# Estimating the Cost of Wasted Energy During Overcharging Smartphones and Using COVID19 Apps

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**Abstract—**Energy wastage through irresponsible smartphone use comprises a significant sum. Using a secondary desk-based literature review, this paper evaluates contemporary literature to calculate an approximate estimate of the amount of energy wasted through irresponsible smartphone use by US users on an annual basis. Conservative estimates purely based on overcharging of smartphones in the US suggest that the figure is in excess of US$400m per annum. A variety of factors contribute to irresponsible smartphone use, which are predominantly behavioral in nature. This paper highlights some of the impacts of excessive smartphone use and considers steps which might be taken by users themselves to reduce energy wastage during smartphone use. In addition, suggestions are made to manufacturers to help them 'nudge' users into more responsible behavior through the principles of behavioral economics.

**Keywords—**energy-consumption, smartphones, sustainability, user-behavior, COVID19

## 1 Introduction

### 1.1 Background

Smartphone use has arguably become ubiquitous on a global basis, with smartphones becoming an almost essential item for everyday use. However, as Bokhari in [1] observe, surprisingly little attention is directed towards the energy use of smartphones, and more specifically irresponsible or unintended habits in smartphone use which contribute to energy waste. Although on the one hand some research suggests that practices such as overcharging have minimal cost on an individualized basis [2], the aggregation of this individual waste is likely to contribute to a very significant sum indeed.

### 1.2 Problem statement

The purpose of this paper is to conduct a secondary literature review of contemporaneous research papers' efforts to estimate the approximate amount of energy wasted annually by smartphone users. Further, to evaluate the different irresponsible or unintended usage habits which contribute to this waste, and offer recommendations to both smartphone manufacturers and users to decrease the battery charging time and thus hopefully reduce the amount of energy wasted through irresponsible smartphone use.

### 1.3 Relevant literature

One of the first problems likely to be encountered in seeking to evaluate energy waste through irresponsible smartphone use, is that in the words of Pärssinen in [3] "there are no commonly agreed ways to assess … total energy consumption". Multiple factors are likely to contribute to energy waste through smartphone use, including but not limited to, overcharging or continuous unnecessary recharging [4]; using cheap nonbranded charges whose energy usage can be anything up to 20 times that of branded or recommended chargers [5]; having an excessive number of apps open at any one time [6]; failing to timeout screens during non-use [6]; playing videos purely for the purposes of listening and not watching [7]; and keeping unnecessary apps open, e.g. location services, when not in use [8].

A variety of factors might explain such irresponsible usage habits. These factors include: (1) a strong emotional desire to be permanently connected to the Internet; (2) an unawareness of the impact of irresponsible use in energy wastage terms; and (3) a belief that small-scale minor irresponsible individualized use makes no difference to wider energy wastage or consumption. A study by Fullwood in [9] indicates that for younger smartphone users, emotional factors drive these behaviors including a fear of missing out and an almost visceral desire to be permanently connected to the Internet because it is associated with friendship, leading to behaviors that are almost addiction-like in their manifestation.

### 1.4 Value of the paper

From the perspective of manufacturers, it appears that although they have conducted market research with regards to the expectations of battery use time by users, and also the ways in which battery runtime can be improved, there does not appear to be joined up thinking with app providers about users' behavioral habits. This apparent gap in the research contributes to the value of this paper, in that it attempts to consider both sides of the problem of energy wastage through smartphone use, most notably changing behavioral habits of users, prompted or 'nudged' by manufacturers under the principle of behavioral economics.

### 1.5 Proposed approach

The proposed approach is to conduct a systematic literature review based on timely literature (within the last five years) from reputable sources.

## 2 Method

The method adopted in this paper is of systematic secondary literature review. This method has been increasingly embraced into research discipline of technology and is regarded by Johnston [10] as a methodology whose time has come. Xiao and Watson [11] assert that in order to "push the knowledge frontier, we must know where the frontier is", going on to further assert that it is only "by reviewing relevant literature, we understand the breadth and depth of the existing body of work and identify gaps to explore".

To conduct this type of research, it is necessary to clearly articulate the research problem, and to define the key terms. Table 1 below reflects this approach.

**Table 1.** Problem statement and key search terms

| | |
|---|---|
| **Research question** | What is the approximate annual energy waste from smartphone use, and what factors contribute to this? |
| **Search sentence** | "Smartphones" AND "energy waste*" AND "battery discharge*" OR "overcharging*" OR "app use*" |
| **Sources of information** | SCOPUS, Google Scholar, Emerald, Industry sources |

Inclusion and exclusion criteria require only incorporating timely research papers published within the last five years (i.e., from 2017 onwards) and favouring reputable academic sources such as highly cited journals. In addition, recent practitioner papers from reputable sources were also incorporated, particularly in relation to quantitative evidence on the amount of energy wasted. Industry papers were also considered relevant in order to evaluate practical methods for helping to reduce battery discharge times. Once papers were identified using the systematic literature approach, they were grouped according to the three key themes of this paper, with the results and discussions below.

## 3 Results and discussion

### 3.1 Approximate amount of energy wasted

Figures vary on estimates as to the approximate amount of energy wasted by smartphone users on an annual basis. Much depends on the methodology of calculation, and also making quite broad estimates as to the behavioral factors and habits which contribute to energy use. A simple first step by Matyjaszek [5] was to calculate the cost in financial terms of unnecessary overcharging, the most common habit or practice identified in the paper by Gao [4] as contributing to energy wastage through smartphone use.

Matyjaszek [5] found that two key factors directly contributed to energy wastage which are first, charging the device for longer than is necessary, because the chargers continue to draw energy from the power grid. Second, using nonbranded charges, which in his experiment he found to be anything up to 20 times more inefficient than branded charges. Matyjaszek [5] went on to compare energy usage costs across three states in the US to illustrate that financial cost implications of overcharging are likely to vary contingent on geographical location, but ultimately determining that for one device, overcharging per year probably costs in the region of US$1.46.

However, as Matyjaszek [5] observes, whilst this might appear to be a very small sum of money aggregated across the year, if individuals have multiple devices, and if even half of the population of US smartphone users are engaging in this practice, then the energy wasted costs are likely to be in excess of US$220.20m across the US as a whole. Data gathered by Statista [12] reveals that across the US, there are an estimated 301.65m smartphones in active use in 2022 (Figure 1) meaning that using very broad averages, the approximate amount of energy wasted annually by smartphone users in the US alone purely on the basis of battery overcharging can be estimated at US$440.40m.

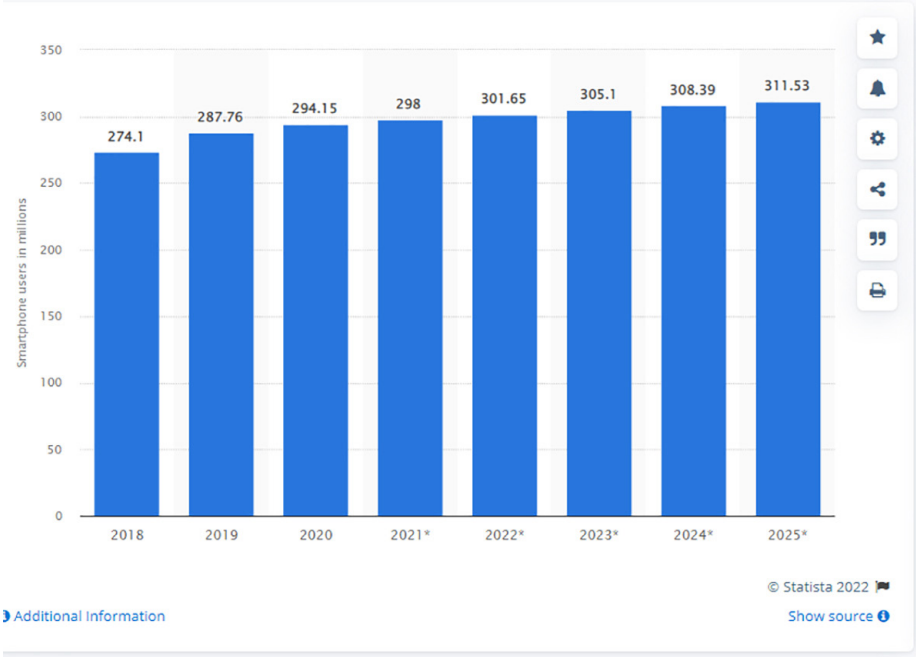


**Fig. 1.** Number of smartphones registered active in the US 2018–2025*

### 3.2 Attempting to establish unit measures of energy wastage

An alternative approach to establish unit measures energy wastage was carried out by Tawalbeh in [13] who evaluated energy consumption and waste through app usage on iOS and android devices, specifically Galaxy Note3 and Sony Xperia Z. The purpose

of this study was to obtain a "more accurate understanding of how these components [apps] participate to the overall power consumption of the smart phone [sic]". Looking at specific applications in use of each device, they found consistently that operating 3G (the study was carried out in 2016) was the most power-hungry element of each device, being more power-hungry in the galaxy than the Sony, but that the OL ED (organic light-emitting diode) was also a highly power hungry element. Collectively, the use of 3G, the OL ED, and the Wi-Fi interface accounted for approximately half of the energy usage of any device (Figure 2). The authors concluded that improvements could be made to energy usage by mobile phone providers in these three areas specifically to help improve the battery life devices, and dissuade users from frequently and unnecessarily charging their devices because of power consumption.

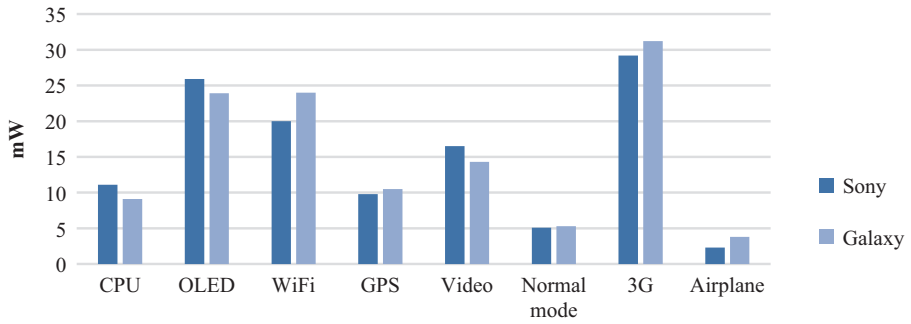


**Fig. 2.** Comparison of energy usage on selected apps between a Sony Xperia and a Galaxy

A subsequent study conducted by Riaz [14] in 2018, extended of the work of Tawalbeh [13] by repeating the experiment in relation to 10 devices. Riaz [14] found that even by two years later, mobile device manufacturers had already managed to improve power consumption from the Wi-Fi interface, but in some instances, power demand for 3G, and also either OLED/LED consumption also considerably increased. This appeared to be matched to the size of the device screen, and also expectations about resolution of the images. Riaz [14] did not speculate as to what might have caused actual increase in power demand for particular apps, but it is speculated that as camera quality has increasingly become a desired feature of smartphone devices; this may partially explain the spikes in demand. From this it can be inferred that developers and manufacturers are aware of these differences, but are not making active changes to systematically improve power consumption.

### 3.3 Irresponsible or unintended habits causing waste

Considering some of the behavioural habits which are identified as contributing to the unintended energy waste through smartphone use, it can be reasonably confidently asserted that these are predominantly behavioural driven by a desire to remain 'perpetually connected', consistent with the findings of Fullwood in [9].

Pivetta [24] brought together several studies that highlight a few problematic behaviors that may be associated with excessive smartphone use; including symptoms related

to addiction, stress and sleep disturbances, financial problems, dangerous driving, or antisocial and prohibited use. Furthermore, the possibility of being constantly connected to the Internet has been found to increase the potentially unregulated and excessive use of smartphones for entertainment purposes such as social networking, video games and gambling or streaming services [28].

It can be assumed that even small changes in consumption habits in the use of smartphones can help to reduce energy waste. Furthermore, these new habits can contribute to the reduction of potential environmental and human health impacts from e-waste Kang, DHP [26].

An empirical study by Twenge [15] evidenced that small practices such as encouraging users to delete unused apps or shut down apps when not in use helped with unnecessary energy use. Also, changing the timeout screen to remind users to use less energy when the device is not in use [27]. Such settings can be manually changed by users, but could also be predetermined by manufacturers before selling smartphones, and behaviorally it is quite likely that a proportion of users would not change the manufacturer settings [15]; either because they do not know how to, or because it does not occur to them to do so. Changing behavioral habits associated with overcharging devices is more difficult, because of the perception of the need to be permanently connected, but in a study by Saxena [16] it was found that it was possible to encourage users to at least reduce their charging practices to once-a-day rather than leaving their devices permanently plugged in.

### 3.4 Recommendations to decrease battery charging times

Recommendations to manufacturers to decrease battery charging times would be to install presets which engage with screen timeouts, and do not visually encourage users to charge unnecessarily, for example showing the battery as 30% in red font which creates a sense of unnecessary danger [17]. Also, not preinstalling as many apps, referred to in industry jargon as ‘bloatware’ when these apps run likely to be used [18]. Also, behavioral ‘nudges’ such as visual reminders on smart phones to turn off the device when not in use and to preset screen timeouts at a shorter timeframe. Once again, relying on the principle of the accumulation of incremental gains, manufacturers can also contribute to practices to reduce energy wastage by smartphone users through the application of behavioral economics principles.

### 3.5 COVID-19 apps and the social need for energy

Several health authorities with a wide network of digital solutions for controlling the spread of COVID-19 are using mobile applications to measure the proximity of contacts, whether by GPS, Bluetooth or other wireless technologies. Note that in [19] some European Union (EU) countries are funding a mobile application report to support the location of contacts in the fight against the pandemic. An application model that can be used on animals and individuals by means of a passive RFID tag without the presence of a smartphone, guarantees anonymous execution until the carriers have tested positive for COVID-19. The data is sent to the IoT component hardware [19].

The model uses blockchain for data storage. To minimize the high congestion of data collection in applications through the cell phone and the transfer of all this data to the cloud, the researchers developed a new IoT structure called a real-time monitoring system for patients with COVID-19 (RS- SYS), which has an endpoint and contains different information about the status of users obtained through a sensor [20].

For COVID-19 disease control to be effective, contact tracking technology must be accurate, contacts must be tracked quickly and a significant percentage of the population must use a contact tracking application on the smartphone. For that, an app was created to evaluate efficiency and cost a stochastic model that becomes a deterministic model for detecting contacts with the disease. The application works via Bluetooth, which allows greater selectivity to place people in quarantine and has a great impact on the social and economic cost [21]. The researchers Sowmiya alerts to a growing concern with the collection, use of data and security in the use of these applications. The authors analyzed a large set of applications to track and implement different security and privacy measures [22][23].

## 4 Conclusion

This short paper has carried out a secondary systematic literature review to investigate the problem of energy wastage through irresponsible smartphone use. The review has determined that it is predominantly behavioral factors by users which contribute to energy wastage, the most prominent of which being overcharging, and unnecessary background running apps on devices. It is very difficult to derive a precise estimate for the approximate amount of energy wasted, but for overcharging alone across smartphone devices currently registered as active in the US the amount has been estimated at US$440.40m annually. The present study is relevant because according to the World Health Organization (WHO) [25] the dysfunctional and excessive use of electronic devices is a public health problem of international relevance (2015), supporting the need to provide scientific evidence on the individual factors involved in its startup and maintenance. Practical recommendations for users and manufacturers to help reduce this issue have been offered.

## 5 Acknowledgment

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