The Effect of Ad Blockers on the Energy Consumption of Mobile Web Browsing

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ABSTRACT
Online advertising forms the economic backbone of the internet. Content and services the user should normally pay for can now be accessed for free. However, advertisements are not always appreciated by the user. Due to the disturbances caused by advertisements ad blockers are becoming popular.

Downloading and rendering advertisements costs energy. An ad blocker prevents the browser from downloading advertisements. This might lead to less energy consumed while browsing websites that serve ads.

This paper researches the effect of ad blockers on the energy consumption of mobile web browsing. An energy model is developed to estimate the energy consumption of advertisements. This model includes the network infrastructure energy usage and energy consumed in the data centers. The client side energy usage and data transmission is measured during the experiments. With these values and the determined model, the energy reduction by using ad blockers is estimated.

The results indicate that on average, the energy saved by using an ad blocker is 28J for Wi-Fi and 324J for 4G/LTE. From the results it becomes clear that advertisements are responsible for 15 – 53 percent of the total energy consumed when browsing a website with advertisements on a smartphone. The average energy consumed by advertisements is 27% of the total energy consumed by smartphones.

Therefore, using an ad blocker largely brings down the energy consumption of mobile web browsing.

Keywords
Internet, ad blockers, online advertisements, energy consumption model, smartphone, mobile, web browsing, experiment, data transmission, data centers

1. INTRODUCTION

Almost every user of the internet has experienced them, online advertisements. Major technology companies rely heavily on income from online advertising. 89% of Google’s Q1 2016 revenue came from online advertising [1]. Facebook’s revenue came for 96% out of online ads in Q4 2015 [2]. Internet advertising revenues in the United States totaled $27.5 billion for the first six months of 2015. This is a 19% increase over the first six months of 2014 [3]. It’s safe to say that online advertising is the economic backbone for a very large portion of the companies active on the internet.

However, online advertisements are not always appreciated by the users and are considered disturbing. Most advertisements take up screen real estate, are heavy in terms of bandwidth, CPU and energy usage, take a long time to load, are distracting and are often served by third-party ad providers. This last fact influences the privacy of internet users, because most ad providers place tracking cookies (trackers): web scripts for building user profiles, serving targeted advertisements, tracing browsing behaviors and website statistics [4]. Also, ads threat the user’s security caused by cybercriminals who serve malicious content as ads.

The above disadvantages of advertisements have led to the rise of ad blockers. Ad blockers are pieces of software that remove advertisings of websites by amongst other things stopping the network requests for the advertisements. Examples of ad blockers are: Adblock Plus [5], Ghostery [6] and uBlock [7].

Adblock plus has reported in May 2016 that they have 100 million active users (active device installations) [8]. A 2015 report by PageFair and Adobe states that the number of people using ad blockers globally grew by 41% year over year. In the Netherlands there were 2.2 million monthly active users of ad blockers [9].

The Reuters Institute for the Study of Journalism at the University of Oxford talks about the following key finding in their Digital News Report 2015:

“Finally we find significant consumer dissatisfaction with online advertising, expressed through the rapid take up of ad blockers.”

This research shows that consumer annoyance with advertising has led to large numbers of ad blockers installations on their PC, mobile or tablet. 39% of the UK respondents (n = 2149) and 47% of the US respondents (n=2295) have installed ad blockers on their PC, mobile or tablet. The figures are even higher for the people between 18 and 24 (56% and 55% respectively) [10].

There is also a downside from blocking advertisements on the internet. Ad blocking results in decreased revenue to apps and websites that are dependent on advertisements for their finance. The report by PageFair and Adobe states that the estimated loss of global revenue due to blocked advertising during 2015 was 21.8 billion dollars. The global cost of ad blocking is expected to be 41.4 billion dollars by 2016 [9].

1.1 The problem

Although there are positive and negative aspects about online advertisings and ad blockers, there is another aspect that is often ignored: the impact of online advertisements on the energy consumption and the environmental footprint of the internet.
Advertisements are often animated and contain much graphical elements to attract and seduce the website visitor. This leads to advertisements that consume much client resources such as CPU, battery and bandwidth.

Online advertisements require energy for:
- the client for downloading, displaying and processing ads (CPU, memory, battery, networking)
- the infrastructure that is required for the data transmission between the client and the data centers of the ad providers
- the data centers that serve the online advertisements

Advertisements also lead to unnecessary extra connections from the client to the ad providers. This is shown in the sequence diagram of figure 1.

With this increase in energy consumption, the impact on the environment increases as well. Energy generation from coal, gas and nuclear power remains the status quo to power the internet. The International Energy Agency states that in 2013 80% of the worlds power consumption comes from non-renewable energy [11, 12]. In 2007, Gartner estimated that the pollution caused by the world’s internet usage was as high as the pollution of the entire airline industry [13].

Most surveyed studies focus solely on the client side energy consumption. Advertisements also require energy for the data transmission and the data centers. This research does include those factors and estimates the energy consumption of the whole system. Another focus point of most surveyed studies is the energy usage of ads on PCs and in-app advertisements on smartphones, but not the energy consumption of advertisement during mobile web browsing [14, 15]. This can be seen in the next section related work. This research focuses on the energy consumption of advertisements during web browsing on the smartphone.

This research focuses on smartphones when speaking about client side devices. This is the fastest growing platform when it comes to displaying online advertisements [3].

1.2 Related work

Research done at the University of Twente approximates that the power required to download and display web advertisements increase the total energy consumption of PCs by 3.4% [14].

Microsoft Research in association with UC Berkeley, looked at the energy consumption of popular apps on Android and Windows phones. The researchers found that a typical mobile app refreshes its ads every 12-120 seconds, which forces the radio network to be constantly re-awakened, after which the app will keep its 3G radio connection open for another 25 seconds. This period, known as ‘tail time’, results in the high-energy overhead incurred by ads. On average, ads consume 23% of the total energy, or 65% of the communication energy, of an app [15]. This is not about advertisements during mobile web browsing, but show results that advertisements do actually impact the energy consumption.

Dean Murphy, the developer of one of the first ad blocker for iOS 9 (Crystal), revealed benchmarks from a small experiment showing that it makes webpages load 3.9 times faster on average. The time to load is reduced by 74% and the bandwidth is reduced by 53%. By loading ten pages with ad blocker instead of without, 70 seconds and 35MB was saved [16]. Also network activity stops after the page is loaded with an ad blocker. This should reduce the impact on the battery of the device [17].

The New York times did a test with the iOS ad blockers Purify, Crystal and 1Blocker about their results on the 50 most popular news sites. They found out that more than half of all data came from ads and other content filtered by ad blockers. The battery life of the used iPhone increased by 21% when ad blockers were used, this is in the case the user only uses his iPhone to browse the web. They did not take into account the extra battery used by ads after the initial page has loaded [18].

Researchers of the Simon Fraser university showed that there is a 25% to 40% reduction in bytes downloaded when using ad blockers in a university network [19]. They used PCs in the setup, but the number might count for mobile as well.
1.3 Research questions
In this paper we try to answer the following research questions:
1. What are the factors that play a role in the energy consumption of online advertisements?
2. How can a model be developed to determine the energy usage of online advertisements?
3. Looking at the variables of the model developed in question 2, what is the effect of an ad blocker on the determined variables?
4. What is the influence of using an ad blocker on the energy consumption of the internet?

1.4 Approach and structure
It is difficult to directly measure the exact energy necessary for the processing on the client, the data transmission and the servers that serve the ads. Instead we determined the variables that influence the energy consumption of ads. This leads to a link between the determined variables and energy usage. Then we conduct an experiment to measure the effect of ad blockers on the determined variables. With these results we can determine the effect of ad blockers on the energy consumption of internet usage.

The rest of this paper is organized as follows. Chapter 2 explains the setup of the experiment to measure the effect of ad blockers. In chapter 3 we investigate the energy usage of online advertisements in depth and declare an energy consumption model for online advertisements. The results of this experiment are shown in chapter 4 and linked with the model from chapter 3. In chapter 5 the results are discussed. Chapter 6 contains the conclusion and answers to our research question.

2. TESTING METHODOLOGY
The challenge is to compare the total energy consumption of web browsing with and without an ad blocker enabled. To measure this, we need to separate the regular website content from the advertisements. By this we can measure the client side energy usage with and without advertisements and also the bandwidth costs in both scenarios. By measuring these values and comparing our developed energy model we can determine the energy consumption with and without an ad blocker.

2.1 Ad blocking
There are two main techniques used for ad blocking:
- URL blocking – With this method, every URL the browser requests is checked against a black list with known ad providers. If the URL is on the list, the request is blocked and the ad cannot be loaded.
- Content blocking – The website content is filtered by HTML and CSS rules. When an advertisement is found, the HTML will be removed and thus the browser won’t show the ad.

With content blocking the advertisement is downloaded but not rendered. When using URL blocking, the advertisement providers never receives a request and thus the advertisements is not even downloaded. URL blocking is more common [3] and is more energy efficient because it reduces the unnecessary load on the network infrastructure.

There are multiple ways to block web advertisements by URL blocking on a smartphone. Browser plugins like Purify [20] and Crystal [21] are popular options. However, we do not use these options in this research for the following reason: the plugins change the way the mobile browser works and thus our measurements can become inaccurate. It requires extra activities and computation power on the client for these plugins to work.

Instead of handling the URL blocking on the client we will use a separate device for the ad blocking process. An option is to use a HTTP proxy server to filter content. The proxy can block advertisements because all traffic flows through the proxy server. Disadvantages are that SSL traffic and JavaScript generated content are harder to block.

Instead of a proxy we use a Raspberry Pi 2 model B [22] with Pi-hole [23] installed. The Raspberry Pi functions as our own external Domain Name System (DNS) server. Users identify and remember websites by their URL (e.g. http://google.com). Servers in data centers are accessible by an IP address (e.g. 192.168.0.1). The DNS system is a mapping between the URL and the corresponding IP address. Before the browser can fetch the content of a website, it has to know the IP address that corresponds to the given URL. Therefore, the browser has to first do a DNS query to lookup the IP address. This process is shown in step 1 and 4 of the sequence diagram in figure 1. After the requested website is loaded (step 1-3), the JavaScript code that came with the requested website instructs the browser to load the advertisements from the advertisement providers. Again a URL (that leads to the ad provider) is given and the corresponding IP address is requested at the DNS server, our Raspberry Pi (step 4). The Pi checks every DNS request with the blacklist that contains all known advertisement providers. If the requested domain name is on the blacklist, it returns a domain name not found error. This behavior prevents that the advertisement is even requested, because the necessary IP address is not known.

We modified our rooted Android smartphone to use the Raspberry Pi as DNS server.

2.2 Client side energy consumption
We measure the energy consumption with and without advertisements with the mobile application PowerTutor [24]. The application can be used to rapidly, accurately, and conveniently determine the power consumption of an app. It is developed by researchers of the University of Michigan and Google for research purposes [25]. The app is optimized for the HTC G1, HTC G2 and Nexus one, the power measurements on other phone types can be less accurate because they have not been tested in the research. We conducted the tests with a rooted Samsung Galaxy S5 [26]. Because all tests are conducted on the same phone, the accuracy will not be an issue.

2.3 Bandwidth measurements
The data transmitted is measured by using Wireshark [27] installed on a MacBook pro 2012 retina 15 inch [28]. Wireshark runs in monitor mode which allows to capture all the packets exchanged between the smartphone browser and the webservers. By running Wireshark in monitor mode, all packet sniffing is passive and thus does not require any activities on the smartphone.

2.4 Web browsing
The webpages to visit should be realistic. This means that the websites should be common and well known and the amount of advertisements should be realistic. We visit 10 common websites in this research (see results). The websites are selected from Alexa [29], a ranking for popular websites. We chose the most accessed Dutch news and entertainment websites.

The list of websites visited is due to resources limited. Automated testing was not possible due to the EU Cookie Law which requires every website to ask their visitors whether they accept cookies. The automated script we built was not able to skip these pop-ups because they are not standardized.

Every website is visited on the Android Smartphone with the Chrome browser over Wi-Fi and 4G/LTE. The web browsing
process should be like an average person’s browsing habits. The websites are opened for 30 seconds and are scrolled from top to bottom. The cache is cleared before each visit so that the entire website is fetched and rendered every time. Every website is visited 5 times to filter out inconsistencies. The average is used as final result for each website.

3. ENERGY CONSUMPTION MODEL
To determine the factors that play a role in the energy consumption of advertisements on the internet we have to look at the energy consumption of the internet in general. We can define three major components in the internet system: energy consumption of end user devices when displaying advertisements, energy consumption of the network infrastructure to connect the client to the advertisements providers and the energy incurred in data centers [30–34]. The next sections explain for each component what variables influence the energy consumption of online advertisements.

Precisely estimating the power consumption of the entire internet is extremely hard because every data center is different, the route of each bit can differ over the network infrastructure and client side consumption differs per device. The model defined below tries to estimate the energy consumption in an average as possible.

The internet itself has a certain idle energy consumption. The core and metro/edge network require power, no matter what data is transferred. We estimate the extra energy per bit in the model below, not the total energy per bit.

3.1 Client side energy consumption
The process for displaying an ad is described in the sequence diagram in figure 1. The extra steps necessary specifically for the ad are shown in the bottom part of the figure. To display an advertisement on a smartphone, it needs to be fetched via the network interface (Wi-Fi or 4G), rendered by the CPU and displayed with the CPU and GPU [35–37]. To display ads there are extra network requests necessary because ads are not served by the content provider itself, but by third party advertisements networks. Examples are Google display ads [38] and AdRoll [39]. The display and network interface are the most energy consuming components of a mobile device [40, 41]. These components are used to display and fetch advertisements.

We estimate the energy usage on the client in the context of ads and without ads.

3.2 Data centers
The impact of data centers will be a fast growing part of the global IT sector energy footprint; their energy demand will increase 81% by 2020. Estimations are that the aggregated electricity demand of the cloud (data centers + networks, not devices) was 685 billion kWh in 2011 [42].

The power consumption and capacity of a general content server are gathered from [30]. The maximum power consumption is 225W and the maximum capacity 800Mbps. These numbers are based on typical content servers for advertisement servers [30, 43]. The baseline power usage with these servers is more than 80% of the overall power usage at peak load [30, 31, 44]. Thus we state the idle power usage to be 180W for a conservative estimation.

The power consumption of network devices increases almost linearly when the load increases [30, 31, 45]. Thus when looking at the active server that handles the request, the extra energy per bit is given by:

\[ P_{\text{max}} = \frac{P_{\text{idle}}}{C_{\text{max}}} \]

Where \( P_{\text{max}} \) is the maximum power consumption, \( P_{\text{idle}} \) is the power consumption in idle state and \( C_{\text{max}} \) is the mean network element maximum capacity.

Because datacenters should be capable to handle a surge in activity that could slow or crash their operations, datacenters are often over provisioned [44, 46, 47]. This means there is a utilization threshold of servers for adding new servers (\( \rho \)). 20% is a value often used for \( \rho \) [35]. For the idle power necessary for the overprovisioning to handle a surge in activity, the extra energy per bit is given by:

\[ \frac{(\frac{\rho}{2})P_{\text{idle}}}{C_{\text{max}}} \]

When we add these two formulas to estimate the mean incremental energy per bit (\( E_b \)) for both the extra energy necessary for the active server handling the request and the overprovisioning, we get:

\[ E_b = \frac{(\frac{\rho}{2})P_{\text{idle}} + P_{\text{max}}}{C_{\text{max}}} \]  \[35\]

Given the estimated data above, we state that the extra energy per bit is 1.2 \( \mu \)J/bit. This number can be used to estimate the extra power necessary for processing an advertisement request on the data center side.

3.3 Data transmission
When a user visits a website, the browser first downloads the content from the company’s webservers. This content contains the location of the advertisements. So after the actual webpage is loaded, the browser sends a request to the content servers of the ad providers.

When we look at the energy consumption of the network infrastructure to connect the client to the advertisements providers, there are 3 major components: the access network, the metro/edge network and the core network [48].

Figure 2: Internet network infrastructure (we include backbone in the core network). From [49]
There is a large amount of literature available about the energy consumption of the internet network infrastructure. To determine the energy consumption necessary for transmitting the advertisements, we will look at the results from these studies. This gives a more accurate estimation of the power consumption of the network infrastructure when keeping resources for this paper in mind.

The access network equipment connects homes and business to the local internet exchanges. Three technologies dominate the access network: fiber, copper and wireless [48].

The metro/edge network concentrates a large amount of access network connections. The local connections are routed around the local network, the rest is routed into the core network [48].

The core network is used for intercity and international communications. This internet traffic is exchanged between the core routers before being routed back to the metro/edge network [48].

A smartphone accesses the internet either via Wi-Fi or 2G, 3G or 4G/LTE. We will look at the energy consumption of downloading ads via Wi-Fi and 4G/LTE. For the metro/edge and core network, there is no difference in energy usage when sending data over 4G/LTE or Wi-Fi. Both traffic uses the same equipment. The energy usage of the access network equipment does differ when comparing Wi-Fi to 4G/LTE.

The EARTH (Energy Aware Radio and network technologies) project estimates in 2010 the energy consumption of a 4G/LTE connection under typical circumstances to be around 328 μJ/bit and 613 μJ/bit [50]. This difference is caused by a difference in traffic demand. The higher the traffic demand, the more efficient the cell towers function. The safer estimation of 328 μJ/bit is used in this research (20% heavy users).

When looking at energy efficiency improvements per year of wireless systems, we use the value of 26% [51]. When calculating the improved energy efficiency in 2016 with the 2010 value, we get the estimation for energy usage of 54 μJ/bit.

For Wi-Fi, we assume that a commercial Wi-Fi system (hotspot in airport for example) is used. From [52] we find that the energy per bit of a commercial Wi-Fi system (802.11.n using 2x2 MIMO, 300 Mb/s capacity at 30% network load) is 0.4 μJ/bit. The Ethernet switch adds around 0.007 μJ/bit. Thus, the energy usage of transmitting an ad via Wi-Fi is estimated at 0.4 μJ/bit.

Based on [30, 34] by using power consumption figures for representative commercial equipment in the edge and core network, the estimated energy required for transmitting advertisements over the metro/edge and core network is equal to 2.7 μJ/bit. This includes the Ethernet aggregation switch that forms the entry point to the metro/edge network and the Ethernet switches in the LAN inside the data center. Redundancy for all network elements is taken into account.

### Table 1: Energy consumption model summarized

<table>
<thead>
<tr>
<th>Type</th>
<th>μJ/bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datacenter</td>
<td>1.2</td>
</tr>
<tr>
<td>Metro/edge + core network</td>
<td>2.7</td>
</tr>
<tr>
<td>Wi-Fi access network</td>
<td>0.4</td>
</tr>
<tr>
<td>4G/LTE access network</td>
<td>54</td>
</tr>
</tbody>
</table>

### 4. RESULTS

The most important results from the experiment are shown in table 2. The values are given by measurements without an ad blocker minus the values with an ad blocker. This gives the extra energy consumption and data traffic that is a consequence of downloading and rendering advertisements.

The total energy in joules is the sum of the client side energy consumption plus the energy consumed in the network infrastructure and data center. The energy consumption of the network infrastructure and data center is estimated with the variables estimated in chapter 3 (see table 1) and the extra bandwidth used because of advertisements. The ad overhead is the percentage of energy used for downloading and rendering advertisements.

On average, the energy saved by using an ad blocker was 28J for Wi-Fi and 324J for 4G/LTE. From the results it becomes clear that advertisements are responsible for 15 ~ 53 percent of the total energy consumed when browsing a website with advertisements on a smartphone. The average energy consumed by advertisements is 27% of the total energy consumption.

### Table 2: Extra energy consumption and data traffic due to advertisements

<table>
<thead>
<tr>
<th>Website</th>
<th>Connection</th>
<th>Client side energy usage (J)</th>
<th>Bandwidth (MB)</th>
<th>Total energy (J)</th>
<th>Ad overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>voetbalzone.nl</td>
<td>Wi-Fi</td>
<td>0,4</td>
<td>28</td>
<td>71</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>10</td>
<td>13</td>
<td>238</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>21%</td>
</tr>
<tr>
<td>tweakers.net</td>
<td>Wi-Fi</td>
<td>0,5</td>
<td>19</td>
<td>43</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>6</td>
<td>238</td>
<td>53</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>20%</td>
</tr>
<tr>
<td>rtlnieuws.nl</td>
<td>Wi-Fi</td>
<td>0,7</td>
<td>28</td>
<td>47</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>12</td>
<td>336</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>336</td>
<td>16%</td>
</tr>
<tr>
<td>urc.nl</td>
<td>Wi-Fi</td>
<td>0,7</td>
<td>30</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>13</td>
<td>337</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>337</td>
<td>16%</td>
</tr>
<tr>
<td>ad.nl</td>
<td>Wi-Fi</td>
<td>0,5</td>
<td>20</td>
<td>43</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>6</td>
<td>238</td>
<td>43</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>335</td>
<td>22%</td>
</tr>
<tr>
<td>voetbalzone.nl</td>
<td>Wi-Fi</td>
<td>0,9</td>
<td>37</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>7</td>
<td>424</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>424</td>
<td>15%</td>
</tr>
<tr>
<td>volkskrant.nl</td>
<td>Wi-Fi</td>
<td>0,4</td>
<td>19</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>4G/LTE</td>
<td>6</td>
<td>191</td>
<td>24%</td>
<td>24%</td>
</tr>
</tbody>
</table>

### 5. DISCUSSION

The results show that there is a remarkable energy impact caused by displaying advertisements on a website. The estimations for the energy consumption model from chapter 3 are based on conservative assumptions. An assessment [53] of multiple internet energy consumption researches shows that there is a substantial difference between estimations for the internet energy usage. Partly because the included components of the internet differ per research. In this paper all components are included and the estimations are on the lower side of the spectrum.
Ad blocking itself costs energy too. This research used an external ad blocking mechanism which is not very common. Most ad blockers run in the browser and thus require energy from the client. We estimate that this energy consumption is relatively low compared to the entire energy usage of advertisements, but for a complete overview it should be researched further.

What has not been discussed is that by improving battery life by using an ad blocker, there is a positive effect on the battery replacement cycle which might eventually lead to even less energy consumed when users use an ad blocker [54]. This is not in the scope of this research however.

Advertisement is one of the most popular business models on the internet, but not all websites have ads. This research only looked at websites that server advertisements. Regular internet users also visit websites without advertisements.

6. CONCLUSION

The factors that play a role in the energy consumption of online advertisements are:
- the client side energy consumption for downloading, displaying and processing advertisements
- the core, metro/edge and access network that is required for the data transmission between the client and the data centers of the ad providers
- the processing and overprovisioning in the data centers that serve the online advertisements

In this paper a model is developed to estimate the energy consumption of advertisements when transported over the network infrastructure and the power consumption of the data centers that serve the advertisements. Most works on the topic of energy consumption of advertisements have ignored the energy consumption of advertisements in the access network, edge/metro network and core network. Also data center energy usage is not always included. This paper includes these components as well as the client side energy usage.

The estimated energy saved by using ad blockers is 28J when the user browses the web over Wi-Fi and 324J when using 4G/LTE. The average energy consumed by advertisements is 27% of the total energy consumption. This number is an estimation but indicates that ad blockers do have a significant positive impact on reducing the energy consumption of mobile web browsing.

Most energy is saved because of the lower amounts of data traffic. The most energy is consumed in the network infrastructure. When data traffic is less, this is reduced. Also 4G is an energy hog compared to Wi-Fi. With 54 µJ/bit, every advertisement that is not downloaded leads to a large energy consumption saving.

The results in this paper show that an ad blocker should be used when users want to lower their energy consumption while web browsing and eventually want to lower their impact on the environment. Reducing the size of advertisements would also help to reduce the energy impact of advertisements.

The implications of this paper become clear after reflecting the results on a real world example. Based on data [55] of the Statistics Netherlands we state that 94% of the Dutch population has access to the internet. 81% of these internet users use it (almost) every day. When we estimate that the average user visits 5 websites with advertisements a day, we find that 12,943,800 Dutch daily active internet users visit roughly 24,000,000,000 websites with ads a year. We assume 1/3 of the websites is accessed over 4G and 2/3 is accessed over Wi-Fi. When all Dutch internet users use ad blockers, 3,036,000,000,000 Joules a year is saved on average solely by the Dutch daily active internet population.

The average energy consumption of a Dutch household was 3050 kWh in 2014 [56]. 3,036,000,000,000 Joules a year is equal to 843333 kWh. This is the yearly energy consumption of roughly 275 Dutch households.

6.1 Further work

Due to practical limitations of the EU cookie law automated testing was not possible, thus the amount of websites researches is limited. For future work it will be interesting to conduct the same experiment with more websites to visit.

Also it would be interesting to look at the actual energy cost of ad blocking when executed on the client. Although most energy is saved in the network infrastructure, ad blocking will costs some energy.

When conducting the experiment, the number of requests made and time to load were also logged. From the results becomes clear that with an ad blocker enabled, the number of request was between 36% and 56% lower than without an ad blocker. Not only the amount of bits transported but also the number of requests made might influence the energy consumption. Further research should be done to conclude this.

7. REFERENCES


