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ANALYSING INSTAGRAM'S ENERGY CONSUMPTION: TIPS FOR AN ECO-FRIENDLY USE

Elisa Jimenez, Carlos Pulido, Coral Calero, Mª Ángeles Moraga,
Félix García and Alberto Gordillo
Institute of Technology and Information Systems, University of Castilla – La Mancha.
Camino de Moledores, Ciudad Real, 13005, Spain

ABSTRACT

(1) Background: The internet's widespread use has made social media platforms (SMPs) an integral part of everyday life, transforming global communication and information sharing. Instagram, one of the leading SMPs, has 500 million daily users and offers various functionalities, such as stories and posts. However, the environmental impact of using these platforms remains largely unexplored. (2) Methods: Using the FEETINGS framework, this paper investigates the energy consumption of Instagram by conducting measurement studies of various functionalities on both tablets and PCs. (3) Results: The study found significant differences in energy consumption across different Instagram features. Sharing videos in stories and reels was identified as one of the most energy-intensive activities, and device choice was found to influence overall energy consumption, with PCs consuming more energy than tablets. (4) Conclusions: The study highlights the importance of optimising Instagram use for greater energy efficiency. Prioritising energy-efficient features and considering device choice can mitigate environmental impact and promote sustainable digital practices

KEYWORDS

Social media, Instagram, energy consumption, software sustainability

1. INTRODUCTION

The Internet has become an integral part of our lives in recent years, offering endless possibilities for entertainment, communication and information. Proof of this is that 66.2% of the world's population have access to it by 2024 (We are social & Meltwater, 2024).The Internet has transformed the way we carry out many everyday activities, including the way we interact with others.

Social Media Sites (SMS) are digital communication platforms that connect users worldwide via the internet. The first social network, SixDegrees (BBC News World, 2019), was created in 1997 and allowed users to locate other members of their network and create lists of friends, based on the theory of 6 degrees of separation (Kirvan, 2022). Since then, social media applications have become increasingly popular among people of different ages. Depending on their profile, age, and interests, users choose one social network over another. Modern social networking sites have added new features, such as real-time chatting and the ability to share content, and have even diversified to include specific activities, such as job searching or partner seeking.

For this reason, social media is one of the most widespread online activities worldwide. Today, social media usage is massive, with 5.04 billion users worldwide (We are social & Meltwater, 2024), representing 62.3% of the global population, and this number is expected to increase to 5.85 billion by 2027, according to (Dixon, 2023). On average, people spend 2 hours and 23 minutes per day on social platforms (We are social & Meltwater, 2024). Over the last 20 years, social media adoption has surged, fueled by mobile device penetration and affordable data plans. However, this extensive use comes with significant environmental costs, as the sector's emissions contribute notably to global greenhouse gas levels.

According to the BEREC report, the information and technology (IT) sector is currently responsible for between 2% and 4% of global greenhouse gas emissions. This is equivalent to twice the emissions of the civil aviation sector. Of course, the software sector, which includes social media, is a fundamental part of IT and therefore also contributes to greenhouse gas emissions. Specifically, according to (Kimberley, 2021), in May 2021, the number of active users of social media will amount to 4.33 billion (55.1% of the world's population) and the emissions corresponding to this use are equivalent to 0.61% of global EqCO2 impacts in 2019 and more than half of France's carbon emissions (56%).

Instagram was launched in 2010 as a photo-sharing platform, but over time, the social network has evolved and now offers additional features such as stories, short videos, and messaging with other users. It has grown to become one of the most popular social networks globally. As of recent reports, Instagram is the favorite social network, with 16.5% of active users (We are social & Meltwater, 2024), reflecting its significant engagement among users. Compared to text-based platforms like X (Twitter), visual-centric networks like Instagram and TikTok are gaining prominence due to their support for a broader range of activities, including video content. Instagram stands out as the preferred platform for sharing photos and videos, with 70.4% of users actively using it for this purpose (We are social & Meltwater, 2024).

Given Instagram's vast user base and the multitude of activities it supports, its environmental impact cannot be overlooked. The energy required to power servers, transmit data, and store vast amounts of multimedia content contributes to the platform’s overall carbon footprint. As users increasingly engage with features like Reels, Stories, and live streaming, the energy demands of Instagram grow, amplifying its environmental impact. Understanding these dynamics is crucial for promoting more sustainable digital practices among users and within the industry.

Beyond environmental concerns, the sustainability of Instagram and other social networks can be examined along three dimensions: economic, environmental and social.

Economically, Instagram supports various monetisation strategies for content creators and businesses (Meta, 2024b), while remaining free for the end users.

From the social perspective, Instagram plays an important role in shaping cultural norms and social interactions, so promoting, despite some cases, diversity, inclusion and positive community engagement is essential, avoiding undesirable behaviors and defending ethical practices.

Balancing these three dimensions ensures that Instagram can continue to thrive as a platform while minimising its negative impacts.

This paper is focused specifically on the environmental dimension by analysing the different functionalities of Instagram (Meta, 2024a) from the point of view of its energy consumption. The results of this study will be used to provide recommendations for a more sustainable use of this social network.

Aligned with the pursued objective, three research questions have been defined:

- RQ1: Which Instagram features result in higher consumption?
- RQ2: Does the inclusion of multiple parameters in the same functionality lead to an increase in consumption?
- RQ3: Is the consumption for performing the same functionality equivalent on both PC and tablets?

To address the research questions, two studies were conducted, one on tablet and the other on PC, measuring the different combinations available on Instagram for uploading and viewing content. As not all features are available on PCs, we have defined different actions for each device.

To explain the results of our study, this document is structured as follows: Section 2 presents work related to sustainability in social media, Section 3 describes the methodology used to perform the measurements, Section 4 presents and analyses the results obtained from both studies. Section 5 explains the threats to validity, and finally, Section 6 presents the conclusions.

2. RELATED WORK

There are several scientific and informative articles in the literature that address sustainability in social networks from its three dimensions. However, few studies have examined the energy consumption of social networks.

The work of (Dunia et al., 2018) aims to perform a measurement on the power consumption of social networks on a mobile device, specifically measuring Whatsapp, Line and BlackBerry Messenger. The experimental circuit was developed using a microcontroller that measures an android smartphone on a controlled network. The results of the experiment show that Whatsapp consumes less energy than the others in standby and chat. Blackberry is the worst performer.

A recent study (Yosh Ben, 2023) examines the environmental footprint of social networking applications. Unlike the previous works mentioned, this is not a scientific study but rather an analysis carried out by Greenspector, a company specialised in optimising the energy efficiency of digital applications, mobile devices, and websites. The study evaluates the energy consumption and carbon emissions of several popular social media, including Facebook, Instagram, LinkedIn, TikTok, and X (Twitter), across different devices and networks. The results show that Instagram and TikTok are among the most resource-intensive applications due to their heavy reliance on video content and continuous user engagement.

The same company (Greenspector) also carried out a study on the energy consumption of some messaging platforms. Specifically, they measure the same scenario with 18 steps in Discord, Slack, Whatsapp and Teams. The main conclusion is that Whatsapp is the most efficient application due to its low data consumption and its efficient compression of images and GIF files. On the other hand, Slack has the highest impact, emitting 44% more CO2eq than Whatsapp.

In another similar study, (Rammos et al., 2021) empirically assess the extent to which the number and distribution of instant messages received impacts the energy consumption of Android devices. To do so, they run the experiment on WhatsApp and Telegram, two of the most popular and widely used messaging apps. As a result, they confirm that the power consumption of the Android device tends to be proportional to the number of messages received in both applications. When the number of messages received is fixed, the frequency of their arrival does not significantly affect the power consumption of the Android device.

Even though (Brain, 2019) does not carry out an empirical study as such, it does provide us with some relevant data on Youtube's energy consumption. After Netflix and embedded videos, YouTube is the third largest consumer of Internet bandwidth worldwide. Approximately 11.4% of global Internet traffic is consumed by YouTube. The total global electricity consumption is 21,372 TWh. YouTube therefore uses about 243.6 TWh (more than 1% of the world's electricity). In the United States, the average annual electricity consumption of a household is 10,766 kWh. So, that translates, the annual global use of YouTube could power a US household for about 2 billion years. Or 127 million US households for about 8 years.

The report prepared by The Shift Project (The Shift Project, 2019) analyses the environmental impact of online video consumption, highlighting that this type of content is responsible for a significant part of global data traffic. According to the study, online video generated more than 60% of global data traffic in 2018, and its consumption contributed to 1% of global CO2 emissions. In addition, it proposes solutions such as reducing file sizes and using more energy-efficient video platforms. The Shift Project raises the urgent need to consider the environmental impact of digital use and encourage more sustainable practices in the consumption of online content.

Similarly, in (Herglotz et al., 2023), they take as a basis that currently more than 1% of global greenhouse gas emissions are related to online video. For this reason, the paper reviews the latest findings regarding the energy consumption of online video from a systems engineer's perspective, where the systems engineer is the designer and operator of a typical online video service. As a result, they find that end-user devices and video encoding have the greatest potential for energy savings. Furthermore, they provide an overview of recent developments in improving the energy efficiency of video streaming and propose future lines of research for energy-efficient video streaming services.

Although they do not focus directly on measuring the energy consumption of social networks, there are several works that look at how to reduce the energy consumption of the devices on which they are used. For example, (Asnani et al., 2021) present a method for producing energy-efficient and contrast-enhanced images for OLED-based mobile devices. By reducing RGB intensity levels and using image enhancement techniques such as white-balance and retinex filter, the method achieves better visual quality and reduces power consumption by an average of 13.16%. (Yin et al., 2021) propose the MILECR algorithm to prioritise important messages and reduce energy consumption in opportunistic social networks. It uses node energy and message importance for routing, and a cache replacement strategy to optimise cache space. The experimental results show that MILECR reduces message delay and energy consumption and increases the delivery success rate. Finally, (Wang et al., 2017) proposes an energy-optimised routing strategy based on communities in mobile social networks. It uses a Markov chain model and optimal stopping theory to minimise energy consumption and message delivery delay, achieving better performance on both metrics than alternative strategies.

Although (Istrate et al., 2024) do not focus specifically on social media, their contribution to digital content is noteworthy. The authors assess the environmental impact of various digital activities in relation to the Earth's carrying capacity. They find that current global average consumption of web browsing, social networking, video and music streaming, and video conferencing could account for about 40% of the per capita carbon budget compatible with limiting global warming to 1.5°C. Additionally, this consumption represents approximately 55% of the per capita carrying capacity for mineral and metal resource use and over 10% for five other impact categories.

As can be seen, there are very few studies focused on the energy consumption of social media, and none of them offer practical recommendations to users for making more efficient use of these platforms. Our work aims to fill this gap by providing actionable insights and guidelines to help users to reduce the environmental impact associated with their use of Instagram.

3. WORKING METHOD

In order to perform the energy consumption measurements required to answer our research questions, we used GSMP (Green Software Measurement Process) (Mancebo, Calero, & García, 2021), a specific process for measuring the energy consumption of software. GSMP is the methodological component of FEETINGS (Framework for Energy Efficiency Testing to Improve Environ-mental Goals of the Software) (Mancebo, Calero, Garcia, et al., 2021), which is a framework designed to promote the reliable capture, analysis, and interpretation of software energy consumption data. In addition to the methodological component mentioned above, FEETINGS consists of two other components: A conceptual component (GSMO), which contains the terminology related to the measurement of software energy consumption, and a technological component, consisting of the EET (Energy Efficiency Tester) and Elliot. EET (Mancebo et al., 2018) is a hardware device designed to measure the power consumption of the processor, hard disk, and the total power consumption of the computer (i.e. DUT-Device Under Test) when running software. The data captured by EET is analysed using the ELLIOT tool (Gordillo & Mancebo, 2022).

GSMP consists of seven phases (see Figure 1). Initially, the requirements and software system to be evaluated are defined. The next two phases focus on configuring and preparing the measuring environment. The fourth phase is the measurement of energy consumption. Finally, the data obtained is analysed and reported in the last phases.

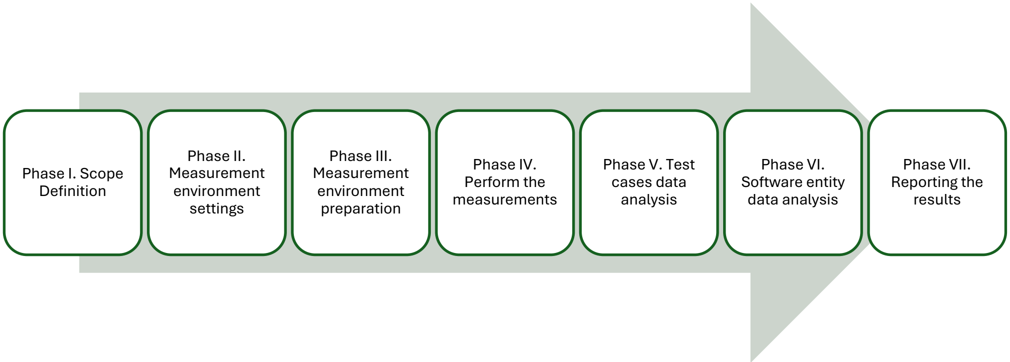

Figure 1. GSMP phases for evaluating the energy efficiency of a software

The scope of the present study (Phase I) is to analyse how the use of Instagram features affects consumption, including sharing one's own content and viewing external content. We have considered the following Instagram features to measure the consumption of one's own content:

- Stories are audiovisual contents that include photos, videos, and images, and are available to the public for only 24 hours.
- Posts consist of sharing photos or videos without a predetermined duration.

In both cases, a publication can be uploaded using a combination of different additional elements available on the social network, such as music or effects.

And for the external content viewing, we have considered the following three features:

- Stories: This section of Instagram allows us to see the content posted by our contacts for a period of 24 hours.
- Reels: Reels are vertical full-screen videos with a maximum duration of 90 seconds. Randomly selected videos provided by the application are available in the Reels section.
- Content visualisation: Involves viewing different types of content.

According to the considered Instagram features, the actions to be analysed for the tablet and PC studies are shown in Table 1 and Table 2 respectively. It is worth emphasising that for Action13 to Action15, measurements will be made by randomly viewing content for a period of 120 seconds. It is important to note that not all the selected Instagram features will be available on the PC, as Instagram is a social network designed for use on tablets. Therefore, only the actions shown in Table 2 will be analysed in the PC study.

Table 1. Actions of the study in Tablet

Software Entity	Test Case	Description
Stories	Action1	Storie with a photo.
	Action2	Storie with a photo and text.
	Action3	Storie with a photo and music.
	Action4	Storie using a combination of photo, music, and text.
	Action5	Storie with a photo that has a static effect and background music.
	Action6	Storie with a photo that has a dynamic effect and background music.
	Action7	15-second video storie.
Posts	Action8	Post a photo.
	Action9	Post a photo and comment.
	Action10	Post a photo with effect and comment.
	Action11	Post a 15-second video.
	Action12	Post a 15-second reel.
Content visualisation	Action13	Visualising stories.
	Action14	Visualising reels.
	Action15	Visualising general (standard use).

Table 2. Actions of the study in PC

Software Entity	TestCase	Description
Posts	Action16	Post a photo.
	Action17	Post a photo and comment.
	Action18	Post a 15-second reel.

During Phase II, we chosen EET on its version for PC and for Tablet, as measuring instruments. The specifications of the two Devices Under Test (DUTs) used (Tablet and PC) are detailed in Table 3.

Table 3. DUT specifications for Tablet and PC

DUT specifications for **Tablet**	
Model	Lenovo TB-X306F
Screen	HD IPS (1280 x 800) de 25,65 cm (10,1") y 400 nits
Processor	MediaTek P22T (4 2,3 GHz + 4 1,8 GHz)
RAM	2 GB LPDDR4x
O.S.	Android 10

DUT specifications for **PC**	
Monitor	Philips 170s6fs LCD
Motherboard	ASUS Prime B460-Plus
Processor	Intel i7 10700 2900MHz
RAM	2 modules of 16GB Kingston Hiperx Fury DDR4
Graphics card	Sapphire ATI Radeon X1950 GT, 256mb RAM DDR3
Hard disk	Western Digital Blue 500GB SSD
Power supply	360 PS5805 – 580W
O.S.	Ubuntu 20.4 LTS

While the tablet EET captures the power consumption of the entire tablet, the PC EET can measure the power consumption of various parts of the PC. However, in this study we decided to analyse just the power measurement of the entire PC, to align another aspect with the tablet study and be able to make the comparison between the two. In the Phase III we decided to run each test case 10 times to assure the accuracy of the measurements. Considering that both EETs can capture 100 samples per second, 10 measurements are a good sample size to mitigate the impact of outliers. Once the measurements have been taken (Phase IV), it is possible to analyse the data obtained using ELLIOT (Gordillo & Mancebo, 2022), which ensures greater reliability of the analysis obtained. The data analysed by ELLIOT can then be interpreted to answer our research questions (Phases V and VI). It should be noted that the consumption data analysed are those obtained after subtracting the baseline, i.e. the consumption of the operating system and hardware devices in the background.

4. RESULTS

This section presents and analyses the results obtained during the measurement of energy consumption in the two studies (Tablet and PC). The energy consumption data obtained from the measurements can be found in https://github.com/GrupoAlarcos/InstagramEnergyConsumption

To answer the research questions, the following comparisons will be presented: Actions on Stories, Actions on Posts, Actions on Content Visualisation, Actions on Stories vs. Actions on Posts and Actions on Tablet vs. Actions on PC (see Table 1 and Table 2).

4.1 Tablet

Firstly, the study was carried out on a tablet to find out which features lead to higher energy consumption. Table 4 shows the time and consumption results obtained after performing the measurements. These values, provided by ELLIOT after removing the baseline (idle DUT consumption), represent the average of all the time data captured by EET during the execution of the corresponding feature. The energy consumption has been calculated by using the time and the data power consumption average, also provided by ELLIOT.

Table 4. Tablet actions time and energy consumption

	Time (s)	Energy consumption (J)
Action1	18.062	27.403
Action2	29.972	28.126
Action3	65.845	96.050
Action4	74.474	128.928
Action5	80.288	139.176
Action6	137,549	218,789
Action7	45.000	82.647
Action8	17.770	25.952

	Time (s)	Energy consumption (J)
Action9	29.619	39.907
Action10	32.011	44.058
Action11	54.590	103.604
Action12	100.117	207.732
Action13	120.000	193.849
Action14	120.000	198.405
Action15	120.000	213.588

4.1.1 Stories

This section aims to compare the difference in consumption when posting an Instagram storie with different content. The results show that Action1 (post a storie with a photo), obtained the best result. Table 5 shows the percentage of increase in consumption and the time required to add more parameters when posting stories (Action1 vs. Action2-Action6). In most cases, there is a significant difference in the amount of energy consumed, which increases by almost 700% compared to Action1. Similarly, in terms of time, the percentage increase compared to Action1 is also very high, reaching a maximum of approximately 662% of increase. Figure 2 shows the relationship between the number of parameters added and the corresponding increase in time and energy consumption required for publishing a photo.

Table 5. Time and energy consumption comparison: Action1 vs. Action2-Action6

	Action1 time with respect Action n (%)	Action1 energy consumption with respect Action n (%)
Action2	65,943	2,641
Action3	264,562	250,512
Action4	312,337	370,492
Action5	344,526	407,890
Action6	661,561	698,417

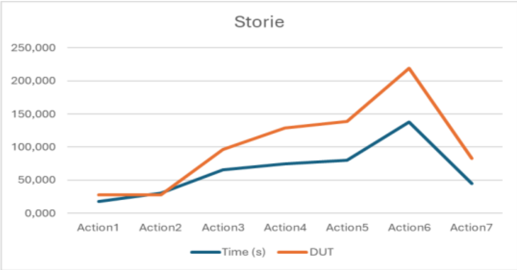

Figure 2. Evolution of time and consumption across stories actions

On the other hand, publishing a 15-second video storie (Action7) results in an increase in both time and consumption compared to a storie with just a photo and text (Action2). However, it involves less time and consumption compared to other cases (Action3-Action6). Table 6 displays the percentages of increase and savings of Action7 in comparison to the other Actions.

Table 6. Time and energy consumption comparison: Action7 vs. Action1-Action6

	Action7 time with respect Action n (%)	Action7 energy consumption with respect Action n (%)
Action1	149.148	201.599
Action2	50.141	193.839
Action3	-31.658	-13.955
Action4	-39.577	-35.897
Action5	-43.952	-40.617
Action6	-67.285	-62.225

4.1.2 Posts

As a continuation of the analysis, we will compare the difference in time and energy consumption between the content posts functionalities. As in the previous case, the best results in terms of time and energy consumption are obtained by the simplest post, which contains only a photo. Table 7 shows the percentage increase in these variables that Action9-Action12 entail compared to Action8. In this case, publishing a video or a reel takes more time and consumes more energy than publishing photos in any of their variants. The increase in consumption can be up to 700.46% in the most extreme case (Action12).

Figure 3 illustrates the increase in time and energy consumption for the different types of posts.

Table 7. Time and energy consumption comparison: Action 8 vs. Action9-Action12

Action 8 Time with respect Action n (%)	Action 8 Energy consumption with respect Action n (%)
66.682	53.774
80.145	69.769
207.205	299.220
463.409	700.458

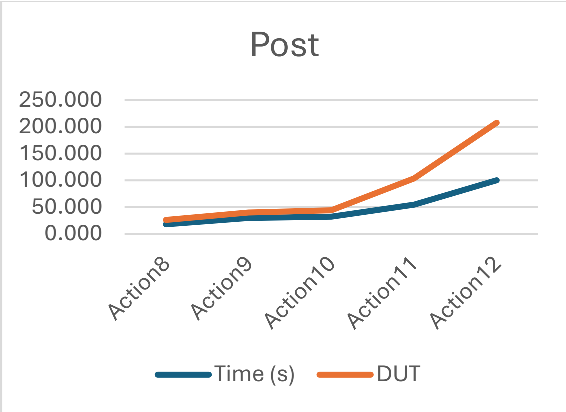

Figure 3. Evolution of time and consumption across post actions

Therefore, it can be concluded that:

- Including additional parameters in images increase their consumption.
- Videos in any of their variants consume more energy than images.

4.1.3 Visualisation

This section compares the energy consumption required to randomly view different content for 120 seconds. The action with the best consumption results was viewing only stories (Action13). Table 8 displays the percentage increase in consumption compared to Action13. Figure 4 illustrates the variations in energy consumption among the different display actions.

Table 8. Energy consumption comparison: Action13 vs. Action14-Action15

	Energy consumption with respect Action13 (%)
Action14	2.350
Action15	10.182

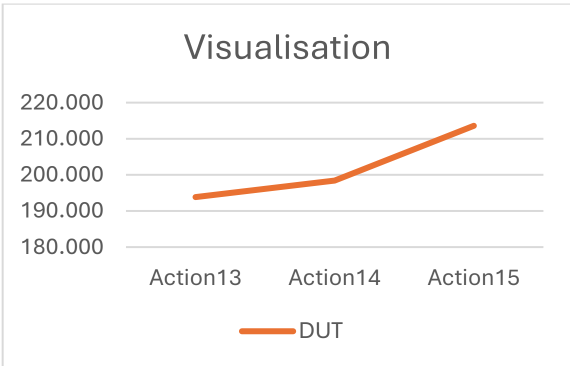

Figure 4. Evolution of consumption across visualization actions

It can be concluded that:

- Displaying specific content separately is better than displaying content alternately due to the considerable differences between some of the actions

4.1.4 Post vs. Story

To conclude the analysis of tablet functionalities, this section compares the time and consumption differences between sharing content as a story or a post. Due to varying available parameters, comparisons include: Action8 vs. Action1; Action9 vs. Action2; and Action11 vs. Action7. Table 9 displays the percentage difference when sharing the same content in post or story format.

There is minimal difference in time and effort between sharing a photo as a story or a post, with posts requiring slightly less time. However, adding text significantly increases the posting time by almost 42%. Similarly, posting a video takes 25% more time. Conversely, there is only a small-time difference for sharing photos and photos with text, with a 1-2% decrease in time when posting. Videos, however, show a 21% increase in posting time compared to stories. Figure 5 illustrates the time and consumption differences for the three comparisons.

Table 9. Comparison rates between posts and stories

	Time (%)	**Energy consumption (%)**
Action8 vs. Action1	-1.615	-5.296
Action9 vs. Action2	-1.177	41.884
Action11 vs. Action7	21.311	25.358

Figure 5. Difference in time and consumption between post and story

In two out of the three actions, sharing content in post format resulted in higher consumption compared to story format. As the remaining actions represent only a minimal percentage, it can be concluded that:

- Sharing content in the form of stories seems to be more effective than permanent posts.
- Sharing a photo without effects seems to be more efficient to do as a permanent post.

4.2 PC

As already mentioned, the functionalities of Instagram for PCs are very limited, as it is a social network designed to be used on tablets. Table 10 shows the results obtained after measuring the only three actions available on PCs (see Table 2).

Action16 obtained the best results among the actions by uploading a photo without any additional content. Table 11 shows the percentage increase in time and consumption for the remaining actions compared to Action16. The data presented in Figure 6 shows that adding text to a photo results in a 90% increase in consumption and a 63% increase in time.

Posting a video results in the highest consumption, with a 189% increase compared to posting a photo. Similarly, Action18 results in a 151% increase in time compared to posting a photo.

Figure 6 shows the increase in time and consumption for the different PC actions.

Table 10. Time and energy consumption of PC actions

	Time (s)	Energy consumption (J)
Action16	18.951	1937.193
Action17	30.893	3681.768
Action18	47.599	5608.286

Table 11. Time and energy consumption comparison: Percentage increase Action17-18 vs. Action16

	Time with respect Action16 (%)	Energy consumption with respect Action16 (%)
Action17	63.013	90.057
Action18	151.165	189.506

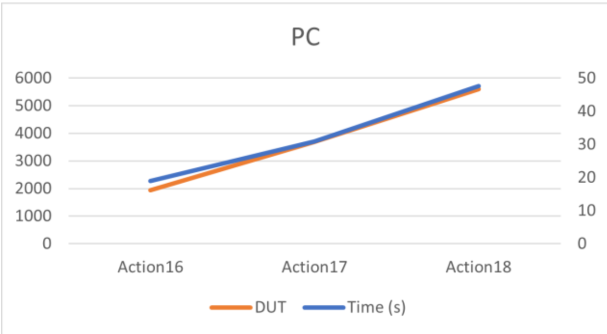

Figure 6. Evolution of time and consumption across PC actions

Based on the analysis of the obtained data, it can be concluded that:

- Publishing a photo on a PC, either alone or with text, seems to consume less energy and time compared to publishing a video.
- Publishing a photo without any additions requires the least amount of time and energy.

4.3 Tablet vs. PC

Finally, to see whether the same functionality consumes more on PC or Tablet, this section compares the results of both. As the features available on PCs are less than those available on tablets, the following comparisons are made: Action16 vs. Action8; Action17 vs. Action9; Action18 vs. Action11.

Table 12 shows the percentage increase in PC functionality over tablet functionality. As shown, although the time differences are small, the percentage differences in power consumption are significant. This is because the power required by the components of a PC is much greater than that of a tablet.

Table 12. Comparison of increase and savings of PC compared to Tablet

	PC time with respect Tablet (%)	PC energy consumption with respect Tablet (%)
Action16 vs. Action8	6.648	7364.625
Action17 vs. Action9	4.301	9125.882
Action18 vs. Action11	-12.807	5313.176

Based on this data, it can be concluded that:

- Using Instagram on a tablet seems to be more energy efficient than on a PC.

5. THREATS TO VALIDITY

This section tackles the threats to the validity of the study by following the recommendations in (Wohlin et al., 2012) and how we have tried to minimize their effects:

Construct validity. The first point concerns the reliability of the measurements. We have used two different hardware measurement devices (for Tablet and PC, called EET) to obtain accurate measurements of the energy consumed by the tablet and the PC in a small-time interval (approximately one hundred samples per second).

Obviously, the measurements obtained are specific to the PC and Tablet where the studies are run and may differ if others are used. However, based on our experience, although the energy consumed figures would vary depending on the PC or tablet, the classification remain. Also, the results would be different if other measurement mechanisms as estimation would be used. However, the hardware measurement devices have already been validated and shown to be reliable (Mancebo et al., 2018) and have been used in the past in other measurement studies of this type demonstrating to be more accurate and reliable than the use of estimators.

Internal validity. The most significant uncontrolled factors relate to measurement conditions. To control these aspects, we carried out all the measurements under the same temperature conditions and at the same time of day to avoid influences from Internet load or lab temperature.

In addition, several runs were performed to mitigate possible consumption-related outliers. The same DUT (Tablet or PC) has been used to perform the runs and capture the energy consumption and measures have been taken to ensure that the DUTs were always in the same conditions for the execution of each of the different functionalities. In addition, before starting each measurement, all programs that could cause interference were closed and the base consumption corresponding to each DUT was subtracted.

Regarding the number of measurements performed, 10 measurements were carried out. Although some authors such as (Kern et al., 2018) recommend performing at least 30 repetitions to evaluate software power consumption in a controlled environment, the reliability of our measurement devices has shown a low variability among the results of each run (unless when some kind of error occurs), so we think the number of repetitions to be sufficient to consider the results valid.

External validity. Finally, about the generalisability of the results obtained in this experiment, the results are based on the analysis of the functionalities available in the Instagram application at the time of the study. Currently, Instagram has added new functionalities and modified others, such as the reel templates, which could alter its energy consumption. It could be the case that the last included functionalities could affect to the analysed ones, but we think it probably will change the consumption but not the classifications obtained. However, the aim of this study is to make users aware that not all features consume the same amount of energy, and to offer some tips for more responsible use, so the changes made by Instagram do not affect the objective of our work.

6. CONCLUSION

The use of social media has become a ubiquitous activity in the daily lives of millions of people around the world. However, the environmental impact of their use is rarely considered. As (Kimberley, 2021) demonstrates, Instagram, as one of the most popular platforms, is a clear example of how the everyday use of digital technology can have a significant energy cost. In this context, our study has focused on analysing and comparing the energy consumption of various Instagram functionalities on tablet and PC devices.

In this paper we have presented two studies aimed at analysing the energy consumption of Instagram functionalities on a Tablet and a PC. Throughout the research, we have compared the energy consumption required by different actions performed on Instagram on both devices, and we have identified significant differences in the environmental impact depending on the device used, being more energy demanding when used on PC. We also observed a clear increase in energy consumption as the number of elements added to posts and stories increased.

In order to have more understandable results we have applied the Ward's hierarchical clustering method (Murtagh, 2011) to the Tablet data to group actions with similar energy consumption. The RStudio tool was employed for the clustering process. A total of 5 clusters were identified. Figure 7 shows the clusters obtained.

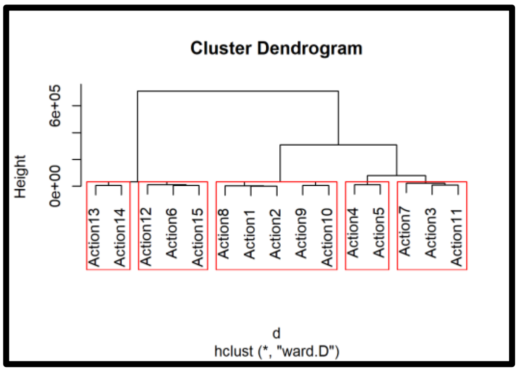

Figure 7. Clusters obtained

From the clusters obtained, we were able to provide the tier list of the different Instagram functionalities shown in Figure 8. To be aware of the importance of the classification done, we present some examples. For instance, the energy required to upload a story with a photo and music (B level) could instead be used to upload 3.5 photos as posts (A level). Posting a video (B level) consumes enough energy to upload nearly 4 photos (A level). When it comes to applying effects, the energy used for a story with a photo and a dynamic effect (E level) could alternatively support 2.27 stories with just a photo and music (B level). Finally, the energy consumption for posting a reel (E level) is significantly higher, equating to the energy required to post 8 photos (A level).

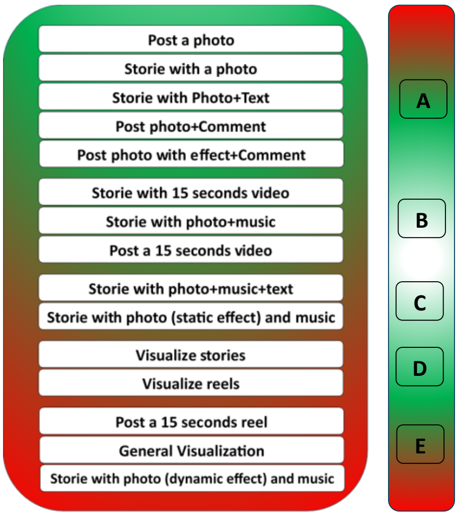

Figure 8. Tier list of Instagram functionalities

In addition to the scientific conclusions derived from the study, this work has allowed us to develop a series of practical tips for users to use Instagram more efficiently (Figure 9). These recommendations, which encourage more sustainable behaviour, are key to reducing the carbon footprint associated with social media use.

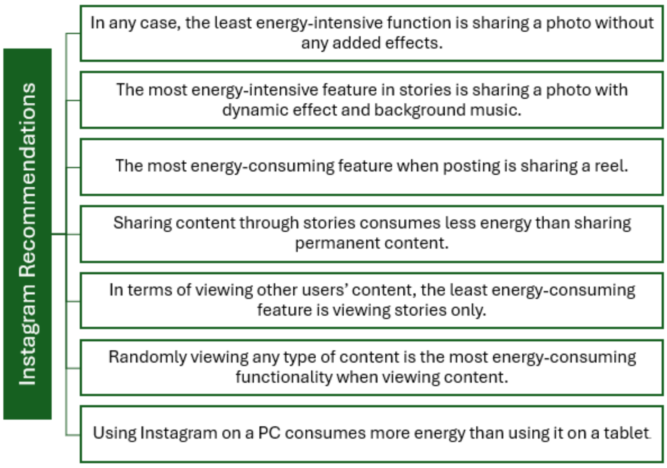

Figure 9. Instagram recommendations for users

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REFERENCES

Asnani, S., Canu, M. G., Farinetti, L. and Montrucchio, B., 2021. On producing energy-efficient and contrast-enhanced images for OLED-based mobile devices. *Pervasive and Mobile Computing*, Vol. 75, 101384. https://doi.org/10.1016/j.pmcj.2021.101384

BBC News World, 2019. Six Degrees: What it was like and who created the internet's first social network, inspired by the theory of 'six degrees'. *BBC News*. Available at: https://www.bbc.com/mundo/noticias-48558989

Brain, 2019. How much electricity does Youtube use? *Fact Source*. Available at: https://thefactsource.com/how-much-electricity-does-youtube-use/

Dixon, S., 2023. *Number of social media users worldwide from 2017 to 2027*. Available at: https://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/

Dunia, A., Rambe, A. and Fauzi, R., 2018. *Measuring the power consumption of social media applications on a mobile device*, Vol. 978, No. 1, 012104.

Gordillo, A. and Mancebo, J., 2022. Elliot: Gestión y Análisis de Datos de Consumo de Software. In S. Abranhão, C. Calero et al. (eds.) *Calidad y Sostenibilidad de Sistemas de Información en la Práctica* (1st ed.). Ra-Ma.

Herglotz, C., Kränzler, M., Schober, R. and Kaup, A., 2023. Sweet Streams Are Made of This: The System Engineer's View on Energy Efficiency in Video Communications [Feature]. *IEEE Circuits and Systems Magazine*, Vol. 23, No. 1, pp. 57-77. https://doi.org/10.1109/MCAS.2023.3234739

Istrate, R., Tulus, V., Grass, R. N., Vanbever, L., Stark, W. J. and Guillén-Gosálbez, G., 2024. The environmental sustainability of digital content consumption. *Nature Communications*, Vol. 15, No. 1, 3724.

Kern, E., Hilty, L. M., Guldner, A., Maksimov, Y. V., Filler, A., Gröger, J. and Naumann, S., 2018. Sustainable software products—Towards assessment criteria for resource and energy efficiency. *Future Generation Computer Systems*, No. 86, pp. 199-210.

Kimberley, D., 2021. What is the environmental footprint for social media applications? 2021 Edition. *Greenspector*. Available at: https://greenspector.com/en/social-media-2021/

Kirvan, P., 2022. Six degrees of separation. *WhatIs.Com*. Available at: https://www.techtarget.com/whatis/definition/six-degrees-of-separation

Mancebo, J., Arriaga, H. O., García, F., Moraga, M. Á., García-Rodríguez de Guzmán, I. and Calero, C., 2018. EET: A Device to Support the Measurement of Software Consumption. *2018 IEEE/ACM 6th International Workshop on Green And Sustainable Software (GREENS)*, pp. 16-22.

Mancebo, J., Calero, C. and García, F., 2021. GSMP: Green Software Measurement Process. In C. Calero, M. A. Moraga and M. Piattini (eds.) *Software Sustainability*. Springer, Cham, pp. 43-67.

Mancebo, J., Calero, C., Garcia, F., Moraga, M. A. and Guzman, I. G.-R. de, 2021. FEETINGS: Framework for Energy Efficiency Testing to Improve Environmental Goal of the Software. *Sustainable Computing: Informatics and Systems*, Vol. 30, 100558. https://doi.org/10.1016/j.suscom.2021.100558

Meng, W., Yuan, G. and Sun, Y., 2023. Expansion of social networks and household carbon emissions: Evidence from household survey in China. *Energy Policy*, Vol. 174, 113460. https://doi.org/10.1016/j.enpol.2023.113460

Meta, 2024a. *Instagram*. Available at: https://about.instagram.com/es-la

Meta, 2024b. *Instagram creators*. Available at: https://creators.instagram.com/

Murtagh, F., 2011. Ward’s hierarchical clustering method: Clustering criterion and agglomerative algorithm. *ArXiv Abs/1111.6285*.

Rammos, S., Mundra, M., Xu, G., Tong, C., Ziolkowski, W. and Malavolta, I., 2021. The impact of instant messaging on the energy consumption of android devices. *2021 IEEE/ACM 8th International Conference on Mobile Software Engineering and Systems (MobileSoft): [Proceedings]*. Institute of Electrical and Electronics Engineers Inc.. https://doi.org/10.1109/MobileSoft52590.2021.00007

The Shift Project, 2019. *Climate crisis: The unsustainable use of online video”: Our new report on the environmental impact of ICT*. Available at: https://theshiftproject.org/en/article/unsustainable-use-online-video/

Wang, G., Peng, Y., Wang, N. and Li, T., 2017. A Routing Strategy with Energy Optimization Based on Community in Mobile Social Networks. *2017 IEEE International Symposium on Parallel and Distributed Processing with Applications and 2017 IEEE International Conference on Ubiquitous Computing and Communications (ISPA/IUCC)*, pp. 159-166. https://doi.org/10.1109/ISPA/IUCC.2017.00032

We are social, & Meltwater, 2024. *Digital 2024 Global Overview Report*. Available at: https://indd.adobe.com/view/8892459e-f0f4-4cfd-bf47-f5da5728a5b5?allowFullscreen=true

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B. and Wesslén, A., 2012. *Experimentation in software engineering*. Springer Science & Business Media.

Yin, S., Wu, J. and Yu, G., 2021. Low energy consumption routing algorithm based on message importance in opportunistic social networks. *Peer-to-Peer Networking and Applications*, Vol. 14, No. 2, pp. 948-961. https://doi.org/10.1007/s12083-021-01072-y

Yosh Ben, A., 2023. What is the environmental footprint of social networking applications? 2023 Edition. *Greenspector*. Available at: https://greenspector.com/en/what-is-the-environmental-footprint-of-social-networking-applications-2023/