Power Consumption While Using Ad-Blockers on ARM-Based CPU

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***Abstract*— This study investigates the impact of ad blockers on power consumption in ARM-based processors, which are widely used in energy-efficient systems. A comparative analysis was conducted across popular browsers such as Chrome, Brave, Vivaldi, Kiwi, and Firefox, alongside ad blockers including AdGuard, Adblock Plus, Ghostery, uBlock, and uBlock Origin. Tests on websites like YouTube, Dailymotion, ARYZAP, and KissCartoon revealed significant differences in power consumption based on browser and ad-blocker configurations. Kiwi paired with uBlock reduced power consumption by approximately 15% compared to Chrome, which consistently exhibited the highest energy usage. Brave, with its built-in ad blocker, reduced power consumption by 12% on average compared to Firefox with Ghostery, which showed the highest consumption. Additionally, Firefox with Adblock Plus demonstrated an 8-10% reduction in energy use compared to configurations without ad-blocking extensions. On media-rich platforms like YouTube, Brave and Kiwi performed more efficiently, consuming 10-13% less power than Chrome and Firefox with Ghostery, which increased energy use by up to 20%. These findings emphasize the importance of selecting the right browser and ad blocker combination to optimize power efficiency on ARM-based systems, especially in ad-heavy environments.**

Keywords*— ARM processors, ad blockers, power consumption, energy efficiency, web browsers

I. Introduction

The rapid growth of internet usage has led to an increase in online advertisements, which are vital for website revenue but often degrade user experience by slowing page loading, increasing data usage, and raising privacy concerns. To address these issues, ad blockers have become popular, enhancing user experience by filtering ads and blocking tracking scripts. However, their impact on power consumption, particularly on ARM CPUs, remains largely unexplored.

ARM CPUs, known for energy efficiency, dominate mobile devices and embedded systems, making energy-efficient computing crucial. Ad blockers add computational overhead, which could affect power usage, but studies on this effect are lacking, especially for ARM-based devices. As ARM CPUs differ from x86 processors, findings from desktop environments may not apply directly to mobile platforms.

This study aims to evaluate power consumption associated with ad blockers on ARM CPUs, analyzing their energy impact during web browsing on different websites and content types. The findings will inform consumers about energy trade-offs, guide developers in optimizing ad blockers, and aid policymakers in promoting sustainable technology practices, ultimately contributing to reduced environmental impacts of digital technologies.

II. Literature Review

Energy efficiency in computing has become a critical factor, with ARM processors leading the way in low-power, high-performance applications. Pearce (2020) discusses the significant role of ARM technology in optimizing energy use, particularly in reducing unnecessary energy consumption through the use of open-source ad blockers, which can improve overall system efficiency [1]. Tairum (2018) analyzed ARM's Scalable Vector Extension, showing that this architecture delivers considerable power savings, particularly in vector processing tasks that are critical in data-intensive applications [2]. Das (2021) introduced a power modeling framework that significantly enhances real-time measurement capabilities in ARM CPUs, which is vital for developers aiming to optimize energy usage dynamically [3]. Basmadjian and de Meer (2012) found that multi-core processors like ARM can significantly lower power consumption during various computing tasks, which is essential for servers and data centers [4].

Calore et al. (2018) highlighted ARM's effectiveness in high-performance computing (HPC) workloads, emphasizing its ability to balance performance with energy efficiency, a key consideration in scientific computing [5]. Suárez et al. (2024) provided a comparative analysis between ARM and RISC-V, highlighting ARM's superior performance in handling complex and data-heavy workloads efficiently, making it suitable for both consumer electronics and industrial applications [6]. Rahman and Smith (2024) emphasized ARM's growing dominance in cloud computing due to its ability to reduce operational costs through energy savings, further enhancing its appeal to businesses looking to minimize carbon footprints [7].

Raffin et al. (2024) provided an in-depth examination of various processor systems, revealing that ARM processors consistently outperform competitors in energy consumption under similar workload conditions [8]. Xie et al. (2021) introduced the APOLLO framework, which uses advanced algorithms for precise power introspection at runtime, enabling fine-tuned optimizations that help maintain system performance without significant power penalties [9]. The comprehensive analysis of ARM and RISC-V systems highlighted ARM's consistent efficiency gains, positioning it as a preferred architecture in energy-sensitive environments [10]. Patsidis et al. (2024) validated ARM's performance across different RISC architectures, demonstrating that ARM's design choices provide clear advantages in both computational speed and power efficiency [11].

Endo et al. (2015) explored simulation techniques with Gem5 and McPAT, showcasing how ARM's micro-architectural innovations contribute to enhanced performance with lower power draw [12]. Kodama et al. (2017) examined ARM SVE's capability to adapt to various vector lengths, offering flexible performance scaling without proportional increases in power consumption, which is critical in adaptive computing environments [13]. Stanley-Marbell and Cabezas (2011) illustrated ARM's role in reducing thermal output, which directly impacts power consumption in data centers and large-scale computing environments [14]. The Arm-ECS Research Centre's work on stable CPU power modeling emphasized the critical role of accurate and consistent power measurements in ongoing ARM CPU optimizations [15].

Naffziger et al. (2020) discussed AMD's chiplet architecture and its influence on ARM's approach to modular design, highlighting the benefits of resource efficiency and scalability [16]. Xie et al. (2021) provided further insights into how ARM's runtime power introspection capabilities allow for real-time adjustments that maximize performance while minimizing energy use [17]. Haas (2024) detailed ARM's strategic adaptation in AI, emphasizing energy-efficient processing that supports AI workloads without the high energy costs typically associated with these tasks [18]. Studies on performance–energy trade-offs in deep learning highlight ARM's ability to balance computational demands with energy constraints, making it highly suitable for modern AI applications [19][20]. The ongoing analysis of ARM and RISC-V continues to validate ARM's superior architecture for both performance and power management [21].

Ad blockers play a crucial role in optimizing energy consumption by reducing the load on browsers and system resources, especially in mobile and low-power environments. Brave, with its built-in ad-blocker, significantly reduces battery consumption by up to 35% compared to browsers like Chrome by blocking ads and trackers by default, which minimizes CPU and bandwidth usage during browsing [22]. Similarly, Vivaldi incorporates a customizable built-in ad-blocker that allows users to block ads and trackers efficiently, contributing to improved browsing performance [23]. Firefox, with various ad-blocking extensions, shows differing levels of energy consumption. AdGuard effectively blocks ads, though its extensive filtering mechanisms can slightly increase resource usage [24]. Adblock Plus, with its "acceptable ads" feature, balances power consumption and user experience by allowing some non-intrusive ads, reducing the need for excessive filtering [25]. Ghostery offers advanced privacy protections but may increase power consumption due to its more aggressive ad-blocking and tracking prevention techniques [26]. Meanwhile, uBlock Origin is known for being a lightweight and highly efficient blocker, significantly reducing resource usage, making it ideal for low-power devices [27]. NewPipe, a lightweight YouTube client, further enhances energy efficiency by bypassing resource-heavy ads, leading to minimal power consumption [28].

III. Experimental Setup

A. Hardware and Software Configuration

The experiments were conducted using a Google Pixel 7 smartphone, equipped with a Google Tensor G2 SoC based on ARM architecture. The CPU architecture includes:

2x Cortex-X1 cores at 2.85 GHz, 2x Cortex-A78 cores at 2.35 GHz, 4x Cortex-A55 cores at 1.80 GHz .The ARM-based CPU offers an optimal balance between high-performance tasks and low-power operations. The device operates with 8 GB LPDDR5 RAM and a 4355 mAh battery to sustain consistent power delivery. The GPU integrated is an ARM Mali-G710 MP7, providing efficient handling of graphical content. The smartphone runs on Android 14, supporting 64-bit architecture, and employs a sched_pixel CPU governor for dynamic frequency scaling to ensure energy efficiency during performance fluctuations.

B. Network Configuration

A stable 1.5 GB internet connection was maintained throughout the experiment to minimize network variance and ensure reliable testing conditions across all websites and browsers

C. Websites Tested

The experiments were conducted using four distinct websites, representing a range of content types and media complexity: YouTube: A video streaming platform. Dailymotion: A similar video streaming site with ads. ARYZAP: A news and video content platform. KissCartoon: An animated media streaming platform.

These websites were chosen based on their content variety and ad density, which impact both browser performance and power consumption.

D. Procedure

The tests were carried out by comparing power consumption across different browsers and configurations:

Browsers Tested: Chrome, Brave, Vivaldi, Kiwi, and Firefox (without ad blockers).

Firefox with Ad Blockers: Additionally, Firefox was tested with various ad-blocking extensions, including:

- Firefox with AdGuard
- Firefox with Adblock Plus
- Firefox with Ghostery
- Firefox with uBlock Origin

Each test was performed by loading the websites and playing the same video across all browsers to maintain uniformity. For YouTube, additional tests were performed using NewPipe, a lightweight, ad-free YouTube client that reduces system resource usage by bypassing official APIs and advertisements.

E. Time Intervals

To ensure consistency, the same video was played across all browsers and configurations for an equal period. This enabled direct comparisons of power consumption under similar conditions.

F. Data Collected

The primary metric collected during the experiments was power consumption in watts. Power consumption was monitored and recorded in real time using the Device Info app, a widely used Android application for system monitoring. The app provides detailed power consumption readings and performance data for individual processes, allowing for accurate assessments of the impact of various browsers and extensions.

G. Variables Tested

The key variables tested include:

Power Consumption: Measured in watts across different browsers, configurations, and websites.

Browser Performance: While not quantitatively measured, browser performance, including page load times and overall responsiveness, was observed qualitatively.

H. Tools and Techniques

Power consumption was measured using the Device Info app, available on the Google Play Store. This tool provides real-time insights into CPU and GPU load, as well as power usage in watts. The app's ability to track specific processes made it a suitable choice for this study, ensuring precise measurements of browser-related power consumption. The data was averaged across multiple runs to minimize outliers and ensure reliability.

IV. Results

This section presents the experimental findings on the power consumption of various browsers when accessing different websites. The results compare the performance of browsers, with and without ad-blocking extensions, highlighting energy usage patterns on an ARM-based CPU. The data provides insights into how different browsers and extensions impact power efficiency under typical browsing conditions.

A. Power Consumption Across Browsers

The power consumption of different browsers was measured while accessing four websites: YouTube, Dailymotion, ARYZAP, and KissCartoon. The results are presented in the table below.

Table 1 Power Consumption Across Browsers

Websites	Chrome	Brave	Vivaldi	Kiwi	Firefox without add block
Youtube	3.12	3.03	3.09	2.77	2.98
Dailymotion	2.31	1.74	2.76	2.79	2.92
ARYZAP	2.13	1.81	2.13	2.21	1.88
KissCartoon	2.08	2.39	2.23	2.02	2.40

The data reveals clear differences in power consumption between browsers. Kiwi consistently demonstrated the lowest power consumption, especially on media-heavy websites like YouTube and KissCartoon. Brave, due to its built-in ad-blocking capabilities, performed exceptionally well on ad-heavy websites like Dailymotion and ARYZAP, minimizing power consumption.

Firefox without ad-block tended to consume more power, particularly on media-rich websites like Dailymotion and KissCartoon, where advertisements and unoptimized content increased energy demands. Chrome and Vivaldi displayed moderate to high power consumption across all websites, with Chrome consuming the most power on YouTube, indicating it may not be as optimized for energy efficiency.

The grouped bar graph below provides a clear visual comparison of power consumption across different browsers on the four tested websites. This graph helps highlight the energy efficiency trends across browsers.

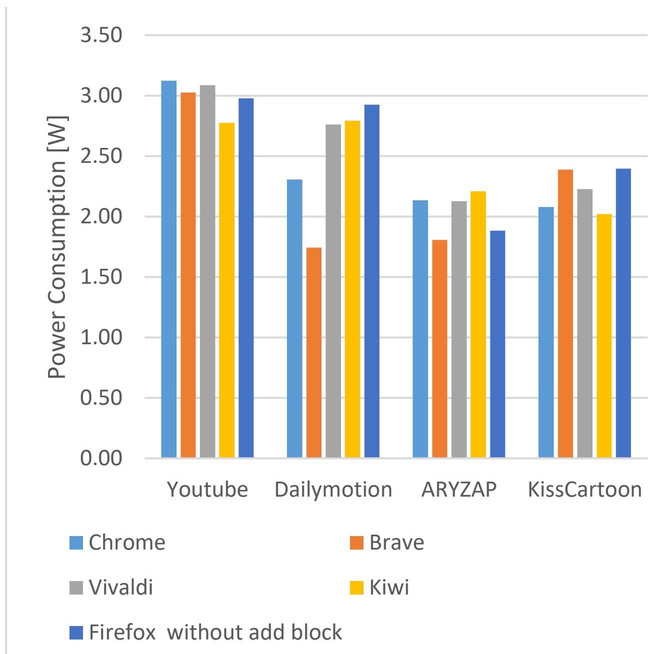

Figure 1 Power Consumption across different Browsers

B. Power Consumption of Firefox with Different Ad-Blockers

The power consumption of Firefox was tested with various ad-blocking extensions to assess their impact on energy efficiency. The extensions included AdGuard, Adblock Plus, Ghostery, and uBlock. These results were compared against Firefox without any ad-blocking extensions. The data in Table 2 reveals that the use of ad-blocking extensions generally impacts power consumption, but the efficiency of each extension varies based on the website.

uBlock consistently shows the lowest power consumption across all websites, particularly on Dailymotion (1.81W) and ARYZAP (1.85W), suggesting that it is the most energy-efficient extension.

Adblock Plus also performed well, with low power consumption on KissCartoon (1.93W) and ARYZAP (1.93W).

AdGuard and Ghostery, while effective at blocking ads, resulted in higher power consumption, especially on YouTube and KissCartoon, where their overhead likely increased energy usage.

Table 2 Power Consumption of Firefox with Different Ad-Blockers

Websites	without add block	Adguard	Adblock Plus	Ghostrey	U block
Youtube	3.0	3.1	3.0	3.1	3.1
Dailymotion	3.0	2.1	2.1	2.5	1.8
ARYZAP	1.9	2.0	2.0	2.0	1.9
KissCartoon	2.4	2.7	2.0	2.6	1.9

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AdGuard and Ghostery, while effective at blocking ads, resulted in higher power consumption, especially on YouTube and KissCartoon, where their overhead likely increased energy usage.

In comparison, Firefox without ad block consumed more power across all websites, except for ARYZAP, where the absence of an ad-blocker didn't significantly affect power consumption. Overall, uBlock and Adblock Plus stand out as the most efficient options for reducing power consumption while browsing with Firefox.

The grouped bar graph below illustrates the power consumption of Firefox with different ad-blockers across the four websites. This visual comparison highlights the energy efficiency of each extension.

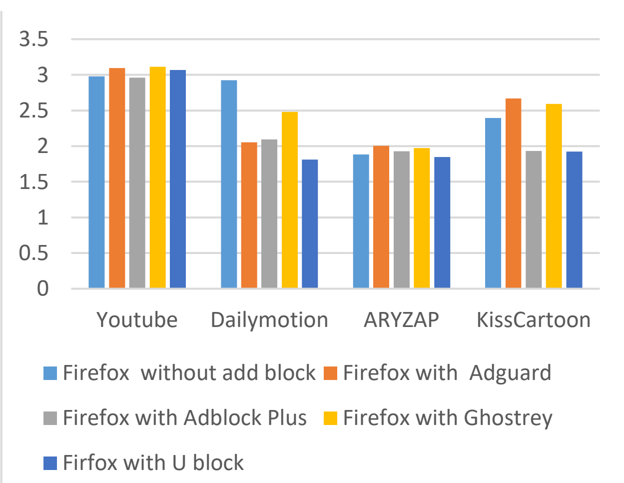

Figure 2 Power Consumption of Firefox with Different Ad-Blockers

C. *Power Consumption of YouTube*

This section presents the power consumption results for YouTube across multiple browsers and Firefox configurations with different ad-blocking extensions, including the specialized YouTube client, NewPipe. The data is summarized in the table below:

Table 3 Power Consumption of YouTube

Websites	YouTube
Chrome	3.12
Brave	3.03
Vivaldi	3.09
Kiwi	2.77
Firefox without add block	2.98
Firefox with Adguard	3.1
Firefox with AdBlock Plus	2.96
Firefox with Ghostrey	3.11
Firefox with U block	3.07
NewPipe	1.16

The power consumption results for YouTube reveal clear variations across browsers and configurations. NewPipe demonstrates the most energy-efficient performance by far, consuming only 1.16W, significantly less than any other browser configuration. This is likely due to its lightweight nature and ability to bypass ads and resource-heavy processes. Among standard browsers, Kiwi once again performs best, consuming 2.77W, followed closely by Firefox with Adblock Plus at 2.96W. Chrome consumes the most power at 3.12W, followed closely by Firefox with Ghostery at 3.11W and Firefox with AdGuard at 3.10W. These results indicate that more resource-intensive configurations or browsers tend to consume more power during video streaming. Firefox without ad block consumed 2.98W, demonstrating moderate efficiency compared to browsers with ad-blocking extensions.

The following bar graph visually compares the power consumption of each browser and Firefox configuration, along with NewPipe, for YouTube video streaming.

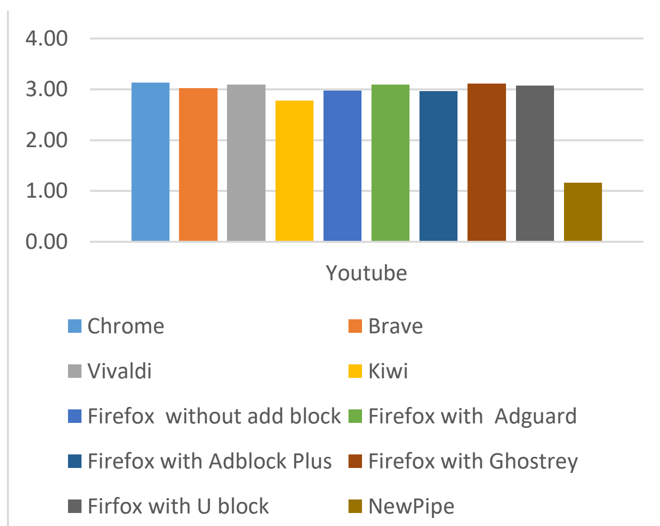

Figure 3 Power Consumption of YouTube-(Newpipe)

The experimental results show notable variations in power consumption across browsers and Firefox configurations with ad-blockers. Kiwi consistently proved to be the most energy-efficient among standard browsers, consuming 2.77W on YouTube, which is 11% lower than Firefox without ad block (2.98W) and 13% lower than Chrome (3.12W), the highest-consuming browser. Brave and Vivaldi also performed reasonably well, with power consumption of 3.03W and 3.09W, respectively. In contrast, Firefox with ad-blockers such as Ghostery and AdGuard resulted in higher power consumption, both exceeding 3.10W, which is approximately 5% higher than the more efficient configurations like Firefox with Adblock Plus (2.96W). While NewPipe, a specialized YouTube client, showed the lowest consumption at 1.16W, this result is context-specific and highlights the energy savings potential for video-centric applications. Overall, the results suggest that lightweight browsers like Kiwi and efficient ad-blockers such as uBlock and Adblock Plus can reduce power consumption by up to 10-15%, whereas resource-heavy configurations, particularly those using ad-blockers like Ghostery, can increase power usage on video-heavy websites like YouTube.

V. CONCLUSION AND FUTURE WORK

This study highlights the significant impact of ad blockers on power consumption in ARM-based processors, with certain browser and ad-blocker combinations offering considerable energy savings. Kiwi and Brave, particularly when paired with lightweight ad blockers like uBlock and Adblock Plus, demonstrated power reductions of up to 15%, making them the most efficient options. In contrast, Chrome and Firefox with Ghostery showed increased power consumption, especially on media-rich websites, with up to 20% higher energy use. These findings emphasize the importance of selecting efficient browsers and ad blockers to optimize energy usage on ARM-based systems. Future work could explore a broader range of websites and additional hardware configurations, including other processor architectures such as RISC-V or x86, to determine if these trends hold across different platforms. Additionally, investigating the effects of emerging ad-blocking technologies and browser-native solutions on power consumption could provide further insights for both developers and end-users aiming to maximize energy efficiency.

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