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Shifts in Digital Music Streaming's Energy Infrastructure and Life Cycle Processes, examined in the case of Hanoi and Vietnam

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ABSTRACT

Digital music streaming is becoming increasingly prevalent in the public's music consumption, but with any type of consumption it affects the environment. Pre-existing research has shown that the various processes and infrastructure supporting digital music streaming produce greenhouse gas (GHG) emissions. Globally, emissions induce severe environmental consequences such as ocean acidification and air pollution. Yet, most music consumers remain largely unaware of these severe repercussions.

Thus, this literature review identifies digital music streaming's associated energy infrastructure and life cycle processes, examines their changes in the context of Hanoi and Vietnam, and outlines potential solutions for consequent negative effects. Here, I find that the resource extraction, manufacturing, waste disposal sectors contribute greatly to environmental impacts. Simultaneously, Vietnamese consumers' preference for audio-and-visual content through video and social media platforms enhance streaming repercussions. Hence, it is necessary to experiment with and implement large-scale, long-term technological solutions and push for public behaviour change to prevent drastic degradation and destruction of Vietnam's biodiverse ecosystems.

INTRODUCTION

Global emissions produced from energy reached peak levels for the fourth successive year in 2024. Equally alarming, global energy demand has also risen to a new maximum of 592 EJ. Similarly, electricity demand grew 4% and maintained a faster growth rate than total energy demand, suggesting worldwide electrification of the energy system (Energy Institute 4). As climate change accelerates, the need to identify and resolve the environmental consequences of energy consumption becomes more pivotal than ever before.

The music industry is one of many industries contributing to growing energy emissions, and the increasing prevalence of digital music streaming has only exacerbated its impacts. The music industry's growth and digital streaming's importance are showcased in a graph adapted from the International Federation of the Phonographic Industry IFPI (see fig. 1): The global revenue of the recorded music

industry achieved a new record of 29.5 billion dollars in 2024, with streaming producing the majority at 20.4 billion dollars. According to Webster, "music streaming services rent access to the history of recorded music" (1); therefore, digital music streaming is the consumption of music online through a rented access format. This includes audio, video, and social media platforms.

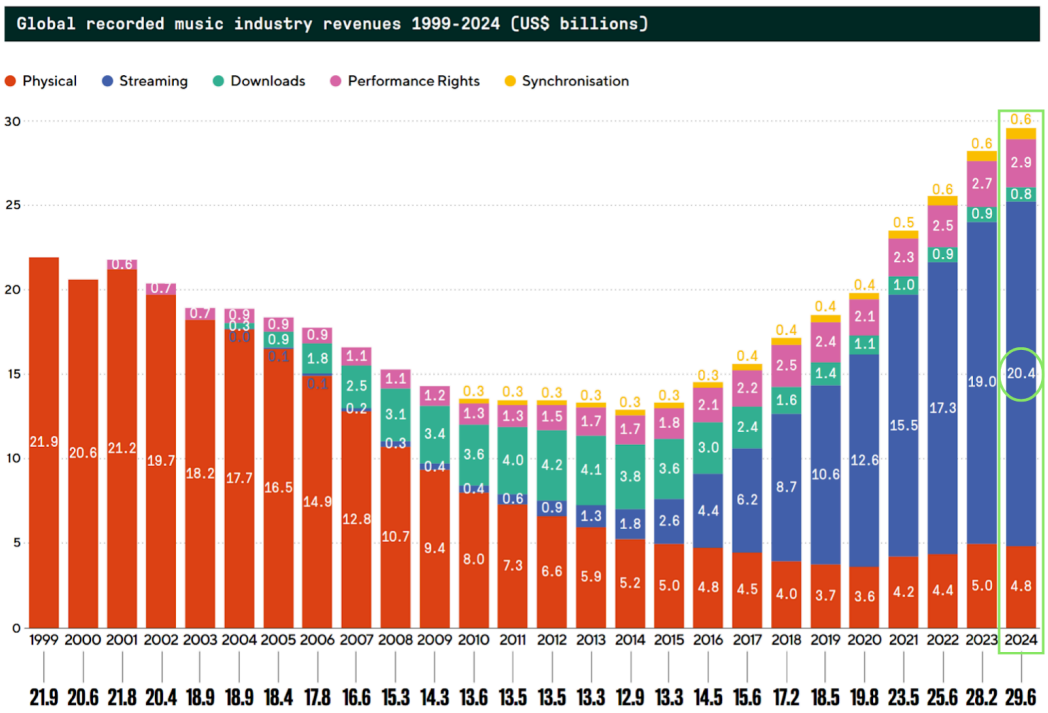


Fig. 1. Adapted from IFPI, *Global recorded music industry revenues 1999-2024 (US$ billions)*, 2025.

This overall growth for the music industry and increasing prevalence of digital streaming applies to Vietnam's situation. As a country placed 16th amidst the most biodiverse countries globally by the Biodiversity Finance Initiative BIOFIN, an initiative that assists countries in securing money to invest in conservation and environmental protection, any environmental consequences of rising energy emissions could cause detrimental effects to the ecosystem (biofin.org). In highly-industrialised cities like the capital city Hanoi, environmental deterioration is devastating and can expose large populations to illnesses and physical casualties.

Because digital streaming requires digital devices to fetch and process data, it is important to consider the impact of Information and Communication Technology (ICT) goods on the environment. In table 1 UN Trade and Development (UNCTAD) data was compiled, which states that in 2024 the estimated global percentage of ICT goods exported per total trade is 12.30% and for imports this estimated percentage rises to 13.23%; similarly, the global value of exports in ICT services reached $1,181,860 USD in 2024 (unctadstat.unctad.org).

The transportation of these products necessitate vehicle fuels and electricity. Vehicles like ships, airplanes, and trucks require fuels derived from fossil fuels like marine gas oil (MGO), kerosene, and diesel, respectively (Martin et al. 5). For electricity, the Energy Institute documents that electricity generation from fossil fuels still accounts for 59% of the total electricity generated in 2024 (52), and electronics manufacture depends on electricity. Hence, globally, digital devices used for digital music streaming consume lots of fossil fuels and beget massive greenhouse gas (GHG) emissions.

Table 1

UN Trade and Development's (UNCTAD) Export and Import Data

Type		Data	Time Frame
Estimated global percentage of ICT goods exported per total trade[a]		12.30%	2024
Estimated global percentage of ICT goods imported per total trade[a]		13.23%	2024
Global value of exports in ICT services[b]	$	1,181,860	2024

Adapted from: UNCTAD. *Share of ICT goods as percentage of total trade, annual.* https://unctadstat.unctad.org/datacentre/dataviewer/US.IctGoodsShare. Accessed 19 Dec. 2025., UNCTAD. *International trade in ICT services, value, shares and growth, annual.* https://unctadstat.unctad.org/datacentre/dataviewer/US.TradeServICT. Accessed 19 Dec. 2025.

a. These figures are from the first source listed.

b. This figure is from the second source listed.

Fossil fuel combustion releases carbon dioxide (CO_2) to the atmosphere (Gilfillan and Marland 1667). Likewise, Al Mubarak et al. identifies that intentionally flaring and venting natural gas, as well as producing and transporting fossil fuels, increase atmospheric GHG concentrations by releasing methane (CH_4). These GHGs trap heat within the atmosphere (Al Mubarak et al. 1251). Undoubtedly, the environmental repercussions correlated with GHG emissions are numerous:

Table 2
Environmental repercussions

Cause	Effect
Ocean Acidification[a]	GHGs when absorbed into the ocean greatly decrease its pH, negatively impacting ocean ecosystems and the coral reef-building process.
Air Pollution[b]	Fossil fuels production/combustion engenders the release of pollutant gases (e.g., nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x)). These gases can cause acid rain, which reduces oxygen abundance in the close-to-ground atmosphere and induces eutrophication.
Global Sea Level Rise[b]	Increasing atmospheric temperatures melt polar ice sheets and mountain glaciers, causing meltwater to enter the sea. The sea level rise floods low-lying coasts.
Oil Spills[b]	Oil and petrochemical spills contaminate groundwater. Furthermore, the oil and gas industry's water consumption increased tremendously "in the past two decades" because of "fracture stimulation requirements of tight (low permeability) reservoirs"; these fracture-stimulation operations release toxic wastewater containing substances like lead, arsenic, and chlorine.
Plastic Pollution[b]	Nearly 99% of plastics manufactured necessitate petrochemicals, which are processed from fossil fuels. Thus, their production generates massive GHG emissions. Not only that, many are non-biodegradable. Perilously, "tens of millions of tons" become fragments in the ocean and infiltrate the food chain, which eventually may be consumed by humans.

Adapted from: Al Mubarak, Faisal, et al. "Economic, Societal, and Environmental Impacts of Available Energy Sources: A Review." *Eng*, vol. 5, no. 3, Sept. 2024, pp. 1232–65. *www.mdpi.com*, https://doi.org/10.3390/eng5030067.

a. (Al Mubarak et al. 1251)
b. (Al Mubarak et al. 1252)

The threats above are impactful for Vietnam and Hanoi. Vietnam's coast is long (Tran-Anh et al. 2); not only that, World Bank Group states in the line graph "Population, total - Viet Nam" that as of 2024 the population is 100,987,686 (data.worldbank.org). Ocean acidification, sea level rising, oil spills and plastic pollution could harm the fishing industry and agricultural production near coasts in Vietnam, affecting the quality and quantity of food available nationwide.

International trade-wise, depletion of produce and seafood hampers export, limiting Vietnam's economic development. Meanwhile, air pollution would result in frequent cases of respiratory system illnesses. For Hanoi, the National Statistics Office of Vietnam reports that by the midterm of 2024 the population was

8,685,607 ("Thông cáo báo chí kết quả điều tra dân số và nhà ở giữa kỳ năm 2024"). As such, environmental repercussions discussed by Al Mubarak et al. could harm a large population of people.

Consequently, my research on the life cycle processes and energy infrastructure supporting digital music streaming will contribute to discussions around the overlooked relationship between the natural environment and digital streaming. I want to focus on Hanoi because it is an urban area, so I expect more digital music streaming to happen here. To investigate the relationship, I framed my topic in the following research question: "What energy infrastructure and life cycle processes support digital music streaming, and how are these systems changing in Hanoi and Vietnam?"

I will evaluate the resource extraction, manufacture, data transmission processes and data processing performed by digital devices, in addition to digital device disposal. I will also assess how digital streaming preference influences energy consumption and environmental consequences. Then, I analyze the situation in Vietnam and Hanoi for each mentioned factor and compile potential solutions into table 8. In this way, I am addressing the limited literature about digital music streaming's expanding systems and its impacts in Vietnam and Hanoi.

CONTEXT

Before digital streaming reached market dominance like today, physical formats such as vinyl records, cassette tapes, and compact discs (CDs) dominated the music industry (Guo 8). At the time, they were the most durable, reliable, and suitable formats of storing and allowing listeners to enjoy music. In the late 1990's, music's digital distribution became popularized due to the emergence of diverse file compression techniques and faster computer networking (Théberge 20). Guo affirms this shift was generated by digital music formats like MP3 and AAC (9).

These digital mediums encompass higher portability and convenience than physical mediums, as they can be downloaded and "consumed wherever and whenever" (Wagner and Hess 10). Ownership of music developed from owning physical formats to owning licenses which permit listeners' access and download of music; hence, transportable audio players e.g., the iPod became essential for music listeners (Guo 9).

Digital music streaming started appearing around 2010 and gaining popularity from roughly 2015 (Hesmondhalgh 1) - this is a major paradigm shift for the music industry as music, from something owned, transformed into something accessed (Guo 9). Currently, much of music-listening occurs on music streaming platforms (MSPs) like Apple Music, Gaana, Boomplay in addition to video and social media platforms like YouTube and TikTok/Douyin. Devices such as smartphones and laptops became the mediums of access (Hesmondhalgh 2), replacing previous technologies.

Referring to the environmental consequences correlated with ICT goods and the global increase in digital streaming, it is apparent digital music consumption can harm the environment across dimensions. This is seen in GHG emissions produced from electricity used in device transport and manufacture, and the

creation of fossil fuel-based vehicle fuels. Furthermore, digital streaming requires the Internet and data transmission.

As Makonin et al. stated: Even though data centres; networks; devices are increasingly optimized, the work they need to perform increases quicker. This generates ever larger electricity consumption (sec. 3). Previous mediums contain similar environmental costs e.g., in physical music formats and listening devices' manufacture and transport, but require less or no Internet infrastructure to sustain them. Hence, it is difficult to determine if digital streaming is more environmentally-friendly than its predecessors.

As such, I am compelled to research this topic in the context of Hanoi and Vietnam through the lens of my research question: "What energy infrastructure and life cycle processes support digital music streaming, and how are these systems changing in Hanoi and Vietnam?"

METHODS

I searched for scholarly articles on reputable search engines like Google Scholar and Naver Academic, and used Vietnamese government sites for area-specific data and reports. I start from 2021 onwards and expand this scope if I get insufficient information. Most of my English sources are from Google Scholar. I used keywords such as "environmental impacts of energy consumption", "environmental impacts of digital streaming", "methods of electricity production", and "music streaming trends in Hanoi" to search for articles.

Many relevant resources are in Vietnamese, so I searched with keywords such as "xu hướng tiêu thụ nhạc trực tuyến tại Hà Nội" and "tiêu thụ năng lượng tại Hà Nội". When official English versions were unavailable, I translated them. From these search engines, I accessed several databases, including ScienceDirect and Nature.

Upon accessing desired resources, I checked the publishers, abstract, and keywords (when applicable) for reliability and relevance. Sources examining topics like the evolution of music-listening, energy consumption's environmental impacts, music streaming's effect on energy consumption throughout its life cycle, user preference, and potential solutions for produced environmental issues were incorporated into this review.

I considered 44 sources and included 36. Some sources were excluded because their findings do not apply to an entire life cycle stage, overlapping information with more relevant resources, or because they do not contribute a new perspective in addition to other sources. A useful method for finding related research was scanning articles' references, allowing me to develop my literature review cohesively. To streamline my research process, I used the Unpaywall web extension to find legal, open-access fulltexts. When possible, I asked my mentor for help with accessing locked articles.

FINDINGS AND IMPACTS

Scholarship on Digital Music Streaming's Life Cycle Impacts

Depending on the stage of a device's life cycle, varying operations are used, differentially impacting energy consumption. These life cycle stages are as shown:

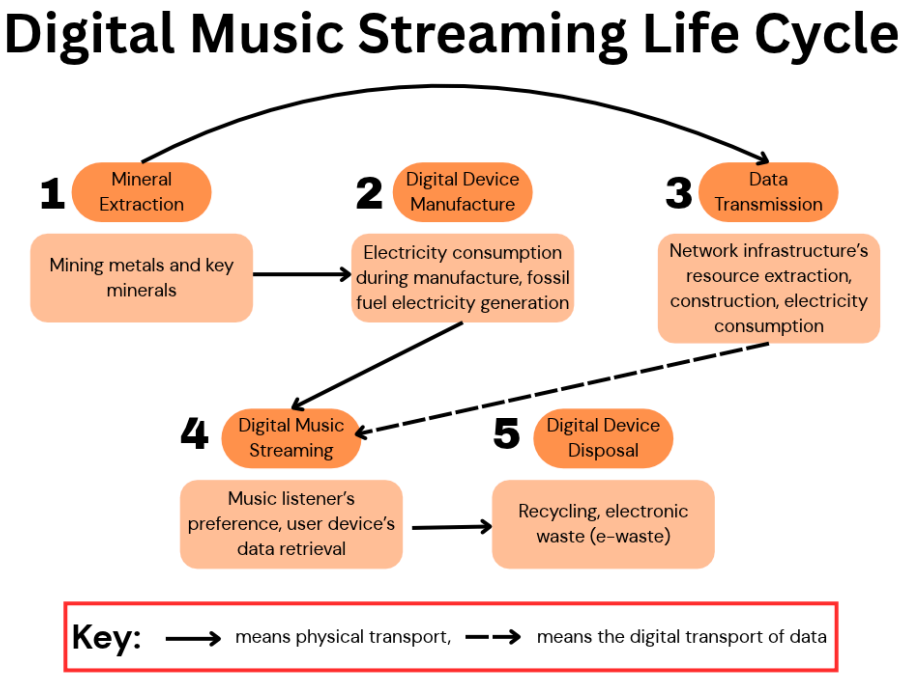


Fig. 2. The Digital Music Streaming Life Cycle

Mineral Extraction

Digital devices consume a vast variety of elements, with the most-consumed elements being "copper, gallium, germanium, gold, indium, platinum - group metals (PGMs), rare earths (REE) and tantalum" (Eerola et al. 23). The extraction and processing of metals release GHG emissions, in addition to causing "air pollution (dust and gases), water consumption and pollution, eutrophication, soil pollution and erosion, and deforestation" (Duporte et al. 3).

Nonetheless, in 2024 mining activities extracting REE "increased by 3.2%" to 0.4 million tonnes of metals taken, meanwhile on average costs of key minerals reduced by 16% worldwide (Energy Institute 5). This discrepancy emphasizes the comprehensive scale and intensity at which Earth's climate and ecosystems are damaged. Considering the decreasing prices, it is possible these minerals are provided to industries in abundance, implying increasingly-high demand. Thus, the extent of environmental destruction from these activities is also dictated by consumers' needs and awareness.

Digital Device Manufacture

Each stage of digital devices' life cycle contributes to their total embodied climate impacts. In terms of manufacturing, most impacts arise from electricity usage - particularly when producing "wafers and printed and integrated circuits" (Istrate et al. 3).
This is evidenced in the Energy Institute's table "Electricity Generation by fuel" where the global amount of electricity generated by fossil fuels in 2024 is 18,309.1 Terawatt-hours, larger than 5,415.2 Terawatt-hours - the amount produced by renewables in 2024 (54). Fossil fuels pollute the ecosphere from extraction, processing, to consumption (Al Mubarak et al. 1245). Considering the environmental repercussions of GHG emissions, it becomes obvious the widespread and severe extent of environmental damage.

Moreover, different end-user devices contain differing amounts of embodied impacts: Istrate et al. found that although 53% of the time spent on the smartphone is for digital content consumption, this device has the lowest average embodied impacts. On the contrary, the desktop computer contains the highest average embodied effects, extending from 28% to 57% "depending on the category" (3). This creates a spectrum of impact severity.

Data Transmission

According to Ruiz et al.'s table 1, the Fourth Generation Long Term Evolution (4 G LTE) data transmission network contains data centers, undersea cables, IP core network (EPC), access network, Customer Premise Equipment (CPE), and end-user devices (3). Resource extraction for and construction of network infrastructure, and electricity consumption of data storage; transmission; processing all yield environmental impacts.

Jones reported that ICT as a whole contributes over 2% in terms of global emissions, demonstrating that its carbon footprint is comparable to the aviation industry's GHG emissions when consuming fuel (164). Although this figure may not seem momentous, as global Internet connectivity increases and more people access digital music content, the amount of emissions and extent of environmental repercussions will grow quickly.

Digital Music Streaming

Before analyzing digital music streaming's impacts, it is important to acknowledge the user's preference because it can increase energy consumption. Music can be consumed in non-traditional ways, one of which is "soundtracking" i.e., "choosing and listening to music to accompany other everyday practices" as defined by Fuentes et al. (qtd. in Beuscart et al. 658). According to Beuscart et al., despite Youtube being general-purpose, it is most often used for soundtracking (655). So, this practice often ensues on video-streaming platforms.

Importantly, Beuscart et al. found that video streaming occupies more data center storage and exhausts more bandwidth than audio streaming (662). I will evaluate video music streaming's energy consumption and environmental repercussions to best represent current trends.

During video streaming a device's network interface card (NIC) is responsible for retrieving video data (Turkkan et al. 154). Afzal et al. notes NICs' power consumption is impacted by whether it is active or idle (18). The time spent in these states is affected by "the ratio of the network bandwidth to the average bitrate of a segment" - the "slackness" as termed by Yue et al. (160). If this ratio is larger, it increases buffer filling rate, subsequently causing the device's active state to elapse quickly. Due to this, there is "less average power draw".

However, it is important to realize that bandwidth correlates positively with the active state's power draw (Yue et al. 160). Therefore, the amount of electricity consumed and consequent GHG emissions released are dependent upon these NIC states as well as the bandwidth. On a global scale where the amount of music video content consumed is extensive, electricity consumed and emissions generated increase greatly, highlighting the role of users' awareness and demand.

Digital Device Disposal

At the end of the life cycle, oftentimes devices containing valuable metals are disposed of; a reason may be because they contain little amounts of various metals which makes recycling and recovering materials difficult or impossible (Eerola et al. 12). This is concerning, as electronic waste (e-waste) consists of more than 1,000 chemicals with many being hazardous (Eerola et al. 14).

This information, in addition to Baldé et al.'s statistic wherein from 2010 to 2022 the global quantity of e-waste created yearly "almost doubled" from 34 billion kg to 62 billion kg (28), testifies to the global prevalence of pollution caused by e-waste. Comparatively, in Figure 3 it is clear that during the same 12-year period the amount of e-waste classified as "formally collected and recycled" increases from 8 to 13.8 billion kg, much less than the total amount generated (Baldé et al. 28). If this trend continues, environmental repercussions will worsen.

Hanoi, Vietnam, and Digital Music Streaming's Life Cycle Impacts

I will reference the following tables to explain the situation in Hanoi and Vietnam at each digital music streaming life cycle stage:

Table 3
Vietnam's Natural Resource Extraction and Digital Products, Computers, Optical Products, Electronics Manufacture Industrial Production Indices (IPIs) relative to 2015

Type	Data	Base Period
Mining metal ores	99.2%	9/2025 compared to 8/2025
	120.6%	9/2025 compared to 9/2015
Mining other ores	100.5%	9/2025 compared to 8/2025
	116.0%	9/2025 compared to 9/2015
Mining coal, crude oil, natural gas (calculated)	222.2%	9/2025 compared to 8/2025
	278.2%	9/2025 compared to 9/2015
Manufacturing digital products, computers, optical products, electronics (calculated)	205.0%	9/2025 compared to 8/2025
	218.9%	9/2025 compared to 9/2015

Adapted from: Ministry of Industry and Trade of the Socialist Republic of Vietnam. "Phụ lục Báo cáo tình hình sản xuất công nghiệp và hoạt động thương mại tháng 9 năm 2025." *moit.gov.vn*, Cổng thông tin điện tử Bộ Công Thương, 27 Oct. 2025, https://moit.gov.vn/thong-ke/phu-luc-bao-cao-tinh-hinh-san-xuat-cong-nghiep-va-hoat-dong-thuong-mai-thang-9-nam-2025.html.

Table 4

Vietnam's Import, Export of Electronics, Computers, Electronic Components and National Industry-based Electricity Supply Data

Type		Data	Time frame
Total Value of Importing electronics, computers, electronic components[a]	$	110,000,000,000.0	First 9 months of 2025
Total Speed of Growth - Exports, imports (%)[a]		41.8%	First 9 months of 2025 compared to 2024
Percent Increase in electricity supplied - Industry and construction[b]		7.3%	First 9 months of 2025 compared to 2024
Percent Decrease in electricity supplied - Residential management and consumption[b]		0.7%	First 9 months of 2025 compared to 2024

Adapted from: National Statistics Office of Vietnam. *Xuất, nhập khẩu điện tử, máy tính và linh kiện - Động lực tăng trưởng xuất khẩu của Việt Nam giai đoạn 2016-2025*. 10 Oct. 2025, https://www.nso.gov.vn/du-lieu-va-so-lieu-thong-ke/2025/10/xuat-nhap-khau-dien-tu-may-tinh-va-linh-kien-dong-luc-tang-truong-xuat-khau-cua-viet-nam-giai-doan-2016-2025/., Ministry of Industry and Trade of the Socialist Republic of Vietnam. "Báo cáo tình hình hoạt động sản xuất công nghiệp và thương mại tháng 9 năm 2025." *moit.gov.vn*, Cổng thông tin điện tử Bộ Công Thương, 27 Oct. 2025,

https://moit.gov.vn/thong-ke/bao-cao-tinh-hinh-san-xuat-cong-nghiep-va-hoat-dong-thuong-mai-9-thang-dau-nam-2025.html.

a. These figures are from the first source listed.

b. These figures are from the second source listed.

Table 5

Hanoi's Household Electricity Availability and Internet Connectivity Data

Type	Data	Time frame
% of households using electricity in Hanoi[a]	100.00%	2024
% of households with Internet connection in Hanoi[b]	93%	2024

Adapted from: National Statistics Office of Vietnam. "Percentage of household using electricity by province by Cities, provincies and Year." *National Statistics Office of Vietnam*, https://www.nso.gov.vn/en/px-web/?pxid=E1458&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard. Accessed 22 Dec. 2025., National Statistics Office of Vietnam. "Percentage of household having internet connection by province by Cities, provincies and Year." *National Statistics Office of Vietnam*, https://www.nso.gov.vn/en/px-web/?pxid=E1467&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard. Accessed 22 Dec. 2025.

a. This figure is from the first source listed.

b. This figure is from the second source listed.

Table 6

Vietnamese Users' Social Media and Music-Listening App Preferences

Type	Data	Time frame
% of participants using Youtube	99.6%	2024
% of participants using TikTok	99.1%	2024
% of participants using Facebook	96.0%	2024
% Increase in participants using YouTube for music-listening	0.1%	2023 to 2024
% Decrease in participants using TikTok for music-listening	0.2%	2023 to 2024
% Increase in participants using Facebook for music-listening	0.0%	2023 to 2024

Adapted from: Nguyen, Long, et al. "Vietnam Digital Music Landscape 2024-2025: Professionalization, Co-Creation, and Explosion." SSRN Scholarly Paper no. 5331358, Social Science Research Network, 12 Dec. 2024. papers.ssrn.com, https://doi.org/10.2139/ssrn.5331358.

Extraction in Vietnam

Evaluating infrastructure and manufacturing in Vietnam, we see increased growth. In table 3, the industrial production index (IPI) in September 2025 (mining metal ores) was 99.2% compared to the previous month and 120.6% compared to September 2015. For mining of other ores, it was 100.5% compared to the previous month and 116.0% compared to September 2015. The calculated index for mining coal, crude oil, and natural gas in September 2025 was 222.2% compared to the previous month and 278.2% compared to September 2015 (Ministry of Industry and Trade of the Socialist Republic of Vietnam). Largest growths were observed in IPIs for fossil fuel extraction. Although the IPI for mining metal ores in September 2025 relative to August 2025 presents a decrease, it is minor relative to other increases. These IPIs indicate an alarming reality where comprehensive pollution and deterioration occurred in ecosystems nationwide near mining and extraction sites. Certainly, GHG emissions increased greatly.

Manufacture and Transport of Digital Products for Vietnam

In table 3, the calculated IPI for manufacturing digital products, computers, optical products and electronics in September 2025 is 205.0% compared to the previous month and 218.9% compared to September 2015 (Ministry of Industry and Trade of the Socialist Republic of Vietnam). Similarly, The National Statistics Office of Vietnam remarked that the total value of importing electronics, computers and electronic components in the first nine months of 2025 is 110.0 billion USD. Meanwhile, the total speed of growth for exports and imports in the first 9 months of 2025 compared to the previous year measured as a percentage is 41.8% - the highest from 2016 to 2025 (see table 4).

These statistics suggest a high and rapidly-growing demand for digital products. The proliferation of these products allows more consumers to access digital music content, increasing music streaming's energy consumption. In terms of electricity generation, the Energy Institute's table "Electricity Generation by fuel" specifies that Vietnam produced 174.8 Terawatt-hours of electricity from fossil fuels in 2024, an amount considerably higher than the 39.6 Terawatt-hours generated from renewables in the same year (54). It is reasonable to presume a similar situation in 2025.

Correspondingly, because transportation produces large amounts of CO_2 emissions (Pham et al. 10), vehicles that transport digital components and devices to and from Vietnam incur large emissions. Henceforth, the increased manufacturing and trading of digital equipment substantially escalates GHG emissions rate and environmental ramifications like ocean acidification.

Electricity Generation in Vietnam

The Ministry of Industry and Trade of the Socialist Republic of Vietnam described that the electricity industry produced over 247.1 billion kWh in the first 9 months of 2025, increasing 5.5% compared to the same time frame in 2024 ("Báo cáo tình hình hoạt động sản xuất công nghiệp và thương mại tháng 9 năm 2025" 5). Nationwide electricity demand is immense and increasing. Specifically, table 4 states electricity

supplied to industry and construction increased 7.3%, meanwhile electricity supplied to residential management and consumption decreased 0.7% (Ministry of Industry and Trade of the Socialist Republic of Vietnam).

The percentage decrease may imply the environmental impacts of domestic and recreational electricity consumption, including music streaming, are lessening slightly. However, the larger percentage increase suggests industry and construction's associated environmental consequences are aggravating. Industry and construction encompasses the manufacture of electronics sustaining digital streaming. So, it may connote that manufacturing is causing more environmental ramifications in the digital music streaming life cycle than before, rendering decreased user consumption's positive effect insignificant.

The government commented "rooftop solar panels' power consumed directly by households partially reduces pressure on the national electricity-supply system and contributes to environmental protection" (see table 7). The percent difference between these sectors is 6.6%, casting doubt on whether this minor decrease in residential electricity usage advances sustainable digitalization - accounting for huge percentage increases in extraction and manufacturing. Avoided emissions by using solar panels are likely too small to offset GHG emissions and environmental repercussions in other life cycle stages. This data highlights the urgent need to implement effective, large-scale, and long-term solutions.

Electricity consumption and Internet access in Hanoi

Using the National Statistics Office of Vietnam's data for Hanoi in 2024 (see table 5), the percentage of households using electricity is 100.00% ("Percentage of household using electricity by province by Cities, provincies and Year.") and the percentage of households with Internet connection is 93% ("Percentage of household having internet connection by province by Cities, provincies and Year.")

The government classified this data as unofficial. If it is true, it implies Hanoi citizens are more likely to engage in digital music streaming due to easy access to online streaming platforms. It is probable this user base contributes more to streaming's embodied impacts than others elsewhere, and thus could be a target for public education initiatives.

Digital Music Streaming Preference in Vietnam

In relation to digital streaming preference in Vietnam, Nguyen et al. "conducted a 2-phase survey (1/2024 and 7/2024) with 643 digital music listeners across Vietnam" (89) and found that the most popular music streaming platforms are YouTube, TikTok and Facebook (99.6%, 99.1%, and 96% of participants in 2024 respectively; 10). Additionally from 2023 to 2024, the percentage of people using YouTube for music-listening increased by 0.1%, using TikTok decreased by 0.2%, and using Facebook remained the same (Nguyen et al. 10; see table 6).

On average, Vietnamese music listeners were consuming more electricity and energy due to the increased bandwidth brought on by video platforms. The survey has a large and varied sample, so these trends may apply to Hanoi. These trends were also supported by results showing most participants prefer consuming online music content through "trendy videos related to songs", "live performances" and "remixes/covers" (Nguyen et al. 13). Although not soundtracking, this behaviour is comparable, since listeners are departing from listening to music as the main activity. In the long-term, the proliferation of this utility facilitates high energy use and negative environmental impacts.

E-waste in Vietnam

At the final stage (disposal), Bùi and Bùi report that e-waste is "collected and processed with easily-recycled materials" and "the rest are destroyed or brought to landfills for solid waste" (see table 7). The lack of suitable recycling and disposal methods allows toxic chemicals to leak into the local environment and be released into the atmosphere, thereby polluting soils; water sources; and the air. Consequently, humans and endemic species are deprived of safe food and water resources, exposed to chemicals capable of causing dangerous illnesses, and potentially displaced from their homes due to inhabitable conditions.

Due to high demand for electronics in Vietnam, massive amounts of e-waste is produced, improperly discarded, and recycled in locations nationwide. Another issue emerges when e-waste is recycled, as "e-waste is most often collected by garbage collectors, and medium to small recycling plants" then "gathered and recycled at craft villages" according to the authors (see table 7).

Clearly, the scale of operations is limited and the process appears loosely regulated. The recycling at craft villages likely lacks advanced technology and machines, safe workwear, as well as safety protocols to prevent chemical leaks and protect workers. Furthermore, when recycling is dispersed among various villages, government supervision becomes challenging to implement which may promote illegal e-waste imports.

In table 7, I listed my translations of information in Vietnamese and compared them to the original sentences. I am not an official translator and translations are subjected to my interpretation, thus the table serves as reference:

Table 7
Translations of Vietnamese Sources' Information

My Translation	Original
"rooftop solar panels' power consumed directly by households partially reduces pressure on the national electricity-supply system and contributes to environmental protection"	"điện mặt trời mái nhà tự tiêu dùng tại chỗ phần nào giảm áp lực cho hệ thống điện quốc gia và góp phần bảo vệ môi trường." (Ministry of Industry and Trade of the Socialist Republic of Vietnam, "Báo cáo tình hình" 6)[a]
"collected and processed with easily-recycled materials" "the rest are destroyed or brought to landfills for solid waste"	"thu gom và xử lý cùng những loại vật liệu dễ tái chế, phần còn lại bị tiêu hủy hoặc đưa vào các bãi chôn lấp chất thải rắn." (Bùi and Bùi 22)[b]
"e-waste is most often collected by garbage collectors, and medium to small recycling plants" "gathered and recycled at craft villages"	"Rác thải điện tử chủ yếu được thu gom bởi người thu mua phế liệu, các cơ sở tái chế vừa và nhỏ và tập kết lại tại các làng nghề để tái chế." (Bùi and Bùi 23)[b]

Adapted from: Ministry of Industry and Trade of the Socialist Republic of Vietnam. "Báo cáo tình hình hoạt động sản xuất công nghiệp và thương mại tháng 9 năm 2025." *moit.gov.vn*, Cổng thông tin điện tử Bộ Công Thương, 27 Oct. 2025, https://moit.gov.vn/thong-ke/bao-cao-tinh-hinh-san-xuat-cong-nghiep-va-hoat-dong-thuong-mai-9-thang-dau-nam-2025.html., Bùi Huy Hải, and Bùi Thị Nhi. "Xử lý rác thải điện tử: Giải pháp nào cho Việt Nam?" *Tạp Chí Khoa Học và Công Nghệ Việt Nam*, vol. 7, 2024, pp. 22–24. *thuvienso.dut.udn.vn*, http://thuvienso.dut.udn.vn/handle/DUT/6497.

a. This sentence is from the first source listed.
b. These sentences are from the second source listed.

This literature review's methodology has restrictions. The quantity of literature considered is limited because I predominantly used open-access resources; most of which are from the 2020's. The breadth and depth of Hanoi-specific information is reduced because there lacks explicit government data and scholarship about environmental impacts throughout digital music streaming's life cycle in Hanoi.

Since I acquired most data about Vietnam and Hanoi from government resources, I did not equally examine news reports. This decreases the quantity and diversity of information. As aforementioned, I translated Vietnamese resources when official English versions are unavailable, decreasing the translations' accuracy and reliability.

POTENTIAL SOLUTIONS

Upon inspecting the increased growth of mining, manufacturing, and transmitting data in Vietnam, it seems helpful to apply Makonin et al.'s suggestion for a distinction between the concepts: Efficiency, sufficiency, self-sufficiency (sec. 3). By distinguishing these concepts, Hanoi and Vietnam can classify industries and processes that need to be improved upon - upgraded to sufficiency at minimum and ideally to self-sufficiency. Hilty defines these concepts as follows:

Efficiency is a property of "any process that converts inputs into useful outputs", dictated by the ratio "useful output per input" (Hilty sec. 1). Digital streaming's output is the music being played inclusive of all formats like audio-only and video streaming. Its inputs are the mining of natural resources, manufacturing of digital devices, transmission of data from data centres to end-user devices, user desire… Essentially, all processes and storage existing in the digital streaming life cycle, encapsulated as embodied impacts.

Next, Hilty states that sufficiency is seen in a system which maintains its input consumption within specific limits, and only improves outputs by optimizing internal operations. He mentioned mobile computing devices as an example of sufficiency in terms of electricity consumed (sec. 1).

Finally, self-sufficiency is when a system fully eliminates its inputs. In cases where systems remove consumption of some inputs, then they are self-sufficient regarding those inputs; the author described a "pocket calculator powered by a photovoltaic cell" as self-sufficient in terms of electricity (Hilty sec. 1).

Currently, the ICT sector is "designing more efficient systems" to fulfill users' demand, yet their "absolute energy footprint nevertheless is on the rise" (Makonin et al. sec. 3). Henceforth, transitioning to sufficiency and especially self-sufficiency is more environmentally-friendly. Vietnam has different options:

Table 8
Potential solutions for Hanoi and Vietnam

Solution	Strengths	Weaknesses
Renewable Energy	1. Hugely reduce GHG emissions and prevent future emissions in electricity generation 2. Stops environmental pollution generated from fossil fuel extraction, refinement, and utilization (Al Mubarak et al. 1245) 3. Curbs economic dependence on fossil fuels	1. Expensive and challenging to implement, build, and maintain infrastructure 2. Effectiveness depends on local environmental conditions 3. May lead to deforestation if limited land is available
Leasing ICT infrastructure's throughput to businesses[a]	1. Direct control over ICT infrastructure's energy consumption 2. Prevents market competition - a major driver of streaming's wastefulness (Makonin et al. sec. 7) 3. Identifies companies consuming the most energy	1. Challenging and expensive to implement on a large scale 2. Security breaches expose massive amounts of user data 3. Technologies manufactured to maintain ICT infrastructure produce environmental impacts

Change in public attitude	1. Can reduce streaming consumption, addressing user demand 2. Public pressure on companies to reduce environmental impacts 3. Educated work force (i.e., number of scientists and engineers) can grow	1. Local to national change takes a long time 2. Some citizens may not respond and take action 3. Difficult to measure and evaluate effectiveness
Establishing a periodic e-waste collecting system[b]	1. Greatly decreases the amount of e-waste improperly recycled and disposed 2. Limits the amount of e-waste illegally imported into Vietnam 3. Encourages good public e-waste sorting and disposing habits	1. Challenging and expensive to implement on a large scale 2. Ineffective without sustainable, effective recycling technologies and infrastructure 3. Transport produces carbon dioxide emission

Adapted from: Makonin, Stephen, et al. "Calculating the carbon footprint of streaming media: Beyond the myth of efficiency." *Eighth workshop on computing within limits 2022*. LIMITS, 2022., Bùi Huy Hải, and Bùi Thị Nhi. "Xử lý rác thải điện tử: Giải pháp nào cho Việt Nam?" *Tạp Chí Khoa Học và Công Nghệ Việt Nam*, vol. 7, 2024, pp. 22–24. *thuvienso.dut.udn.vn*, http://thuvienso.dut.udn.vn/handle/DUT/6497.

a. (Makonin et al. sec. 7)

b. (Bùi and Bùi 24)

Leasing ICT infrastructure's throughput to the private sector and change in public attitude promote a sufficient data transmission system. Leasing can restrict consumption, decreasing correlated environmental consequences, but as seen in table 8 it poses multiple problems that may outweigh its potential benefits. It might be helpful to experiment with this solution, but it is unlikely to be suitable and effective for Vietnam and Hanoi.

Similarly, convincing the public to decrease and modify streaming consumption (which impedes their convenience) does not prohibit wasteful use. While it can lessen data transmission and processing, there is no guarantee GHG emissions will reduce fast enough to prevent severe environmental impacts. It is necessary to implement this alongside solutions progressing self-sufficiency.

The periodic e-waste collecting system bolsters sufficiency and self-sufficiency. It raises awareness about digital streaming's environmental consequences and ensures proper recycling of e-waste on a wide scale, addressing digital device disposal issues like pollution and negative health impacts. Yet, transport occurring within the system can release CO_2 emissions. To attain self-sufficiency, the government needs to implement and develop the system long-term. Ideally, the e-waste collection system helps sustain a digital music streaming circular economy - eliminating demand for raw resources by replacing them with recycled materials. Realistically for Hanoi and Vietnam, it is unlikely this system will yield good results in the short-term due to complications like logistics and funding. Regardless, it is a suitable long-term investment and can cap GHG emissions if utilised successfully.

It should go hand-in-hand with renewable energy usage to minimize climatic effects. Currently, renewable energy meets some of our energy demands, but it can replace fossil fuels (a monumental source of GHG emissions and pollution). Vitally, renewable energy will massively reduce all life cycle stages' embodied impacts if it replaces fossil fuel in electricity generation. Moreover, it diversifies energy sources, diminishing energy scarcity risks caused by climatic events like natural disasters. Increasing renewable energy usage remains a primary goal for Vietnam and Hanoi.

Overall, some solutions are more suitable and feasible than others. However, everything needs long-term investment to be effective. Nonetheless, these solutions may not decrease GHG emissions fast enough to prevent extreme repercussions.

DISCUSSION

This literature review explored how digital music streaming's energy infrastructure and life cycle processes like mining for metals, minerals, fossil fuels, manufacturing electronics, and generating electricity in Vietnam has increased. Resource extraction and manufacturing sectors experienced the greatest growth, and electricity demand is increasing in the industry and construction sector.

Considering 93% of households in Hanoi have Internet access in 2024 and this is likely to increase for 2025, it is probable more Hanoi citizens are using the Internet extensively for various activities, including digital music streaming. This means the increases seen above may be caused by digital streaming more so than in the past. Furthermore, music listeners nationwide prefer streaming music through video and social media platforms like Youtube and Tiktok, and the types of content preferred combine visual and audio. This preference may apply to Hanoi.

Akin to extraction and manufacturing, recycling e-waste in Vietnam gives rise to diverse issues like soil, air, and water pollution. If the lack of regulations and robust supervision persists, e-waste disposal's serious environmental effects will likely expand in scale and grow in severity. These findings implicate a disturbing trend of rising energy usage and extreme ecosystem decline, reinforced by digital music streaming among other activities.

Overall, the amount of context-specific data and literature was limited. Some information about life cycle processes were available for Vietnam only - including primary drivers of environmental impacts like mining, manufacturing, and e-waste disposal. There is inconclusive evidence to fully examine the scale, changes to, and effects of digital music streaming's energy infrastructure and life cycle processes in Hanoi. The usage of unofficial government data for electricity consumption and Internet access in Hanoi is a direct consequence, exposing a gap in research that needs to be addressed.

CONCLUSION

This literature review summarizes the energy infrastructure and life cycle processes behind digital music streaming and changes to these systems in Hanoi and Vietnam. I identified environmental impacts such as GHG emissions and ecosystem pollution, and distinguished the mining, manufacturing, and disposal sectors as major energy consumers and contributors to global environmental repercussions. The large user base contributes by increasing data transmission and processing' energy consumption.

I did not calculate quantitative energy shares, so it is impossible to determine the most energy-intensive sector and stakeholders, in addition to the quantity of emissions and consumption induced by digital music streaming. Nevertheless, all stakeholders need to be held responsible and the government needs to prioritize solving this issue. There is an urgent need for industries and the government to invest in and develop technologies and systems to reduce GHG emissions and environmental impacts, as well as work towards a circular economy.

To achieve this economy, the government needs to enforce strict regulations on the aforementioned industrial processes and energy infrastructure on a national scale. Trial-and-error implementation of solutions may be necessary to establish which solutions are most applicable to specific issues and regions. Consumer-wise, the public needs to actively learn about streaming's environmental consequences and reduce consumption.

Although digital music streaming benefits populations and economies, it produces numerous severe environmental issues. Decisively, the e-waste created and resources used need to be better managed.

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REFERENCES

Afzal, Samira, et al. "A Survey on Energy Consumption and Environmental Impact of Video Streaming." arXiv:2401.09854, arXiv, 18 Jan. 2024. *arXiv.org*, https://doi.org/10.48550/arXiv.2401.09854.

Al Mubarak, Faisal, et al. "Economic, Societal, and Environmental Impacts of Available Energy Sources: A Review." *Eng*, vol. 5, no. 3, Sept. 2024, pp. 1232–65. *www.mdpi.com*, https://doi.org/10.3390/eng5030067.

Baldé, Cornelis P., et al. "The Global E-Waste Monitor 2024." *E-Waste Monitor*, 20 Mar. 2024, https://ewastemonitor.info/the-global-e-waste-monitor-2024/.

Beuscart, Jean-Samuel, et al. "Listening to Music Videos on YouTube. Digital Consumption Practices and the Environmental Impact of Streaming." *Journal of Consumer Culture*, vol. 23, no. 3, Aug. 2023, pp. 654–71. *SAGE Journals*, https://doi.org/10.1177/14695405221133266.

BIOFIN. "Viet Nam." *BIOFIN*, https://www.biofin.org/viet-nam. Accessed 22 Dec. 2025.

Bùi Huy Hải, and Bùi Thị Nhi. "Xử lý rác thải điện tử: Giải pháp nào cho Việt Nam?" *Tạp Chí Khoa Học và Công Nghệ Việt Nam*, vol. 7, 2024, pp. 22–24. *thuvienso.dut.udn.vn*, http://thuvienso.dut.udn.vn/handle/DUT/6497.

Duporte, Alexandre, et al. "Environmental impacts of digitalisation: what to bear in mind." *Policy Unit, European Association for Innovation in Local Development* (2022).

Eerola, Toni, et al. "Digitalization and Natural Resources." *Geological Survey of Finland*, Open File Research Report 50/2021, 2021.

Energy Institute. "Statistical Review of World Energy 2025." *Energy Institute*, 74th ed., 2025.

Gilfillan, Dennis, and Gregg Marland. "CDIAC-FF: Global and National CO_2 Emissions from Fossil Fuel Combustion and Cement Manufacture: 1751–2017." *Earth System Science Data*, vol. 13, no. 4, Apr. 2021, pp. 1667–80. *Copernicus Online Journals*, https://doi.org/10.5194/essd-13-1667-2021.

Hesmondhalgh, David. "The Global Spread of Music Streaming: Capitalism and Colonialism, Technology and Culture." *Music Streaming around the World*. Edited by David Hesmondhalgh, University of California Press, 2025, pp. 1–31. *luminosoa.org*, https://doi.org/10.1525/luminos.248.

Hilty, Lorenz M. "Computing Efficiency, Sufficiency, and Self-Sufficiency: A Model for Sustainability?" 2015.

IFPI. "GLOBAL MUSIC REPORT 2025." 2025, p. 7.

Istrate, Robert, et al. "The Environmental Sustainability of Digital Content Consumption." *Nature Communications*, vol. 15, no. 1, May 2024, p. 3724. *www.nature.com*, https://doi.org/10.1038/s41467-024-47621-w.

Jones, Nicola. "How to stop data centres from gobbling up the world's electricity." *Nature*, vol. 561, September 2018, pp. 164. *www.nature.com*, https://doi.org/10.1038/d41586-018-06610-y.

Martin, Jonas, et al. "Modeling Cost-Optimal Fuel Choices for Truck, Ship, and Airplane Fleets: The Impact of Sustainability Commitments." *Energy*, vol. 308, Nov. 2024, p. 132882. *ScienceDirect*, https://doi.org/10.1016/j.energy.2024.132882.

Ministry of Industry and Trade of the Socialist Republic of Vietnam. "Báo cáo tình hình hoạt động sản xuất công nghiệp và thương mại tháng 9 năm 2025." *moit.gov.vn*, Cổng thông tin điện tử Bộ Công

Thương, 27 Oct. 2025, https://moit.gov.vn/thong-ke/bao-cao-tinh-hinh-san-xuat-cong-nghiep-va-hoat-dong-thuong-mai-9-thang-dau-nam-2025.html.

———. "Phụ lục Báo cáo tình hình sản xuất công nghiệp và hoạt động thương mại tháng 9 năm 2025." *moit.gov.vn*, Cổng thông tin điện tử Bộ Công Thương, 27 Oct. 2025, https://moit.gov.vn/thong-ke/phu-luc-bao-cao-tinh-hinh-san-xuat-cong-nghiep-va-hoat-dong-thuong-mai-thang-9-nam-2025.html.

Makonin, Stephen, et al. "Calculating the carbon footprint of streaming media: Beyond the myth of efficiency." *Eighth workshop on computing within limits 2022*. LIMITS, 2022.

National Statistics Office of Vietnam. "Percentage of household using electricity by province by Cities, provincies and Year." *National Statistics Office of Vietnam*, https://www.nso.gov.vn/en/px-web/?pxid=E1458&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard. Accessed 22 Dec. 2025.

———. "Percentage of household having internet connection by province by Cities, provincies and Year." *National Statistics Office of Vietnam*, https://www.nso.gov.vn/en/px-web/?pxid=E1467&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard. Accessed 22 Dec. 2025.

———. *Thông cáo báo chí Kết quả Điều tra dân số và nhà ở giữa kỳ năm 2024*. https://www.nso.gov.vn/du-lieu-va-so-lieu-thong-ke/2025/01/thong-cao-bao-chi-ket-qua-dieu-tra-dan-so-va-nha-o-giua-ky-nam-2024/. Accessed 22 Dec. 2025.

———. *Xuất, nhập khẩu điện tử, máy tính và linh kiện - Động lực tăng trưởng xuất khẩu của Việt Nam giai đoạn 2016-2025*. 10 Oct. 2025, https://www.nso.gov.vn/du-lieu-va-so-lieu-thong-ke/2025/10/xuat-nhap-khau-dien-tu-may-tinh-va-linh-kien-dong-luc-tang-truong-xuat-khau-cua-viet-nam-giai-doan-2016-2025/.

Nguyen, Long, et al. "Vietnam Digital Music Landscape 2024-2025: Professionalization, Co-Creation, and Explosion." SSRN Scholarly Paper no. 5331358, Social Science Research Network, 12 Dec. 2024. *papers.ssrn.com*, https://doi.org/10.2139/ssrn.5331358.

Pham, Hong Chuong, et al. "Time-varying interlinkages between digitalization, globalization, and carbon emission in Vietnam." *Humanities and Social Sciences Communications*, vol. 12, 2 Feb. 2025, p. 124. *www.nature.com*, https://www.nature.com/articles/s41599-025-04362-5.

Ruiz, D., et al. "Life Cycle Inventory and Carbon Footprint Assessment of Wireless ICT Networks for Six Demographic Areas." *Resources, Conservation and Recycling*, vol. 176, Jan. 2022, p. 105951. *ScienceDirect*, https://doi.org/10.1016/j.resconrec.2021.105951.

Théberge, Paul. *The Cambridge Companion to Pop and Rock*. Edited by Simon Frith et al., Cambridge University Press, 2001. Cambridge Companions to Music. *Google Books*.

Tran-Anh, Quan, et al. "A 10-Km CMIP6 Downscaled Dataset of Temperature and Precipitation for Historical and Future Vietnam Climate." *Scientific Data*, vol. 10, no. 1, May 2023, p. 257. *www.nature.com*, https://doi.org/10.1038/s41597-023-02159-2.

Turkkan, Bekir Oguzhan, et al. "GreenABR: Energy-Aware Adaptive Bitrate Streaming with Deep Reinforcement Learning." *Proceedings of the 13th ACM Multimedia Systems Conference* [New York,

NY, USA], MMSys '22, 2022, pp. 150–63. *ACM Digital Library*, https://doi.org/10.1145/3524273.3528188.

UNCTAD. *International Trade in ICT Services, Value, Shares and Growth, Annual*. https://unctadstat.unctad.org/datacentre/dataviewer/US.TradeServICT. Accessed 19 Dec. 2025.

———. *Share of ICT Goods as Percentage of Total Trade, Annual*. https://unctadstat.unctad.org/datacentre/dataviewer/US.IctGoodsShare. Accessed 19 Dec. 2025.

Wagner, Thomas M, and Thomas Hess. *"It's Not The Same" - Differences In The Consumption Of Digital And Physical Music*. July 2013.

Webster, Jack. *Taste in the Digital Age: Music Streaming Services and the Performance of Class Distinction*. With Jack Webster et al., 2019. University of Southampton, phd. *eprints.soton.ac.uk*, https://eprints.soton.ac.uk/433131/.

World Bank Group. "Population, Total - Viet Nam." *World Bank Open Data*, https://data.worldbank.org/indicator/SP.POP.TOTL?end=2024&locations=VN&start=1960&view=chart. Accessed 22 Dec. 2025.

Guo, Xiaorui. "The Evolution of the Music Industry in the Digital Age: From Records to Streaming." *Journal of Sociology and Ethnology*, vol. 5, no. 10, 2023. *DOI.org (Crossref)*, https://doi.org/10.23977/jsoce.2023.051002.

Yue, Chaoqun, et al. "Energy Considerations for ABR Video Streaming to Smartphones: Measurements, Models and Insights." *Proceedings of the 11th ACM Multimedia Systems Conference* [New York, NY, USA], MMSys '20, 2020, pp. 153–65. *ACM Digital Library*, https://doi.org/10.1145/3339825.3391867.