

Comparison of paper and electronic devices and measures to reduce carbon emission

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Abstract. "Carbon neutrality" goals have become a topic of growing concern in recent years, but the way students read is already causing a lot of carbon emissions to the environment. This article explores the two ways students use paper books and electronic products to read, and compares the annual carbon emissions of these two ways. The results show that traditional paper reading is more low-carbon and environmentally friendly, and has a wider audience, but the carbon emissions of both methods cannot be underestimated. This paper further explores relevant measures that can be taken to minimize the carbon emissions of reading to the environment, such as companies can find more environmentally friendly alternative materials, the government can appropriately increase recycling prices to promote the recycling of waste paper and electronic products, users can improve own reading habits to improve the utilization of paper and electronics, etc. This paper looks forward to finding better solutions to the massive carbon emissions caused by the use of paper books and electronic products, and hopes to mitigate the environmental hazards associated with the use of paper books and electronic products.

Keywords: carbon neutrality, paper reading, paperless reading, carbon emission, measures.

1. Introduction

With the intensification of global greenhouse effect, the harm caused by climate warming has become a pain that is difficult to heal in the 21st century. Climate warming has attracted attention all over the world. At present, the voice of reducing carbon emissions is rising day by day. How to reduce carbon emissions scientifically and effectively has become the focus topic. Reducing greenhouse gas emissions and taking care of the beautiful earth are the common challenges of all mankind. In recent years, under the guidance of sustainable development theory, a series of concepts such as carbon footprint, carbon trading, low-carbon life and low-carbon products have emerged. We should examine the current carbon emissions of paper and electronic products, make use of their respective advantages and cooperate together to create the concept of energy conservation and emission reduction and promote sustainable development. At the 75th UN General Assembly, China proposed to strive to achieve "carbon peak" by 2030 and "carbon neutrality" by 2060, develop green economy and build a green society.

The development of low-carbon economy requires not only low-carbon products, but also low-carbon and reasonable ways of using products. Therefore, how to treat the carbon emission of paper and electronic products is particularly important. Xu Shiyong [1] and Liang Junping [2] proposed in the research on carbon emission accounting and low-carbon development path of China's paper products that according to the estimation of the whole life cycle of paper products and the analysis results of carbon emission impact factors in main stages, feasible ways for green and sustainable development of China's paper products are put forward from the aspects of structure and consumption. However, so far, no scholars have made a targeted comparison between paper carbon emissions and carbon emissions consumed by electronic products. Therefore, this paper studies the carbon footprint

of paper and electronic products and reasonably selects learning and reading methods to reduce carbon emissions.

The purpose of this paper is to explore whether the carbon emission of electronic equipment is higher than that of traditional paper-based learning, and whether the improper recycling of e-waste will lead to further environmental pollution.

2. Method

2.1. Data source

2.1.1. Data source of paper

In 2020, China's paper and cardboard consumption will be 118.27 million tons, with an annual per capita consumption of 75 kilograms [3]. According to relevant statistics, a piece of ordinary A4 paper weighs 5g [4], and the carbon emission of 1 ton of ordinary cultural paper is 1.092 tons [5]. On average, college students use 10 books per semester, with an average of about 300 pages per book [6]. According to Fig. 1 and Fig. 2, students also consume a certain amount of paper when copying and printing.

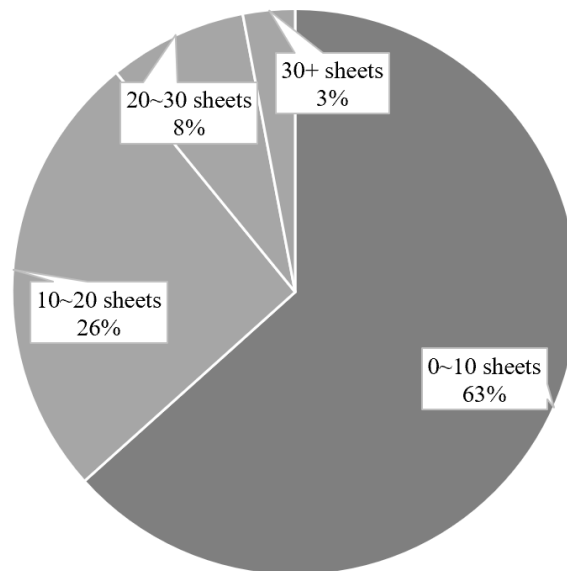


Figure 1. Copying and printing paper consumption by college students in normal weeks [4].

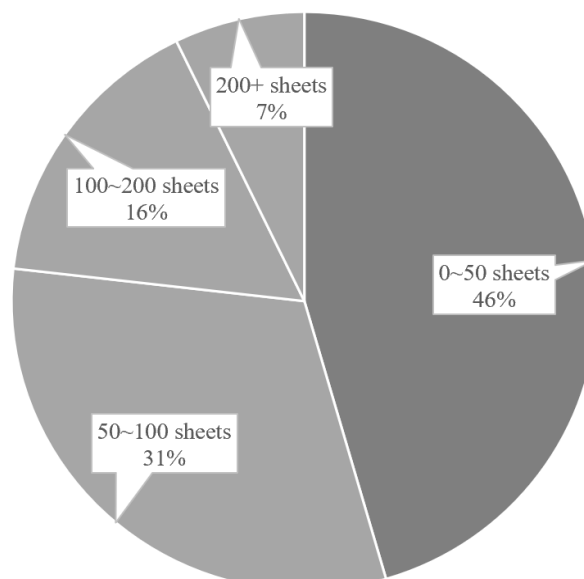


Figure 2. Copying and printing paper consumption by college students in final weeks [4].

2.1.2. Data source of electronic devices

Apple takes a total market share of 37%, making it ranks first in the market. Therefore, here takes Apple products as examples. The annual carbon emission product report released by Apple [7] shows the carbon dioxide emissions of each generation from production to recycling. Among them, the 8th-generation iPad is the most popular. According to Table 1, it ranks first with 56% of the total iPad shipments, followed by the iPad Air 4 with 19% and the iPad Pro series with 18%. [8] Fig. 3 shows that apple’s best seller’s greenhouse emission has actually been decreasing during the past years, from 135kg in 2017 to 70 kg CO₂e in 2020, the 8th iPad generation Reduced CO₂e emissions by half. The one that rises a bit in 2021 is because apple canceled the 32GB storage and upgraded it to 64 G. But overall, the carbon emissions are still on the decline.

Table 1. Carbon Footprint of Different Generations of iPads [7].

Source	Sales	Total emissions (kg CO ₂ e)
iPad Pro(256GB)	18%	110kg
iPad Air 4(256GB)	19%	96kg
iPad 8th(128GB)	56%	78kg
iPad mini(64GB) and others	7%	68kg

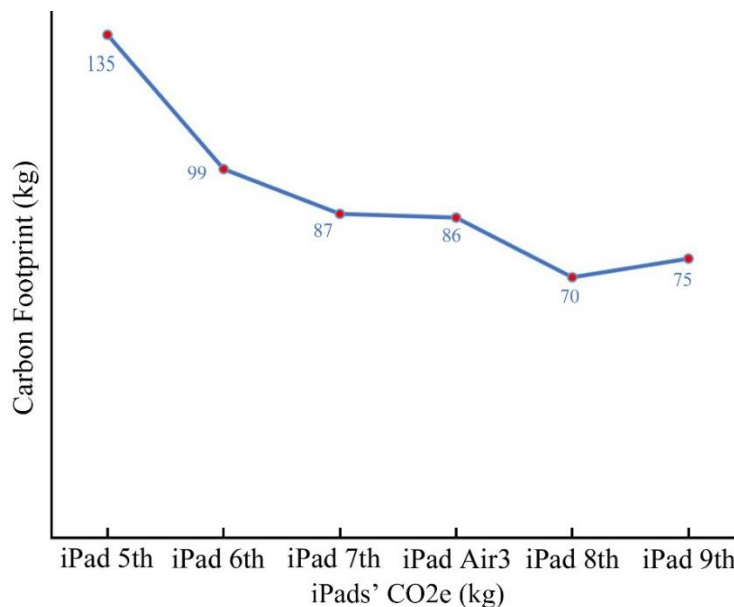


Figure 3. The Carbon footprint trend of typical iPad generation [7].

2.2. Carbon Footprint Calculation Method

2.2.1. Paper

The paper consumption of college students is mainly concentrated in textbooks, and the amount of paper used by students for copying and printing will also occupy a certain proportion, especially during the final exam, a large amount of materials and documents will be copied and printed. Therefore, according to the actual situation of paper consumption, this paper divides the statistics of students' paper consumption into two parts for investigation: the paper consumption of textbooks, and the consumption of copying and printing paper. The amount of paper used for copying and printing will vary significantly with different time periods, so it is divided into two dimensions: the usual week and the end-of-period week. After obtaining the per capita paper consumption of students, according to the carbon emissions of paper, the carbon emissions of students in paper reading can be calculated.

2.2.2. Electronic devices

The calculation of the iPad is direct. Here calculates the proportion of different generations to get an overall average, which represents the carbon emissions of a college student who buys a tablet. At

the same time, extra power consumption would still be taken into account due to the study time and add them together to get the final result. Here, the household electricity' formula would be used to calculate the CO₂e emissions during extra power consumption.

$$\text{CO}_2\text{e} = 1/1000 \text{ watt} * 0.785(\text{kg})$$

3. Results and discussion

3.1. The carbon footprint of paper

According to the relevant survey report on the amount of textbooks used by college students, on average, each college student uses 10 books per semester, and about 20 books in a year. An average book is about 300 pages, and 20 books are about 6,000 pages, so each college student uses about 6,000 pages of textbooks a year. Figure 1 shows the survey statistics on the amount of paper used by college students for printing and copying. The weekly paper consumption is less than 10 sheets, accounting for 62.7%. It can be seen that the daily paper consumption of college students is relatively small. If the weekly paper consumption is less than 10 sheets, it is calculated as 5 sheets, and if the paper consumption is more than 30 sheets, it is calculated as 40 sheets. Through the weighted calculation, the average weekly paper consumption of college students is: $5 \times 62.7\% + 15 \times 26.1\% + 25 \times 8.4\% + 40 \times 2.8\% = 10.27$ sheets. Figure 2 is the survey statistics on the paper consumption of college students during the final exam period. Similarly, the weighted average calculation is performed. If the paper consumption is less than 50, it will be calculated as 25 sheets, and if the amount of paper is more than 200, it will be calculated as 250 sheets. The per capita paper consumption in the period is: $25 \times 45.5\% + 75 \times 31.3\% + 150 \times 16\% + 250 \times 7.2\% = 76.85$ sheets. According to the above two sets of data, the per capita annual copying and printing paper consumption of college students is as follows Statistics: There are 52 weeks in a year, of which 4 weeks are exam weeks, and the other 3 months are winter and summer vacations, so 13 weeks need to be subtracted, so the usual week counts as 35 weeks. Then the amount of paper used for copying and printing for each college student in one year is: $10.27 \times 35 + 76.85 \times 4 = 666.85$ sheets. According to the amount of paper used by students for books and copying and printing in one year, it can be concluded that each college student uses about 6666.85 sheets of paper in one year. The weight of a piece of ordinary A4 paper is 5g, and the carbon emission of one ton of ordinary cultural paper is 1.092 tons. Furthermore, it can be calculated that the paper consumption of students in one year is 33.33 kilograms, and the carbon emission is 36.40 kilograms.

3.2. The carbon footprint of electronic devices

In the latest report [7], the carbon emission of iPad 8th in its life cycle is 78kg CO₂e. If compare with 0.17061kg of greenhouse gas emissions per 1km of medium-sized cars, the carbon emissions of buying and using a tablet computer are equivalent to 457km of medium-sized private cars [9]. For the comparison between paperless learning and paper-based learning, here, calculates an average emission according to the sales ratio of different types of iPads to estimate the average carbon emissions of a college student when buying and using iPads. Therefore, if one college student buy an iPad, the average carbon emissions generated would be:

$$(110\text{kg} * 18\%) + (96\text{kg} * 19\%) + (78\text{kg} * 56\%) + (68\text{kg} * 7\%) = 86.52 \text{ kg CO}_2\text{e}.$$

In the previous screen usage time based on user feedback statistics, users who used 5~8 hours account the most. And the average life span is 5 years. Since the research of paperless learning is mainly focused here, the time that students use the tablets will be the focus of our concern. For college students, if the iPad replaces paper books completely, the study time of a day using the iPad will exceed six hours. Here, assuming that each student uses the iPad to study for 6 hours every extra than normal people (Taking homework into consideration, holiday time will not be subtracted here), and assuming a lifespan of 5 years, the carbon emissions of students using the iPad are shown in Table 2.

Table 2. The Carbon Footprint in Extra Study Time [7].

Source	Total power use (Watt/Hour)	Total emissions (kgCO ₂ /year)
1. iPad Pro(256GB)	2.4	4.13
2.iPad Air 4(256GB)	3.17	5.45
3. iPad 8 th (128GB)	2.73	4.47
4. iPad mini(64GB) and others	1.95	3.29
Electricity carbon emission on average		4.51

Thus, the average carbon emission generated by one student who is assumed using the iPad for paperless learning in one year would be: $(86.52/5)+4.51=21.84\text{kg CO}_2\text{e}$.

3.3. Comparison

From the calculations above, it can be seen that the annual carbon emission of college students studying with paper material is 17.3kg, while the carbon emission of iPad is 21.84kg CO₂e. However, not all of the tablets can be recycled effectively, nor all tablets are as environmentally friendly as Apple. Here uses Apple as an epitome to look at a general carbon figure. There are still many tablet manufacturers that produce more CO₂e in the manufacturing process, not to mention many tables have a shorter life cycle, which means they produce a lot of e-waste in a shorter period of time. That is to say, the overall carbon emission data may be larger than our calculation. What's more, when tablets become scrapped, there comes e-waste. Heavy metals such As, Cd, Cu, Pb, Cr, Mn are important harmful chemicals released in the dismantling process of e-waste. These heavy metals might get into pregnant women's blood and eventually affect the mother and babies [10]. Lead, which is also found in e-waste, is a neurotoxin, and improper handling of it means it can seep into the ground and cause further pollution. Electronic products not only consume a large proportion of resources in transportation, consumption, and recycling but also have very complicated procedures to be completed in the process of disposing of e-waste.

For paper learning, compared with any iPad generation except iPad mini, the emission of it is much lower. What's more, other factors, such as using second-hand paper, borrowing books from libraries, using recycled paper, may all make paper-based learning more environmentally friendly than paperless devices in terms of carbon emissions. What's more, paper also does not need to consider the pollution and other potential harm that e-waste may cause to the environment. In this way, paper-based learning seems to be superior. But tablets certainly have the advantage of convenience and versatility. So how to make electronic products better replace paper study and reduce its impact on the environment will be the concern in the next stage.

4. Measures

4.1. Enterprise

4.1.1. Paper

Xiamen Changsu Industrial Co., Ltd. independently developed an environmentally friendly material, BIONLY. This material can replace the outer plastic film of the product packaging, play the functions of waterproof, scratch-resistant, enhanced touch, etc., and can also improve the packaging texture. Most of the old packaging plastic films are petrochemical-based materials, which are difficult to degrade completely even after hundreds of years. The production and use process will also increase carbon emissions and affect the ecological environment. The raw material of BIONLY comes from starch extracted from plants, which has good biocompatibility and degradability, and its raw material carbon emission is about 70% lower than that of traditional fossil-based plastics such as PP [11]. Not only does this material better display the colors and patterns of the packaging, it also helps reduce glue usage, is environmentally friendly, and can meet the various effects and tactile requirements required for packaging. Moreover, using this material for paper book packaging can play a good

protective role, increase the service life of paper books, solve the problem of plastic degradation, and greatly reduce carbon emissions. In addition, JD.com has proposed "green packaging" measures, which, with the help of green supply chain infrastructure and carbon reduction technologies, can reduce carbon emissions by an average of 400 grams per package [12]. During 2021, a total of 108.3 billion pieces of express delivery will be collected and delivered in my country [13]. If all use "green packaging", it will reduce 43,320,000 tons a year, which is about the carbon emission of paper books for 31 years of national higher education students.

4.1.2. E-waste of Tablets

In the tablets section, enterprises should actively publish annual environmental reports, and let the public jointly supervise and urge enterprises. Firstly, reduce the direct emission of greenhouse gases in the production process and use recycled materials such as aluminum, rare earth elements, plastics, etc. Secondly, improve the utilization rate of renewable energy, such as wind energy, water energy, and biochar, and reduce the impact of traditional energy on the environment. Thirdly, reduce carbon emissions in the process of logistics sales and refuse over-packaging. Finally, enterprises should actively associate with the e-waste reverse logistics centers mentioned above, which makes the whole process form a positive cycle.

4.2. Government

4.2.1. Paper

China Energy Law proposes that a clean, low-carbon, safe and efficient energy system should be built. At the same time, the Chinese government has also implemented a series of policies to encourage people to save resources and live a green life. In 2017, the price of waste paper recycling fluctuated violently. After the sharp rise, there was a cliff-like decline, which led to a violent oscillation in the paper packaging industry chain. Almost all customers were taking measures to de-paper packaging to cope with the skyrocketing price of waste paper recycling. At this time, people began to realize that it is imperative to save resources and establish a recycling system for renewable resources. Therefore, under the premise of stably abolishing the recycling market, the government should appropriately increase the recycling price and establish a recycling and utilization system for renewable resources. This will encourage people to recycle and reuse paper products, and the government can also reduce the cost of waste sorting. As for the recycling system of renewable resources, it is a systematic project involving a wide range of social welfare properties, so the government needs to actively guide it. Sun Yujiao pointed out that the construction of renewable resource recovery system should be included in the government's macro management and regulation. By giving full play to the roles of all aspects, a development mechanism of government guidance and support, enterprise investment, market operation, and social participation will be gradually formed, and the construction of the recycling and utilization system of renewable resources will be improved [14].

Comprehensively improving the environmental protection literacy of college students is also a concern of the government. At present, most of the school education models in our country are indoctrination education, and students receive more theoretical knowledge in textbooks, but they do not have a deep understanding of actual production and life, and they do not have a strong awareness of energy conservation and environmental protection. The government should introduce the relevant advanced practices of developed countries in this regard, such as selecting relevant news disclosed by the media, and carrying out relevant content activities, which are widely and repeatedly publicized on campus, so that college students can reach a very high level of energy conservation and environmental protection awareness.

4.2.2. E-waste of paperless products

In 2019, the world had faced up to 53.6 million tons of e-waste waiting to be dealt with, only 17.4% of e-waste is officially recorded and recycled, which means that most e-waste might be threatening the environment. To prevent the generation of e-waste from the source effectively, it is undoubtedly

a top priority to recycle electronic products. Here, suggestions are provided in several aspects to urge the attention of relevant departments, and also to help countries to achieve the goal of net-zero [15].

In the case of the successful transformation of Guiyu, the "city of electronic waste dismantling" into a positive circular economy, its former ineffective classification only focused on the recovery of economic benefits, and the random landfill and discard of harmful electronic waste had caused a large area of Guiyu's chemical contamination. Because of the importance attached by the government to Guiyu, targeting plans had been implemented. They had improved the original small workshop-style into centralized park management, from focusing only on economic benefits to focusing more on recycling with environmental protection effects. These aspects are worthy of reference and improvement for the classification and treatment of e-waste in the future.

Here, supporting universities to build up student e-waste reverse logistics centers, which is an effective cycle for paperless and other electronic equipment recycling. Taking the university town as the central unit and each school as the sub-unit, an electronic product recycling center could be established. After centralized recycling, classification is carried out, and the sorting equipment is connected with the corresponding operators outside the school, and continuously optimize the transportation in terms of environmental and economic effects. A professional electronic recycling center can ensure that all parts of electronic products can be properly and effectively processed and reused, rather than being randomly discarded and entering into a complex waste treatment plant, which would lead to electronic products not being effectively recycled, but instead causing a negative impact on the environment. Furthermore, the government should urge all enterprises to disclose the carbon emission list, limit the production of enterprises that exceed the standard emission, and punish enterprises that produce piracy, pollution, and use materials that are difficult to recycle, so as to reduce the possible impact of electronic products on the environment and users at the source.

4.3. Customer

In 2019, the contact rate of digital reading methods among Chinese adults was 79.3%, an increase of 3.1% compared with 2018 [16]. This data shows that digital reading has become a common way of reading and has been integrated into our daily learning. However, no matter which reading method students choose, they should have a good reading habit, and maximize the role of electronic reading or paper reading. First of all, students should improve their awareness of the use of the library. Statistics on the borrowing of paper books by students in a certain university in recent years show that the amount of borrowing in the library has become less and less, and the total amount has decreased by about 50% in five years. And the borrowing range has also been significantly reduced by about 33% [17]. If students improve their awareness of the use of the library and increase the frequency of reading materials and documents in the library, it can greatly reduce the number of books students buy each year, and at the same time, it can improve the utilization rate of books in the library and effectively reduce the need for paper reading. aspects of carbon emissions. Second, consumers need to consider whether paperless learning is really right for them. If you bought a tablet but still use paper books heavily (which is fairly common among college students, i.e. tablets are not for learning, but for entertainment. But phones and laptops can also do to this point), then you'll have to weigh whether or not your options will be taxing on the environment before you buy. Last but not least, paperless consumers need to choose more qualified, safer and more environmentally friendly businesses. Whether the product is environmentally friendly and energy-saving, and whether it has a long service life, is not only a consideration for consumers when purchasing, but also a guarantee for the future environment. When the equipment is scrapped and needs to be recycled, choose a professional recycling unit or hand it over to the original manufacturer for recycling to reduce the possibility of environmental pollution caused by electronic waste.

5. Conclusion

Since the epidemic has become normalized, more and more college students can't attend classes over long distances but take classes online. Therefore, the tablet has become a convenient choice for them to take classes online. With the advantage of being lighter than laptops and clearer than mobile phones, the supply of tablets soon falls short of demand. This paper discussed the carbon footprints of both paper and paperless learning. Overall, compared with traditional paper-based learning, the tablet has higher carbon emissions, and the e-waste generated by improper recycling may lead to further environmental pollution. Though it is a more environmentally-friendly choice to study with recycled paper, this paper also puts forward measures to make it possible for paperless learning to become equally environmentally friendly. Therefore, both the government and enterprises should try their best to reduce the carbon footprint of electronic products, especially in the source and manufacturing process, and effectively classify and recycle electronic wastes to maximize their benefits. In this way, no matter how the students learn, they can save energy and reduce carbon. At present, students should choose the learning style that suits them best. In the future, more environmentally friendly materials and better recycling methods need to be discovered and promoted. There is still a great deal of work to be done about the optimization measures of learning means. Effective research in a more environmentally friendly way can make the world reach the goal of net-zero as soon as possible.

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