Limited-edition music releases – Artists can mint a set number of NFT-based albums or singles, giving fans a chance to own a rare collectible version of a song.

²² A non-fungible token (NFT) is a unique digital identifier that is recorded on a blockchain and is used to certify ownership and authenticity.

- **Concert tickets and backstage passes** NFT-based tickets can grant special privileges, such as meet-and-greets, VIP seating, or even lifetime access to an artist's performances.
- Exclusive digital content Musicians can release behind-the-scenes footage, unreleased tracks, or personalized messages as NFT collectibles.
- **Royalties and smart contracts** Some NFTs are programmed with smart contracts, ensuring that artists receive a percentage of resale profits whenever the NFT is sold to a new owner.

One of the most striking examples of the financial potential of NFTs in music came in February 2021, when electronic artist 3LAU made history by selling 11.6 million \$ worth of NFTs in a single auction (Brown, 2021). This event showcased the immense revenue-generating capabilities of NFTs, particularly for well-established artists with devoted fan bases.

The Advantages of NFTs in the Music Industry. NFTs offer several notable benefits for musicians, particularly in a rapidly digitizing world:

- 1. Direct Fan Engagement By offering exclusive content, musicians can cultivate deeper connections with their audience while rewarding dedicated fans with unique, personalized experiences.
- Elimination of Middlemen Traditional music industry structures often favor record labels and distributors over artists. With NFTs, musicians can sell directly to fans, receiving full payment without intermediaries taking a cut.
- New Revenue Streams Streaming services pay artists a fraction of a cent per stream, making it difficult to earn a living solely through platforms like Spotify or Apple Music. NFTs offer an alternative, high-value marketplace where artists can sell one-time digital assets for substantial sums.
- 4. Verifiable Ownership and Provenance The blockchain records every NFT transaction, providing an immutable ledger of authenticity and ownership. This ensures that buyers are purchasing legitimate works, protecting artists from piracy and unauthorized distribution.

Additionally, NFTs have provided a valuable alternative during the COVID-19 pandemic (Oliver, 2022). With live concerts limited or canceled, musicians have turned to virtual performances and exclusive digital content to maintain both revenue and audience engagement.

The Drawbacks and Challenges of NFTs in Music. Despite their potential, NFTs also pose significant challenges and concerns — particularly regarding environmental impact, accessibility, and sustainability. The most glaring issue with NFTs is their staggering carbon footprint. The blockchain networks that power NFTs — especially Ethereum, which relies on a Proof-of-Work²³ (PoW) model — require enormous amounts of computational power, leading to massive energy consumption.

To put it into perspective: A study by Memo Akten, a computational artist, found that the average NFT transaction emits around 200 kilograms of CO2. To understand the scale, this is equivalent to driving a car for approximately 800 kilometers or the monthly electricity use of a European household (Pierre, 2024). French digital artist Joanie Lemercier estimated that the sale of just six of his NFT artworks consumed enough electricity to power his entire studio for two years. This level of energy consumption raises serious ethical concerns about the sustainability of NFTs, particularly in an industry that already faces scrutiny over its carbon emissions.

Although blockchain developers are working on more eco-friendly alternatives, such as Proof-of-Stake (PoS) models and carbon offset initiatives, the fact remains that NFTs currently contribute to environmental degradation at an alarming rate.

Accessibility and Fairness in the NFT Marketplace. While famous musicians like Kings of Leon, Grimes, and Eminem have profited handsomely from NFT sales, smaller, independent artists face a different reality.

- Visibility is a challenge The NFT market is heavily skewed in favor of artists with large, established fan bases. Unknown or emerging musicians may struggle to attract bidders, making it difficult to generate meaningful income.
- High transaction fees "Gas fees" (the cost of executing blockchain transactions) can be prohibitively expensive, eating into profits and discouraging new artists from entering the space.
- Speculative nature The NFT market is highly volatile, with price fluctuations and speculative buying trends creating an unpredictable financial environment.

²³ Proof of Work (PoW) enables transactions to be confirmed and recorded without a central authority. PoW disincentivizes attacks on a crypto's blockchain by making verifying transactions expensive. Proponents of proof of work contend it's more secure than other mechanisms like proof of stake.

Additionally, the lack of regulation and buyer protection means that fraud, plagiarism, and artificially inflated pricing are common issues. Without proper oversight, the NFT space can be exploitative, benefiting wealthy collectors and corporations while leaving smaller artists behind.

In conclusion: Are NFTs the Future of Music? The rise of NFTs presents both exciting opportunities and significant challenges for the music industry. On one hand, they empower musicians by offering direct revenue streams, verifiable ownership, and deeper fan engagement. On the other, they raise serious concerns about environmental sustainability, accessibility, and fairness in the digital marketplace.

For NFTs to become a truly viable, ethical, and sustainable tool for musicians, several key improvements must be made:

- Adoption of eco-friendly blockchain solutions to reduce energy consumption.
- Lower transaction fees and fairer accessibility for independent musicians.
- Stronger regulations and anti-fraud measures to protect buyers and sellers alike.

Ultimately, the success of NFTs in the music industry will depend on whether they can evolve into a more sustainable, inclusive, and artist-friendly technology — one that amplifies creative freedom without compromising environmental and ethical integrity.

3. Audience and Industry Responsibility in Reducing Impact

3.1 Consumer Behavior and the Environmental Cost of Music Fandom

In an era where vinyl records have regained widespread popularity, it is crucial to approach physical music consumption with mindfulness and moderation.

Over the past decade, vinyl sales have experienced an extraordinary resurgence despite the dominance of streaming platforms. According to *Forbes*, vinyl sales in the United States skyrocketed from 9.2 million units in 2014 to nearly 50 million in 2023²⁴. This revival is largely fueled by the influence of social media, which amplifies fan engagement and fosters a culture of music consumerism.

²⁴ Forbes. *Vinyl Sales Grew More Than 50% In 2014*. By Hugh McIntyre. Published on Feb 2015. Available at: https://www.forbes.com/sites/hughmcintyre/2015/02/10/vinyl-sales-grew-more-than-50-in-2014/ [Accessed: 15 February 2025]

Statista. U.S. vinyl album unit sales 2023. Published on May 2024. Available at:

https://www.statista.com/statistics/188822/lp-album-sales-in-the-united-states-since-2009/ [Accessed: 15 February 2025]

Many fans, motivated by a deep sense of connection with their favorite artists, feel compelled to collect as much merchandise as possible. However, the increasing reliance on physical sales as a metric for chart success also incentivizes artists and record labels to capitalize on this demand by releasing multiple versions of the same album. This cycle of consumerism not only prioritizes sales over sustainability but also undermines equitable access to music, particularly for younger fans who may struggle with financial constraints.

While some vinyl collectors argue that the format provides a superior listening experience due to its "warmer" sound, research suggests otherwise. A *Washington Post* study²⁵ revealed that the auditory differences between vinyl and digital recordings are often imperceptible to the average listener. Furthermore, the current vinyl production process frequently bypasses traditional mastering techniques that once distinguished vinyl audio from digital formats. Instead of pressing records directly from raw analog recordings²⁶, many modern vinyls are sourced from digital masters²⁷, effectively negating the very characteristics that audiophiles²⁸ claim to cherish.

Beyond the supposed sound quality, vinyl collecting is often driven by its aesthetic and collectible appeal. This phenomenon is particularly evident among Taylor Swift fans, known as Swifties, who have witnessed the artist release numerous vinyl variants of the same album. For her *Midnights* album in 2022, Swift offered four different-colored vinyl records that, when combined, formed a clock. Similarly, her 2023 re-release of *1989 (Taylor's Version)* introduced several new vinyl designs, despite many fans already owning the original 2014 album. According to *Billboard*, nearly half of vinyl purchasers do not own a record player²⁹, further supporting the notion that many consumers are motivated by collectability rather than functionality.

The trend of excessive vinyl production is not exclusive to Swift. Artists such as Billie Eilish and Olivia Rodrigo have adopted similar strategies, issuing "exclusive" color variants and bonus-track editions to encourage repeat purchases. While this practice may benefit artists by bolstering sales and chart rankings, it also fosters an unsustainable level of consumerism. Much like collecting

²⁵ Washington Post. *The search for the perfect sound*. By Geoff Edgers. Published on September of 2022. Available at: https://www.washingtonpost.com/arts-entertainment/interactive/2022/perfect-sound-quality-vinyl-records/

²⁶ Analog recording is a category of techniques used for the recording of analog signals. This enables later playback of the recorded analog audio. Neumann Sound Engraver VMS-70. Analog audio recording began with mechanical systems such as the phonautograph and phonograph.

²⁷ A digital master is an image, PDF file, digital recording or another digital asset preserved as the "original" for the purpose of archival storage, reuse and re-expression.

 ²⁸ a person who is very interested in and enthusiastic about equipment for playing recorded sound, and its quality.
²⁹ Billboard. *How Vinyl Can Harness the Influence of Superfans (Guest Column)*. Published on April 2024. By Will

Page, Fred Goldring. Available at: https://www.billboard.com/pro/vinyl-releases-before-streaming-date-superfansartists/

baseball cards, fans may enjoy acquiring multiple editions of an album, but the environmental cost of such behavior cannot be ignored.

This issue extends beyond Western pop music into the global music industry, with K-pop exemplifying another sector where excessive physical media production contributes to environmental waste. South Korea's K-pop industry, one of the country's largest cultural exports, has come under fire for its reliance on physical CD sales, despite the reality that most fans primarily listen to music via streaming. According to the Korea Creative Content Agency's 2024 white paper, only 8% of South Koreans use physical albums for music playback, yet CD sales have nearly tripled in just three years, surpassing 119 million units in 2023.

Much of this growth is driven by aggressive marketing tactics that bundle collectible photo cards of band members inside CD packages. These random inclusions encourage fans to purchase multiple copies in the hopes of obtaining a specific member's photo, a strategy that, while profitable for record labels, results in immense waste.

K-pop activist group Kpop4planet has been vocal about the environmental consequences of this practice, particularly as South Korea prepares to host United Nations negotiations on plastic waste reduction. Kim Na-yeon, a representative of the organization, argues that the industry's reliance on physical sales is highly unsustainable. The amount of plastic used in K-pop album production surged to approximately 800 metric tons in 2022, a 14-fold increase from 2017, according to South Korean lawmaker Woo Won-shik. These excessive sales have also contributed to a 13% increase in global physical album revenues, according to the Global Music Report by the International Federation of the Phonographic Industry (IFPI)³⁰.

Despite growing awareness of the environmental impact, K-pop agencies show little indication of changing their practices. Some companies, such as HYBE, the agency behind BTS, have introduced digital alternatives like Weverse albums, which grant fans access to music and exclusive content via QR codes. However, critics argue that these measures are insufficient and accuse the industry of greenwashing — promoting minor sustainability efforts while continuing to mass-produce physical albums. Other major agencies, including SM Entertainment, JYP Entertainment, and YG Entertainment, have remained largely silent on the matter.

The ethical implications of these marketing tactics are also worth considering. Many K-pop fans are in their teens or early twenties, a demographic that is not only highly susceptible to trends but also

³⁰ The Global Music Report is a major annual publication of IFPI and contains the definitive financial record of the recording industry worldwide.

among the least financially secure. As seen in Western music markets, young consumers often feel compelled to purchase multiple versions of the same album despite the financial burden. Given that the national minimum wage in some regions remains under 8\$ per hour, artists and record labels should reconsider pressuring their fans into unnecessary spending.

Of course, not all aspects of physical music sales are detrimental. Independent record stores have benefited tremendously from the resurgence of vinyl and CDs, fostering a sense of community among music enthusiasts and supporting small businesses. However, with the majority of sales occurring through major retailers such as Amazon, Target, and direct artist websites, the commercial exploitation of music fandoms is evident. The notion that multiple editions of an album are essential for fan engagement must be reevaluated.

The carbon footprint of vinyl production is significant. According to *Forbes*, manufacturing a single vinyl record emits approximately 0.5 kg of carbon dioxide³¹, equivalent to the emissions generated by driving a car one mile. When factoring in packaging, shipping, and purchasing multiple copies of the same album, the cumulative environmental impact becomes staggering. As artists continue to exploit vinyl variants to boost their chart positions, and as fans compulsively purchase them, the environmental consequences become increasingly unacceptable.

Despite its impact, the music industry is rarely scrutinized in discussions of environmental sustainability. Yet, it is imperative that record labels and artists take accountability for their role in perpetuating wasteful practices. While the carbon emissions from streaming music are not negligible, the reality is that a significant portion of the nearly 50 million vinyl records sold in 2023 will ultimately end up discarded in landfills.

Beyond environmental concerns, it is also necessary to examine which demographics are most affected by this consumerist push. A *DJ Magazine* study found that 59% of vinyl buyers in 2023 were between the ages of 18 and 24, while participation in the market was significantly lower among older generations. Younger consumers, often more susceptible to marketing trends, are also the least financially equipped to engage in excessive spending. According to *Other Record Labels*, the average vinyl album costs at least 20\$ — an amount that could instead cover nearly two months of music streaming subscriptions. With the national minimum wage still under 8\$ per hour in some regions, it is ethically questionable for artists to pressure their youngest and most devoted fans into purchasing multiple copies of the same album.

³¹ Forbes. *Is The Resurgence Of Vinyl Records Good News For The Environment?* By Jamie Hailstone. Published on April 2022. Available at: https://www.forbes.com/sites/jamiehailstone/2022/04/22/is-the-resurgence-of-vinyl-records-good-news-for-the-environment/

Ultimately, the romanticized notion of owning multiple copies of the same album must be reconsidered. While vinyl records hold an undeniable charm and cultural significance, the environmental and economic implications of excessive consumption cannot be ignored. In an age where sustainability is more crucial than ever, purchasing one copy of a beloved album should be more than enough.

3.2 Education and Outreach in the Music Industry: The EcoTour Case

As the global music industry continues to evolve, so too does its responsibility to promote sustainable practices and environmental consciousness. While discussions around sustainability in music often focus on production and consumption, an equally critical aspect is education and outreach. The power of music as a cultural force extends beyond entertainment — it serves as an influential platform for change, shaping the values and behaviors of future generations. Recognizing this potential, industry leaders and educators are actively working to integrate sustainability into music-related educational programs. One such groundbreaking initiative is EcoTour, an innovative program designed to equip students with both environmental and financial literacy skills while immersing them in the world of live music and touring.

Set to launch in the fall of 2024, EcoTour is a pioneering effort that blends sustainability, education, and entertainment to inspire the next generation of changemakers. Developed by Learn Fresh³² in collaboration with sustainability experts and music industry professionals, the program introduces students to the complexities of planning and executing a performing artist's tour, all while highlighting pressing environmental challenges. By engaging students in a dynamic, hands-on learning experience, EcoTour fosters critical thinking, problem-solving, and a deeper understanding of the intersection between the entertainment industry and sustainability.

The need for initiatives like EcoTour is underscored by growing concerns among young people regarding climate change. A 2022 study published in *The Lancet*³³ revealed alarming statistics about youth anxiety related to environmental issues, emphasizing the importance of comprehensive education in addressing these concerns. With EcoTour, Learn Fresh aims to bridge this gap by empowering students with the knowledge and tools needed to confront climate-related challenges,

³² Learn Fresh is a nonprofit organization dedicated to providing innovative STEM learning experiences that empower educators and inspire students.

³³ The Lancet. *Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey.* Published on December 2021. By Caroline Hickman. Available at: https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00278-3/fulltext

while also alleviating the sense of helplessness — often referred to as 'eco-anxiety'— that many young people experience.

At its core, EcoTour is structured around an interactive board game and curriculum that guides students through every stage of planning an artist's tour across North America. From selecting performers to mapping out tour routes, managing budgets, and executing marketing strategies, participants gain hands-on experience in both the business and sustainability aspects of live entertainment. Additionally, the program introduces students to potential career paths within the music industry, broadening their awareness of opportunities in both the creative and environmental sectors.

Beyond classroom learning, EcoTour incorporates real-world industry engagement, providing students with unique opportunities to interact with professional musicians and sustainability leaders. In December 2023, Learn Fresh hosted an inaugural pilot workshop in collaboration with soul-pop band Lawrence and technology leader AMETEK for students from Passaic Preparatory Academy. This immersive experience featured a live performance and an artist-led discussion on sustainable touring practices, offering students invaluable insights into the environmental impact of live entertainment and potential solutions for a greener industry.

The pilot event also highlighted the role of cutting-edge technology in advancing sustainability goals. Creaform, a division of AMETEK specializing in portable and automated 3D scanning solutions, led an interactive demonstration showcasing how their innovations contribute to sustainability efforts in sectors such as renewable energy and electric vehicle development. Students were captivated by the precision and efficiency of the 3D scanning technology, which provided a tangible example of how technological advancements can drive environmental progress.

Further enriching the experience, students participated in the All-Access workshop led by Record High, a nonprofit dedicated to equipping young people with the skills and knowledge needed to pursue careers in the music and entertainment industry. The workshop provided aspiring industry professionals with valuable insights into the music business while reinforcing the importance of sustainability. The event concluded with an exclusive opportunity for students to attend a Jonas Brothers concert at the Prudential Center as special guests, offering them firsthand exposure to the excitement and logistics of a live music event.

Building on the success of the pilot program, Learn Fresh plans to expand EcoTour with a multicity rollout in the fall of 2024, incorporating similar artist partnerships and industry collaborations. AMETEK has committed to returning as the lead funder, ensuring the program's continued growth and impact.

As EcoTour prepares for its national launch, Learn Fresh remains dedicated to forging partnerships with educators, schools, and communities to implement this forward-thinking program. By harnessing the power of music to educate and inspire, EcoTour represents a transformative step toward a more informed, empowered, and environmentally conscious generation. Through initiatives like this, the music industry can play a vital role in fostering sustainability and shaping a future where both artistry and environmental responsibility go hand in hand.

Conclusion

In conclusion, this thesis has explored the profound and multifaceted influence of the music industry across economic, social, and environmental dimensions. While the industry serves as a powerful engine for economic growth, cultural exchange, and artistic expression, it simultaneously presents significant challenges that demand urgent attention — particularly in terms of sustainability and equitable development.

The economic impact of the music industry cannot be overstated. Beyond its cultural significance, music generates billions in revenue worldwide, sustains millions of jobs, and contributes meaningfully to national GDPs. From record sales and live performances to streaming services and artist branding, the industry has continually evolved, shaping new business models and expanding creative economies. However, this economic expansion must be balanced with ethical considerations, ensuring that financial gains do not come at the cost of environmental degradation or exploitative labor practices.

The environmental footprint of the industry is one of its most pressing concerns. While the transition from physical media to digital streaming has reduced material waste, it has introduced new sustainability dilemmas, including the high energy consumption required to power vast data centers and the carbon emissions associated with music streaming. Similarly, the resurgence of vinyl and excessive production of CDs — often driven by collector culture and marketing strategies — demands a critical reassessment of consumer behavior and industry practices. The need for more sustainable production methods, responsible marketing approaches, and the widespread adoption of green initiatives within the industry is evident. Addressing these challenges requires a collaborative effort from record labels, artists, and consumers to foster a music ecosystem that prioritizes environmental consciousness without sacrificing creative innovation.

On a social level, music remains one of the most powerful forces for unity, cultural preservation, and activism. It transcends linguistic and geographical barriers, fostering a shared sense of identity and belonging among diverse communities. Historically, music has been an agent of change, amplifying voices in movements for civil rights, environmental justice, and political reform. Case studies presented in this research underscore music's ability to inspire action, educate listeners, and provide a platform for marginalized voices. As digital platforms make music more accessible than ever, this industry has an unprecedented opportunity to harness its influence for social good, advocating for inclusivity, equity, and awareness of global issues.

Looking ahead, the future of the music industry is at a crossroads. While it possesses immense potential to align with sustainable development goals, achieving meaningful change will require collective responsibility from all stakeholders. Musicians, record labels, policymakers, technology developers, and fans must work together to reshape the industry in a way that balances artistic expression with environmental stewardship and ethical business practices. Embracing sustainability, promoting fair labor policies, and leveraging technological advancements for eco-friendly solutions are essential steps toward a more responsible industry.

Ultimately, this thesis contributes to a broader understanding of the intricate relationship between music and sustainability. It underscores the industry's responsibility to wield its cultural and economic influence to drive positive change. The journey toward a more sustainable, ethical, and inclusive music industry is undoubtedly complex, but it is also rich with opportunities for innovation and impact. By taking decisive steps today, the music industry can continue to thrive while fostering a future where music not only entertains but also empowers, educates, and preserves the world for generations to come.

Bibliography

Akamai. What is Buffering? Available at: https://www.akamai.com/glossary/what-is-buffering [Accessed: 30 January 2025]

Amazon Web Services. What is a CDN? Available at: https://aws.amazon.com/what-is/cdn/ [Accessed: 29 January 2025]

Analytix Labs. Data Compression Techniques. Available at: https://www.analytixlabs.co.in/blog/data-compression-technique/ [Accessed: 1 February 2025]

AP News. Ed Sheeran Goes Back to School to Launch New Music Foundation. By AP News Staff. Published on January 12, 2025. Available at:

https://apnews.com/article/b1b994ee3639be041f4c4e52dc5b4452 [Accessed: 10 February 2025]

Attack Magazine (2023). Is Music Hardware Environmentally Sustainable? Available at: https://www.attackmagazine.com [Accessed: 25 January 2025]

Billboard. How Vinyl Can Harness the Influence of Superfans (Guest Column). By Will Page, Fred Goldring. Published on April 2024. Available at: https://www.billboard.com/pro/vinyl-releases-before-streaming-date-superfans-artists/ [Accessed: 15 February 2025]

Business Insider. Proof of Work and Proof of Stake Explained. Available at: https://www.businessinsider.com [Accessed: 7 February 2025]

CacheFly. Unlock Green Streaming with Advanced CDN Technologies. Available at: https://www.cachefly.com/news/turn-the-beat-around-using-green-cdns-in-music-streamingservices/ [Accessed: 26 January 2025]

Cambridge Dictionary. Audiophile. Available at:

https://dictionary.cambridge.org/dictionary/english/audiophile [Accessed: 15 February 2025]

Carbon Trust. Who We Are. Available at: https://ghgprotocol.org/about-us [Accessed: 26 January 2025]

CBC (2023). The Environmental Impact of Music Streaming Explained. Available at: https://www.cbc.ca/music/the-environmental-impact-of-music-streaming-explained-1.6843948 [Accessed: 29 January 2025]

Cloudinary. Adaptive Bitrate Streaming. Available at: https://cloudinary.com/glossary/adaptivebitrate-streaming [Accessed: 5 February 2025] Daily Bruin. Second Take: Repeat Purchases of Vinyl Albums Harm Environment, Consumers. By Daily Bruin Staff. Published on June 5, 2024. Available at: https://dailybruin.com/2024/06/05/second-take-repeat-purchases-of-vinyl-albums-harmenvironment-consumers [Accessed: 10 February 2025]

Digicert. Multi-CDN Strategies with DigiCert Constellix DNS. By DNS Trust Manager. Published on May 2, 2023. Available at: https://www.digicert.com/blog/multi-cdn-strategies-in-2023 [Accessed: 7 February 2025]

Earth.org. Fast Fashion's Detrimental Effect on the Environment. Available at: https://earth.org/fast-fashions-detrimental-effect-on-the-environment/ [Accessed: 29 January 2025]

Earth.org. Statistics About Fast Fashion Waste. Available at: https://earth.org/statistics-about-fast-fashion-waste/ [Accessed: 28 January 2025]

Ecotricity (2018). The Carbon Footprint of Getting Dressed. Available at: https://www.ecotricity.co.uk/our-news/2018/the-carbon-footprint-of-getting-dressed [Accessed: 29 January 2025]

EdgeNext. How Will AI and ML Change CDN Optimization for Better Streaming? Available at: https://www.edgenext.com [Accessed: 5 February 2025]

Enel Green Power. How the Music Industry Is Moving to the Rhythm of Sustainability. By Enel Green Power Team. Published in September 2023. Available at: https://www.enelgreenpower.com/media/news/2023/09/sustainable-music-initiatives [Accessed: 9 February 2025]

Environmental Solutions MIT. Music Industry Leaders Tune in to Climate Solutions at Sustainability Summit. By MIT Environmental Solutions Team. Published in 2024. Available at: https://environmentalsolutions.mit.edu/news/music-industry-leaders-tune-in-to-climate-solutions [Accessed: 10 February 2025]

Fairware. The Carbon Footprint of a T-Shirt. Available at: https://fairware.com/the-carbon-footprintof-a-t-shirt [Accessed: 28 January 2025]

Forbes (2015). Vinyl Sales Grew More Than 50% In 2014. By Hugh McIntyre. Published on February 2015. Available at: https://www.forbes.com/sites/hughmcintyre/2015/02/10/vinyl-sales-grew-more-than-50-in-2014/ [Accessed: 15 February 2025]

Forbes (2021). 3LAU and the NFT Boom. Available at:

https://www.forbes.com/sites/abrambrown/2021/03/03/3lau-nft-nonfungible-tokens-justin-blau/ [Accessed: 1 February 2025]

Forbes (2022). Is The Resurgence Of Vinyl Records Good News For The Environment? By Jamie Hailstone. Published on April 2022. Available at: https://www.forbes.com/sites/jamiehailstone/2022/04/22/is-the-resurgence-of-vinyl-records-good-news-for-the-environment/ [Accessed: 15 February 2025]

GeeksForGeeks. What are Data Compression Techniques? Available at: https://www.geeksforgeeks.org/what-are-data-compression-techniques/ [Accessed: 1 February 2025]

Global Society Earth. The Hidden Cost of a Cotton T-Shirt. Available at: https://www.globalsociety.earth/post/the-hidden-cost-of-a-cotton-t-shirt [Accessed: 29 January 2025]

HackerNoon. 5 Caching Mechanisms to Speed Up Your Application. Available at: https://hackernoon.com/5-caching-mechanisms-to-speed-up-your-application [Accessed: 30 January 2025]

Investopedia. Non-Fungible Tokens (NFTs). Available at: https://www.investopedia.com/non-fungible-tokens-nft-5115211 [Accessed: 5 February 2025]

Just Energy. The Power Grid: What is it and How Does it Work? Available at: https://justenergy.com/blog/power-grid-what-is-it-and-how-does-it-work/ [Accessed: 5 February 2025]

Learn Fresh. EcoTour: Education Through Music and Sustainability. By Learn Fresh Team. Published in 2024. Available at: https://www.learnfresh.org/news/ecotour-education-through-musicand-sustainability [Accessed: 10 February 2025]

Lenovo. What is Encoding? Available at: https://www.lenovo.com/us/en/glossary/what-is-encode/ [Accessed: 1 February 2025]

Medium. System Design: Music Streaming Services. By Ishwarya Hidkimath. Published on May 9, 2024. Available at: https://medium.com/@ishwarya1011.hidkimath/system-design-music-streaming-services-64df330b5624 [Accessed: 7 February 2025]

MIT Technology Review. Music Streaming Can Be a Drag on the Environment. These K-Pop Fans Want to Clean It Up. By MIT Technology Review Staff. Published on July 16, 2024. Available at: https://www.technologyreview.com/2024/07/16/1094982/music-streaming-climate-kpop-fan [Accessed: 10 February 2025]

National Grid. What Are Scope 1, 2 & 3 Carbon Emissions? Available at: https://www.nationalgrid.com [Accessed: 26 January 2025]

New York Times (2022). Organic Cotton Fraud in India. Available at: https://www.nytimes.com/2022/02/13/world/asia/organic-cotton-fraud-india.html [Accessed: 27 January 2025]

Opus Codec. Opus Codec Technology. Available at: https://opus-codec.org/ [Accessed: 1 February 2025]

Pitchfork (2022). What Does It Take for a Band to Make Sustainable Merch? Available at: https://pitchfork.com [Accessed: 25 January 2025]

REVERB. Music Climate Revolution: Sustainable Merch. Available at: https://www.reverb.org

ResearchGate. Digital Transformation in the Music Industry: How the COVID-19 Pandemic Has Accelerated New Business Opportunities. Available at:

https://www.researchgate.net/publication/360978142_Digital_transformation_in_the_music_industr y_How_the_COVID-19_pandemic_has_accelerated_new_business_opportunities [Accessed: 7 February 2025]

ResearchGate. The Rise of Non-Fungible Tokens: Exploring the Digital Renaissance. Available at: https://www.researchgate.net/publication/380529489_The_Rise_of_NonFungible_Tokens_Explorin g_the_Digital_Renaissance [Accessed: 5 February 2025]

Reuters. K-Pop's Profligate CD Output Draws Fire as South Korea Hosts Plastic Waste Talks. By Reuters Staff. Published on November 21, 2024. Available at: https://www.reuters.com/sustainability/k-pops-profligate-cd-output-draws-fire-south-korea-hostsplastic-waste-talks-2024-11-21 [Accessed: 10 February 2025]

SAGE Journals. The Environmental Impact of Textiles. Available at: https://journals.sagepub.com/doi/10.1177/00405175231210239 [Accessed: 28 January 2025] Statista. U.S. vinyl album unit sales 2023. Published on May 2024. Available at: https://www.statista.com/statistics/188822/lp-album-sales-in-the-united-states-since-2009/ [Accessed: 15 February 2025]

Strings Magazine. Sounds of Sustainability: How the Music Industry Is Tackling Climate Change. By Strings Magazine Team. Published in May 2024. Available at: https://stringsmagazine.com/sounds-of-sustainability-how-the-music-industry-is-tackling-climatechange [Accessed: 15 February 2025]

Symphonic Blog (2024). Eco-Friendly Merch Ideas For The Holidays. Available at: https://www.symphonic.com/blog [Accessed: 26 January 2025]

The Guardian. Massive Attack Castigate Music Industry Over Climate Inaction. Available at: https://www.theguardian.com/music/article/2024/aug/23/massive-attack-music-industry-climate-inaction [Accessed: 15 February 2025]

The Impact of Fast Fashion. By Yulia Omelich. Published October 2019. Available at: https://www.codogirl.com/blogs/news/the-impact-of-fast-fashion [Accessed: 7 February 2025]

The Lancet. Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. Published on December 2021. By Caroline Hickman. Available at: https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00278-3/fulltext [Accessed: 15 February 2025]

The Washington Post. The search for the perfect sound. By Geoff Edgers. Published in September 2022. Available at: https://www.washingtonpost.com/arts-entertainment/interactive/2022/perfect-sound-quality-vinyl-records/ [Accessed: 15 February 2025]

That Organic Cotton T-Shirt May Not Be as Organic as You Think. By Alden Wicker, Emily Schmall, Suhasini Raj, and Elizabeth Paton. Published on February 13, 2022. Updated April 12, 2022. Available at: https://www.nytimes.com/2022/02/13/world/asia/organic-cotton-fraudindia.html# [Accessed: 7 February 2025]

UNFCCC. What is the United Nations Framework Convention on Climate Change? Available at: https://unfccc.int [Accessed: 27 January 2025]

Vision Factory. How NFTs Affect the Environment. Available at: https://www.visionfactory.org [Accessed: 7 February 2025] Wikipedia. Acrylonitrile Butadiene Styrene. Available at: https://en.wikipedia.org/wiki/Acrylonitrile_butadiene_styrene [Accessed: 26 January 2025]

Wikipedia. Analog Recording. Available at: https://en.wikipedia.org/wiki/Analog_recording [Accessed: 15 February 2025]

Wikipedia. Non-Fungible Token. Available at: https://en.wikipedia.org/wiki/Non-fungible_token [Accessed: 5 February 2025]