DATA CONSUMPTION AND CO_2 EMISSION BY ACTIVITY TYPES ON USER-GENERATED CONTENT PLATFORMS

Hülya Aykaç Özen*, Aleyna Güven

Environmental Engineering Department, University of Ondokuz Mayıs, Samsun, Türkiye

Abstract

This study aims to determine the number of social media platforms and users actively used in Turkey and to calculate the digital carbon footprint resulting from social media use. It has been determined that the platforms actively used in the last five years are WhatsApp, Instagram, Facebook and YouTube, and the time spent in a day for each year is ranked as YouTube, Instagram, WhatsApp and Facebook respectively. In the next stage, the carbon footprint values for the year 2024 were calculated if Wi-if is used as the network type. The carbon footprint in 2024 was found to be 0.0193, 0.0462, 0.0044 and 0.0041 kgCO_2e/day for Instagram, YouTube, Facebook and WhatsApp.

Keywords: *social media, carbon footprint, WhatsApp, Instagram, Facebook, YouTube*

1. INTRODUCTION

Over the past two decades, the rapid acceleration of digitalization has rendered social media platforms an inseparable part of individuals' daily lives. Social media has not only transformed interpersonal communication but has also reshaped how people access news, engage in marketing, form public opinion, participate in e-commerce, and consume digital entertainment. This transformation, accompanied by substantial shifts in user behavior, has led to massive volumes of data production and consumption (Kietzmann et al., 2011; Statista, 2024, Malmodin and Lundén, 2018). The ever-increasing data demand of digital services has consequently driven a sharp rise in energy consumption within the Information and Communication Technologies (ICT) sector. According to Ericsson's 2030 projections, more than 80% of global internet traffic will be attributable to video content, significantly intensifying the energy requirements of data centers and network infrastructure (Andrae & Edler, 2015). High-resolution (HD/4K) video streaming, live broadcasts, and image-based social media platforms—such as YouTube and Instagram—are particularly associated with increased energy consumption per user (Freitag et al., 2021; Batmunkh, 2023). The carbon footprint refers to the total greenhouse gas (GHG) emissions caused directly or indirectly by a particular activity, expressed in terms of carbon dioxide equivalent (CO_2e). The digital carbon footprint specifically denotes the carbon emissions resulting from the energy consumed by individuals or digital platforms (Oo et al., 2023). Previous research has shown that the carbon footprint of digital services is not limited to data centers alone but also includes device production, network transmission, and end-user behavior, all of which play significant roles in overall environmental impact (Malmodin et al., 2014). Among end-user variables, the type of internet connection—mobile data or Wi-Fi—has a direct impact on energy intensity. Although Wi-Fi technology is generally more energy-efficient per unit of data compared to mobile networks, its relative advantage may diminish under conditions of intensive social media use (Hintemann & Hinterholzer, 2019). Moreover, content type preferences (e.g., video, image, text) and screen time are critical factors influencing carbon emissions. In the case of Türkiye, social media usage rates remain above the global average. As of 2024, approximately 80% of the population actively engages with social media platforms, and the average weekly usage exceeds 21 hours per person (We Are Social & Meltwater, 2024). Despite this high level of digital penetration, academic studies focusing on the environmental impacts of social media use remain notably scarce. In particular, the contribution of Wi-Fi-based social media interactions via mobile devices to total carbon emissions has yet to be sufficiently explored by policymakers or academia. In this context, the present study aims to quantitatively assess the carbon emissions associated with the use of four major social media platforms (WhatsApp, Instagram, Facebook, and YouTube) through Wi-Fi-connected mobile devices in Türkiye between 2020 and 2024. The calculations are based on variables including the number of users, average daily usage time, platform-specific data

consumption rates, dominant content types, and literature-based emission factors, and are presented in a comparative manner across years. The findings reveal both the temporal dynamics of digital carbon emissions and the inter-platform differences, offering a data-driven foundation for digital sustainability policies. Accordingly, this study contributes to academic research in the emerging field of digital ecology and seeks to raise awareness among individual users regarding their digital carbon footprint. Ultimately, the results provide practical insights and a methodological framework for future, more comprehensive studies aimed at mitigating the environmental impact of digital behavior.

2. MATERIALS AND METHODS

2.1. Research Design and Data Sources

This study is a quantitative, descriptive, and scenario-based research that aims to analyze the total carbon footprint of the four most widely used social media platforms in Turkey—WhatsApp, Instagram, Facebook, and YouTube—between the years 2020 and 2024. The study takes into account the annual number of users and the average monthly usage durations for each platform. Based on the content type specific to each platform and the energy intensity of the connection infrastructure, annual total carbon emissions were calculated. The dataset of the study was compiled using the "We Are Social & Meltwater Digital Turkey Reports" (2020–2024). From these reports, the number of active users in Turkey and the average monthly usage durations (hours:minutes) for each platform were obtained. The usage times were converted into minutes, and annual total usage durations were calculated to serve as the basis for the emission calculations.

Based on the dominant content structures and user behavior patterns of each platform, three main categories of digital activity have been identified:

- Video viewing / streaming
- Image sharing and viewing
- Text-based messaging and scrolling

The table below presents the approximate distribution of these activity types by platform, as derived from literature and functional platform characteristics:

Platform	Activity Types and Usage Distribution (%)
WhatsApp	Text (60%), Image (30%), Video (10%)
Instagram	Image (40%), Video/Story (30%), Scrolling/Text (30%)
Facebook	Image/Text (50%), Video (40%), Scroll/Interaction (10%)
YouTube	SD Video (20%), HD Video (70%), 4K Video (10%)

Table 1. Distribution of Usage by Content Type Across Social Media Platforms (%)

2.2. Calculation Method

2.2.1 Emission factors: Wi-Fi vs. 4G distinction

The type of network connection used for social media access directly affects energy consumption and, consequently, the carbon footprint. Therefore, the calculations in this study were conducted based on two distinct scenarios:

- Scenario 1 (Wi-Fi): Assumes that all users exclusively use Wi-Fi networks.
- Scenario 2 (4G): Assumes that all users exclusively use 4G mobile data connections.

The per-minute carbon emission factors for each content type, specific to Wi-Fi and 4G connections, were determined based on life cycle assessment (LCA) data from previous studies (Freitag et al., 2021).

Activity Type	**gCO₂e/min (Wi-Fi)**	**gCO₂e/min (4G)**
Text message / scrolling	0.20	0.30
Visual content	0.60	0.90
Video (general)	1.40	2.10
YouTube SD	1.60	2.60
YouTube HD	2.70	4.00
YouTube 4K	4.50	6.00

Table 2. Activity-Specific Carbon Emission Factors for Wi-Fi and 4G Connections (gCO₂e/min)

2.2.2. Annual total CO_2e emissions

The total usage time per year for each platform was calculated using the following formula:

Annual Usage Time (min/year) = Monthly Usage Duration×60×12

Total Platform Usage (min)=Number of Users×Annual Usage Time (min/year)

To calculate the emission intensity per minute, the activity distribution specific to each platform (e.g., video streaming, image sharing, text messaging) was combined with the emission factors (gCO₂e/min) corresponding to each activity type and network type (Wi-Fi and 4G). The following weighted average formula was applied

$$\text{Average Emission (Wi-Fi)} = \sum_i \left(\text{Activity Share}_i \times \text{gCO}_2\text{e/min}_{\text{Wi-Fi},i} \right)$$

$$\text{Average Emission (4G)} = \sum_i \left(\text{Activity Share}_i \times \text{gCO}_2\text{e/min}_{\text{4G},i} \right)$$

After determining the total usage and average emission factors, the total carbon footprint was calculated as follows:

$$\text{Total CO}_2\text{e Emissions (tons)} = \frac{\text{Total Usage (min)} \times \text{Average gCO}_2\text{e/min}}{1,000,000}$$

Calculations were performed separately for both Wi-Fi and 4G scenarios, allowing for a comparative analysis of how different digital infrastructures affect carbon emissions.

3. RESULT

The carbon emission trends associated with social media usage in Turkey between 2020 and 2024 are presented and analyzed. The results are based on annual active user data, average monthly usage durations, and platform-specific emission factors, considering both Wi-Fi and 4G scenarios. Fig. 1. presented Active Users on Social Media Platforms in Türkiye between 2020–2024 years. This graph, illustrating the change in the number of active users in Turkey between 2020 and 2024, sheds light on user trends for four major social media platforms. The data reveals a similar user trajectory for WhatsApp and Instagram. Both platforms peaked in 2021 with approximately 64 million users, but experienced a significant decline in the following years. In 2023 and 2024, this decline stabilized, settling at around 53–54 million users. This trend may suggest that these platforms have reached a saturation point in Turkey or that users have shifted to alternative applications.

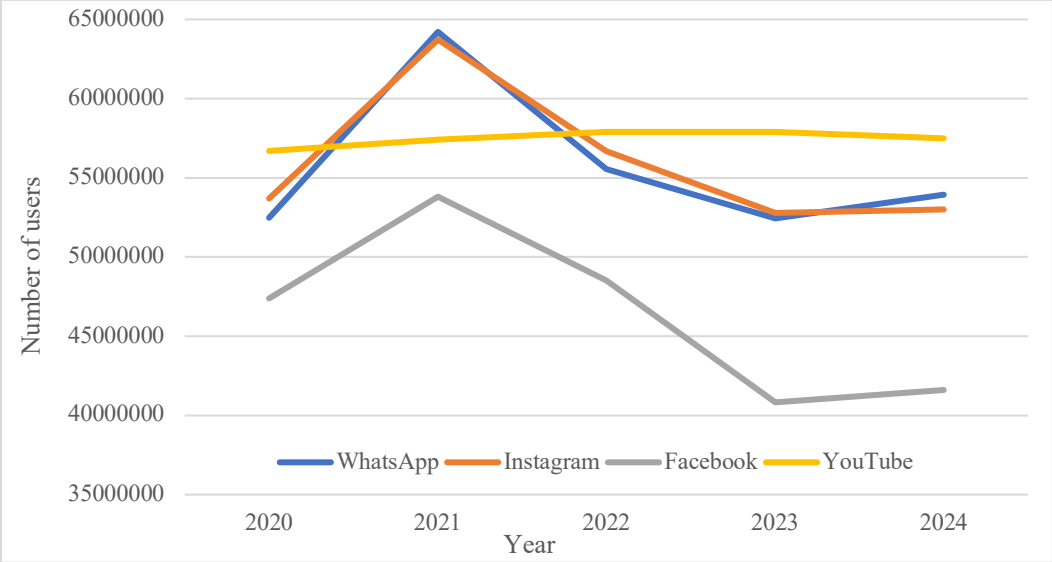

Fig. 1. Trend of Active Users on Social Media Platforms in Türkiye (2020–2024

Source: We Are Social & Meltwater (2020–2024).

Facebook, on the other hand, experienced a steady decline in user numbers throughout the five-year period under review. While the platform had around 53.8 million users in 2021, this number fell below 41 million by 2023. Although a slight recovery was observed in 2024, Facebook remained the platform with the lowest number of users. This decline aligns with global trends, particularly among younger users, who are increasingly favoring more interactive and visually-driven platforms over text- and image-based ones. YouTube stood out as the most stable platform in terms of user base during the entire period. Starting with 56.7 million users in 2020, the number rose to 58 million by 2023 and, despite a slight drop in 2024, remained relatively stable overall. This suggests a sustained demand for video content and reflects YouTube's capacity to appeal to a diverse demographic audience. From a broader perspective, changes in user numbers have a significant impact on the carbon footprint of social media platforms, as increases or decreases in user base directly affect total content consumption and, consequently, digital emissions. Fig. 2 displayed the average monthly usage durations of social media platforms in Turkey between 2020 and 2024, reveals how the time users spent on digital platforms has evolved over the years. It highlights significant differences among the four platforms and suggests that digital content consumption dynamics have developed in a platform-specific manner. Instagram stands out as the leading platform in terms of usage duration throughout the period. The average monthly usage rose from approximately 1,180 minutes (around 20 hours) in 2020 to 1,960 minutes (around 32 hours) in 2023, maintaining that level in 2024. This increase may be attributed to Instagram's emphasis on highly engaging content formats such as videos, stories, and reels. YouTube also showed a similarly

striking rise. Its usage duration remained stable (around 1,100 minutes/month) until 2022 but then surged to 1,860 minutes (about 31 hours) in 2023, before dropping to 1,480 minutes in 2024. This spike may be linked to increased consumption of digital entertainment and informational content in the post-pandemic period, while the subsequent decline may reflect a restructuring of users' screen time habits. In contrast, WhatsApp showed a consistent downward trend in usage duration each year. From about 900 minutes/month in 2020, the average dropped to 588 minutes/month by 2024. This may suggest a decline in reliance on text-based messaging apps or a shift toward alternative communication platforms. Facebook, meanwhile, experienced a decline until 2022 but showed modest recovery in 2023 and 2024.

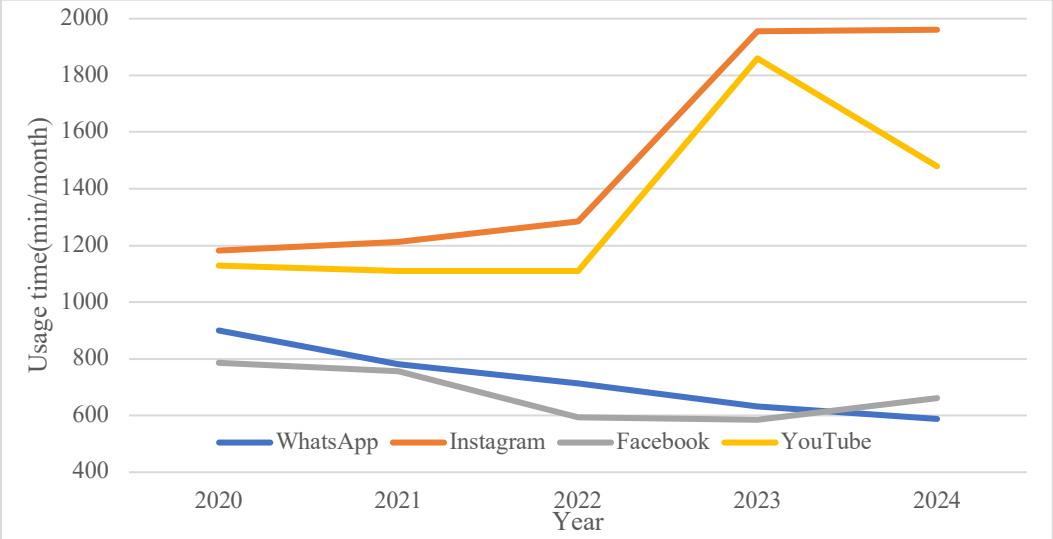

Fig. 2. Changes in the average monthly usage duration of social media platforms in Turkey between 2020 and 2024.

Source: We Are Social & Meltwater (2020–2024).

This trend might reflect sustained loyalty among middle-aged and older user groups. Nonetheless, Facebook remained the platform with the second-lowest monthly usage duration over the observed period. These findings emphasize that differences in user engagement across digital platforms play a critical role in their environmental impact. In carbon footprint calculations, screen time is as decisive a factor as the number of users. Notably, the increase in usage duration on video-intensive platforms such as YouTube and Instagram have a direct effect on energy consumption and emission levels. Fig.3. illustrates the annual carbon footprint ($kgCO_2e$/year) of four major social media platforms—Instagram, WhatsApp, Facebook, and YouTube—between 2020 and 2024, categorized by connection type (Wi-Fi vs. 4G).

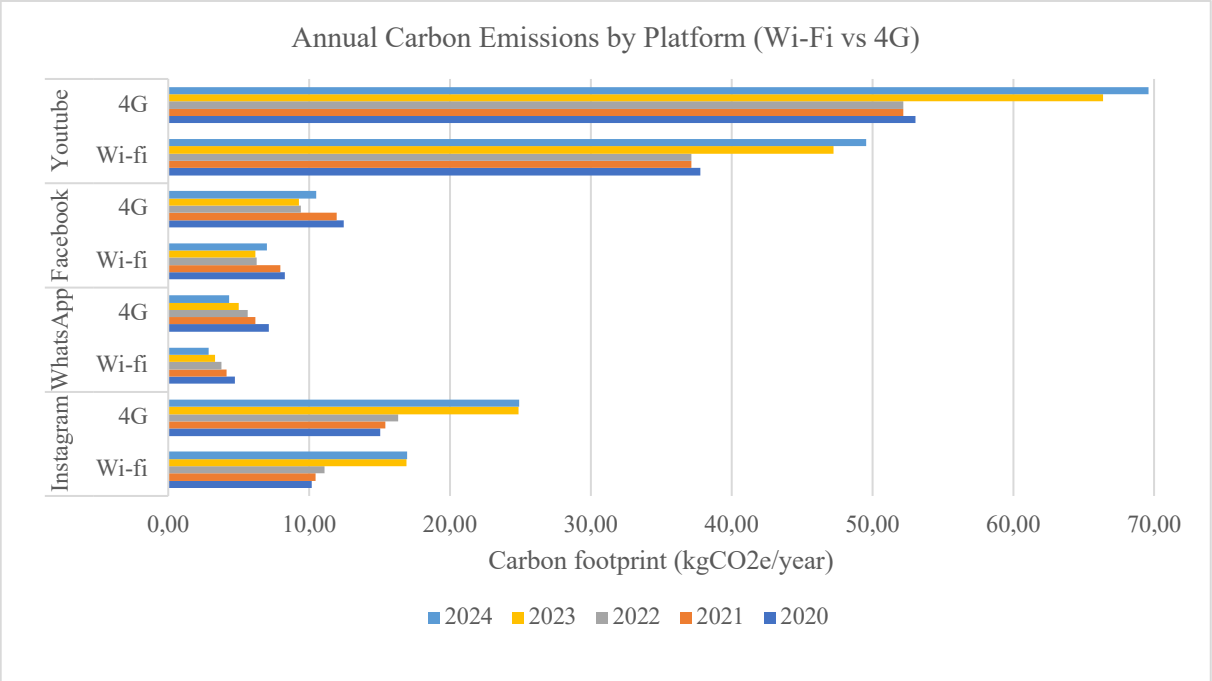

Fig. 3. Annual Carbon Footprint Distribution ($kgCO_2e$/year) of Four Social Media Platforms by Wi-Fi and 4G Connection Types (2020–2024).

Across all platforms and years, 4G usage consistently results in higher carbon emissions compared to Wi-Fi, primarily due to its greater energy intensity per unit of data transferred. YouTube stands out as the platform with the highest carbon footprint throughout the five-year period. In 2024, its 4G-related emissions approached 70 $kgCO_2e$/year, driven by heavy streaming of high-definition and 4K video content. Wi-Fi usage also contributed significantly but remained lower than 4G in every instance. Instagram showed a notable increase in its carbon emissions, particularly in 2023 and 2024. This rise correlates with the platform's increasing reliance on video-based content such as stories, reels, and live broadcasts. In 2024, Instagram's carbon footprint under 4G use neared 25 $kgCO_2e$/year, more than double its 2020 level. Facebook displayed a relatively modest and fluctuating trend. While emissions decreased slightly from 2020 to 2022, a rebound was observed in 2024, likely due to a shift back toward video and multimedia content. WhatsApp remained the lowest-emitting platform due to its primarily text-based usage. Even so, 4G use consistently resulted in a 40–50% higher footprint than Wi-Fi, indicating that even lightweight applications contribute noticeably more when used on mobile data networks. Overall, the chart highlights the environmental impact of mobile connectivity, emphasizing that 4G generates substantially more emissions than Wi-Fi across all platforms. These findings underscore the importance of digital behavior and infrastructure choices in mitigating the carbon footprint of social media consumption. Fig.4 illustrates the comparative evolution of the total annual carbon footprint of WhatsApp, Instagram, Facebook, and YouTube from 2020 to 2024, based on connection types (Wi-Fi vs. 4G). The data were obtained by aggregating the total carbon emissions of all four platforms for each year and emphasize the critical role of network infrastructure in determining the environmental impact of digital consumption.

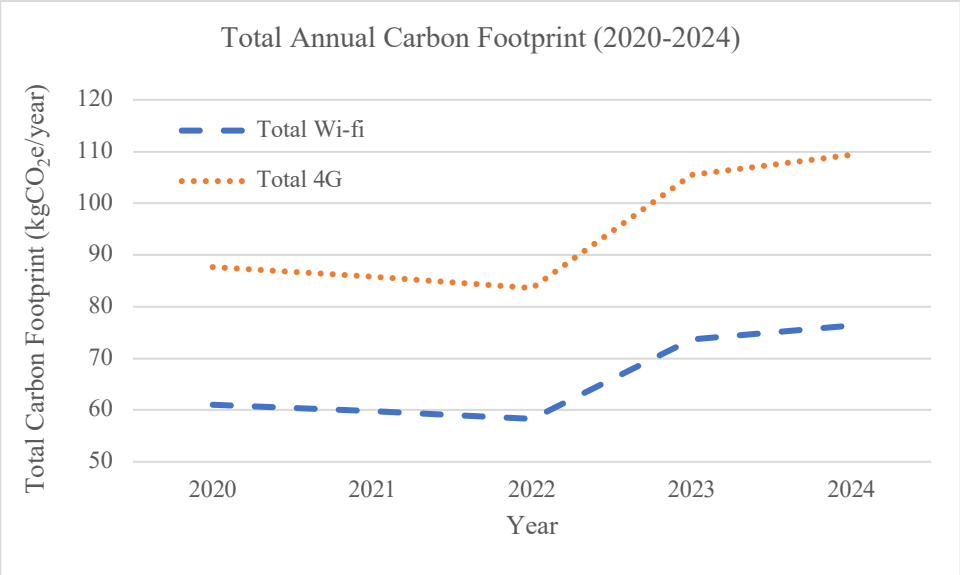

Fig. 4. Total annual carbon footprint by connection type across four platforms (2020–2024).

The carbon footprint resulting from Wi-Fi usage remained relatively stable during the first three years of the study period (2020–2022), fluctuating around 58–61 $kgCO_2e$/year. However, starting in 2023, a noticeable upward trend emerged, likely due to the increasing consumption of video-based content. By 2024, total Wi-Fi-related emissions had reached approximately 76 $kgCO_2e$/year. This rise appears to be driven particularly by the intensification of video content on Instagram and YouTube. In contrast, the total carbon footprint associated with 4G connections remained consistently higher than that of Wi-Fi throughout the study period. From 2020 to 2022, it followed a relatively flat trajectory (approximately 85–87 $kgCO_2e$/year), but in 2023, it showed a sharp increase, reaching around 105 $kgCO_2e$/year, and further rising to nearly 110 $kgCO_2e$/year in 2024. This trend reflects the higher energy intensity per unit of data transmission via mobile networks and indicates the limited energy efficiency of 4G infrastructure. Overall, although Wi-Fi infrastructure has a lower carbon intensity, the widespread use of digital content—especially video—gradually erodes this advantage. Meanwhile, 4G-based connections consistently generate higher emissions due to their greater energy demand. These findings underscore the importance of considering network type in strategies aimed at reducing the digital carbon footprint and highlight the environmental consequences of content policies (particularly the promotion of video) adopted by digital platforms. Fig. 5 presents pie charts showing the proportional distribution of total usage (calculated by multiplying the number of users by average monthly usage time) for Instagram, WhatsApp, Facebook, and YouTube from 2020 to 2024. Each chart reflects the year-by-year contribution to the total platform-specific usage within the five-year period. For Instagram, the highest usage is observed in 2023 (35%), followed by 2024 (19%). This upward trend suggests a significant increase in user engagement and screen time, particularly in the last two years of the study period.

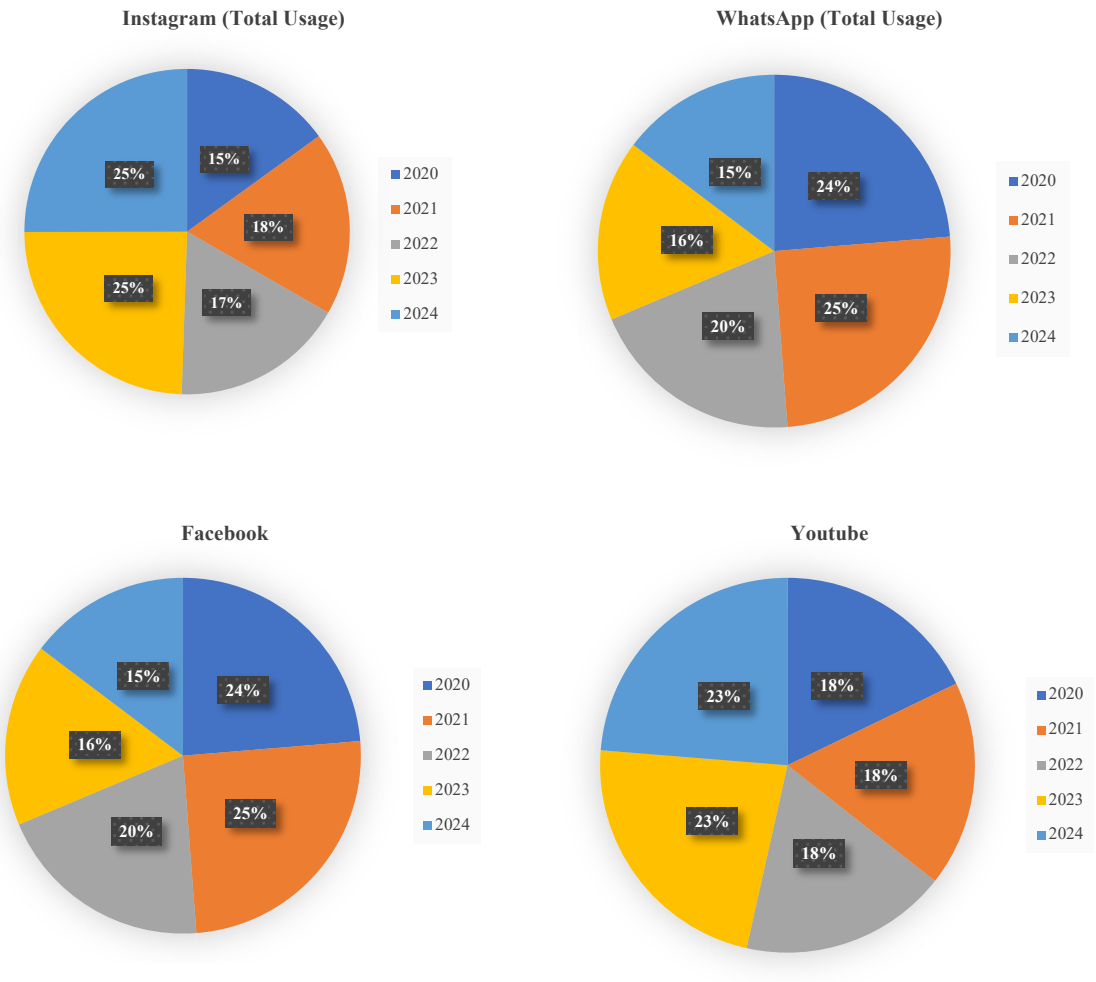

Fig. 5. Proportional annual distribution of total users and usage duration across four major platforms (2020–2024).

WhatsApp usage peaked in 2023 with 29%, followed by 2020 with 24%. This highlights the platform's increased reliance during the pandemic and post-pandemic periods. However, a slight decline is noted in 2024, indicating a possible saturation or shift in communication habits. Facebook demonstrates a clear decline over the years. In 2020, the platform accounted for 30% of its five-year total usage, but this gradually fell to 15% by 2024. This may reflect a decreasing user base or lower engagement among existing users in Türkiye. YouTube shows a relatively balanced distribution across the years, indicating a stable and consistent user base. The highest proportional usage occurred in 2023 (23%), while 2021 and 2022 both contributed 18%. This stability suggests continued preference for video content consumption over time.

4. DISCUSSION

This study quantitatively assessed the carbon footprint generated by four major social media platforms—Instagram, WhatsApp, Facebook, and YouTube—based on user count, usage time, content type, and connection method (Wi-Fi vs. 4G) in Türkiye between 2020 and 2024. The findings reveal several critical insights into the digital behaviors of users and their corresponding environmental impacts. First, a consistent pattern was observed across all platforms in which 4G connectivity produced significantly higher carbon emissions compared to Wi-Fi. This aligns with prior literature stating that mobile data transmission via cellular networks is substantially more energy-intensive than Wi-Fi connections

(Freitag et al., 2021). In our analysis, the carbon footprint under 4G usage was 40–60% higher than Wi-Fi for the same platforms and usage durations. This suggests that infrastructural improvements and behavioral nudges toward Wi-Fi utilization could play a key role in digital sustainability efforts. Among the platforms, YouTube consistently exhibited the highest annual carbon emissions, which is attributable to its video-centric structure—especially high-resolution (HD and 4K) streaming that requires substantial data transfer. Despite a relatively stable user base, the platform's energy demand remained elevated, particularly under 4G conditions. This observation is in line with the projections by Andrae and Edler (2015), who argue that video streaming will dominate global internet traffic and energy consumption by 2030. Instagram, while traditionally more image-based, showed a marked rise in emissions in 2023 and 2024, reflecting its shift toward short-form video content (e.g., Reels, Stories). The platform's rapid evolution toward multimedia engagement led to an increase in data volume and, consequently, in carbon output. Notably, even under Wi-Fi usage, Instagram's emissions more than doubled between 2022 and 2023. Facebook presented a more fluctuating pattern. While emissions decreased steadily until 2022—likely due to a plateau in active users—there was a moderate increase in 2024, possibly due to renewed engagement through video and live content. This rebound warrants further qualitative analysis regarding platform redesigns and user interaction trends. WhatsApp, being a predominantly text-based messaging platform, exhibited the lowest carbon footprint among the four. Nonetheless, even in this case, 4G use nearly doubled the emissions compared to Wi-Fi, reaffirming the influence of transmission medium over content type in environmental terms. The pie charts and total usage bar graphs provided further insight into usage behavior over time. In particular, Instagram and YouTube have increasingly dominated digital engagement, while Facebook's relative share of usage has declined. These shifts are not only behavioral but carry substantial environmental consequences. Platforms with high video consumption disproportionately drive up total digital carbon emissions. From a policy perspective, these findings reinforce the importance of raising awareness about digital carbon footprints and encouraging lower-impact behaviors, such as preferring Wi-Fi over mobile data and opting for standard-definition (SD) video streaming where possible. Additionally, platform providers could integrate sustainability-by-design principles, such as data-efficient algorithms and eco-mode options that reduce unnecessary background data consumption. Overall, this study contributes to the emerging discourse on ICT-related environmental sustainability by offering an evidence-based, platform-specific evaluation of digital carbon emissions in Türkiye. It highlights the urgent need for user-level behavioral changes, infrastructure improvements, and platform accountability to mitigate the environmental cost of rapidly growing digital consumption.

5. CONCLUSION

This study quantified the carbon footprint of social media usage in Türkiye between 2020 and 2024, focusing on four major platforms: Instagram, WhatsApp, Facebook, and YouTube. The findings clearly show that connection type (Wi-Fi vs. 4G) and content format (especially video) are the most influential factors driving digital carbon emissions. Among the platforms, YouTube and Instagram exhibited the highest environmental impact, while WhatsApp remained the lowest, reflecting differences in content consumption patterns. Across all platforms, 4G usage consistently generated higher emissions than Wi-Fi, emphasizing the need for more energy-efficient digital habits. To reduce the environmental footprint of digital behavior, users should be encouraged to prefer Wi-Fi connections and lower-resolution content, while platforms and policymakers must integrate energy-efficient design and infrastructure into digital ecosystems. Without such interventions, the environmental cost of digital consumption will continue to grow alongside our increasing online presence.

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