The Digital Carbon Footprint: Threat to an Environmentally Sustainable Future

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THE DIGITAL CARBON FOOTPRINT: THREAT TO AN ENVIRONMENTALLY SUSTAINABLE FUTURE

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ABSTRACT

With digitalization at its peak, every online action we take has an environmental impact. There is a growing concern about the world's ever-increasing carbon emission due to technological advancement. The vast majority of human actions have been proved harmful to the environment. This effect has been mostly tied to available carbon emissions. On the other hand, recent findings have raised awareness of digital carbon emissions. These harmful emissions represent the available CO2 emissions rate resulting from generic digitization concepts. The advancement of technology has considerably contributed to CO2 emissions. This study paper discusses the total effects of carbon emissions. It also shows the rates of carbon emissions caused by the tech industry worldwide. The article describes how digital services have boosted carbon emissions and the number of regions affected by the higher rates. The study focuses on the relationship between carbon emissions and digitization, remedies to the problem, and an overall analysis of the global digital carbon footprint.

KEYWORDS

Digitalization, Digital carbon footprint, CO2 emission, Global warming, NARDL Approach, FD & CO2 emission nexus, Sustainability.

1. INTRODUCTION

The world is undergoing digital transformation, which is accompanied by the hype of universal buzzwords such as Industrial Internet of Things (IIoT), smart manufacturing, smart banking, digital twins, and Industry 4.0, which is a phenomenon of our time, lauding the possibilities of a new technological revolution [1]. However, there is growing concern over the world's ever-increasing carbon footprint due to excessive data processing and digitization. CO2 emissions have been a leading sustainability issue due to their environmental impacts. Carbon emissions contribute significantly to global warming, and this issue has therefore created a growing problem in the community today. Global warming, in turn, has been researched to result in more global impacts, which inconvenience the lives of most people. One of the significant issues associated with global warming has been the rising sea levels. Reports have indicated that most islands and beaches will be completely submerged in the next thirty years. This leads to the need to manage carbon emissions [2]. However, current remedies have been hampered by rising CO2 emissions caused by increased digitization and technological advancement. Most people's lives have been profoundly impacted as a result of this. The primary purpose of this study is to explain the effects of CO2 emissions and how digitalization has contributed to these effects.

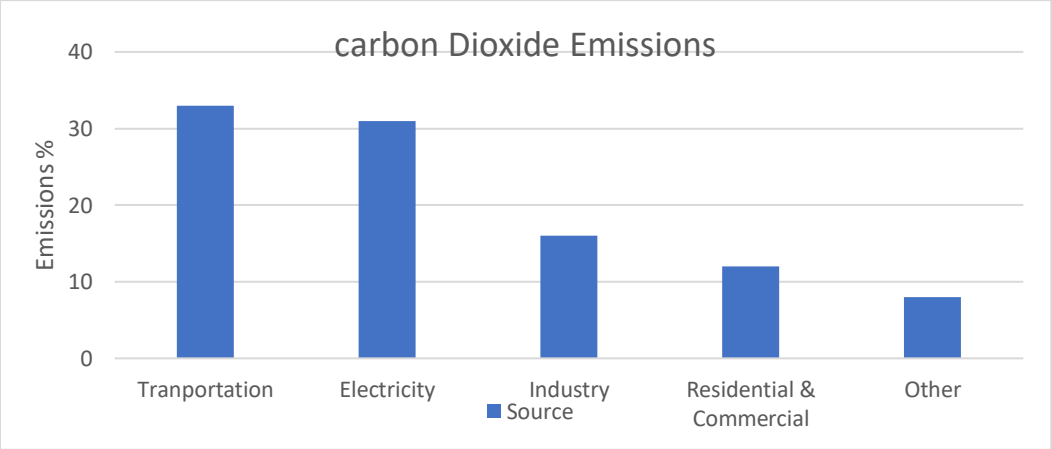
2. OVERVIEW OF CARBON DIOXIDE EMMISIONS

The atmosphere represents the space that surrounds the entire world. It is described as being the blanket that covers the whole planet. The gases which protect the earth in the atmosphere are

regarded as greenhouse gases. The US greenhouse gas emissions overview showcased that CO2 led with a 79% composition, whereas other gases include Nitrous Oxide, methane, and Fluorinated Gases [3]. Each of these gases has been associated with the rise in global warming over the last few decades [4]. They have been associated with the action by different countries and organizations of shifting to less impactful processes. As per the previous BRICS summit, the long-run estimates reveal a negative and significant effect of digitization on CO2 in Brazil, India, and China [5].

CO2 emissions are described to result from several human and natural activities. Each of these activities contributes toward emitting a specific amount of carbon into the atmosphere. Human activities, however, contribute a much larger volume of gases every year, which was the leading reason why the US recorded carbon emissions of 79% [2]. This creates an ultimate problem for the entire nation [6]. The graph displayed below (see Fig 1) shows the sources of carbon emissions in the US in 2020 [2]. The chart shows how different factors have a significant contribution towards impacting the amount of carbon in the atmosphere. Furthermore, economic expansion, financial development, and energy consumption all contribute to increasing carbon dioxide emissions in China and other emerging countries. In light of these findings, environmental scientists recommend developing-country governments to integrate digitalization and environmental development programs by increasing spending in research and development [5].

Fig 1.



Source: Factors contributing to CO2 emission [2]

The graph shows the percentage of all emission estimates of greenhouse gases in the US. The chart shows that transportation has been a leading source of carbon emissions in the US. The graph, however, showcases that electricity is closely followed by 31%. The slight difference has been associated with the rise of electricity as a cause of carbon emission. The graph, therefore, showcases that the overall increase in electricity usage has been associated with the cost to the environment [7]. The graph perfectly represents how people's electricity usage has skyrocketed over the past few years. This could be described as being contributed by the available digitization of the globe over the past few years. The impacts associated with the rise in electricity usage can be seen in the graph. Based on it being a leading energy source, it indicates that electricity is estimated to have been the cause of emission for around 24% of US total greenhouse gas emissions, suggesting that it is a problem.

3. REVIEW OF LITERATURE

Digitization can be described as several processes that contribute to making life easier. Some of the processes associated with digitization include internet communication, cloud computing, server backup, real-time analytics and visualization, and video entertainment. Each of these factors contributes toward making people's lives easier and becoming a standard operation for different individuals every day [8]. Technology has become an effective place where people may obtain various services which they need in their lives.

The use of the internet accounts for the most significant percentage of carbon emissions. The increased electricity usage can be showcased by the people who use electricity to access different online services. Jungblut [9] indicated that the world population has more than half of the people online. Around four billion people are using the internet today [10], and this was by 2019 when several changes happened. The above study found that more than a million people enter online each day. The different online activities have contributed to an increased emission of carbon.

Access to any digital service is becoming expensive every day. The access people obtain to any digital service requires electricity to be used [11]. The electricity used is from the individual using the computer and the servers providing this service [8]. The smartphones also consume a lot of electricity since they require to be charged after the service has been offered [12]. The communication networks and ISPs also use considerable electricity to provide the different services available. The internet is primarily a substantial amount of electricity use due to servers needing to urn 24 hours each day to ensure people access these contents [8]. YouTube servers, for example, are always required to be active so that people may have access to these videos from any part of the world at every time [13]. The computers and servers in these organizations are implemented and required to remain running to ensure that people obtain the services they need.

Digital technologies account for 4% of Greenhouse gases, and their energy consumption increases by 9% per year [14]. Studies have indicated that some server warehouses contain data centers that are always very huge, and these warehouses contain data centers of up to 40,000 square meters [14]. The servers within these data centers always remain operational all year round, resulting in considerable amounts of power being used daily. Therefore, the portion of the electricity used from servers and data centers is vast. Despite a rise in the use of renewable electricity, it accounts for a small percentage of electricity being used by data centers. Studies indicate that around 30% of data centers run on a 24/7 basis. This results in wastage of data estimated to be approximately 5-10% of their total capacity [14].

A recycling and conversation journal report indicated that an hour of video conferencing emits around 157 grams of carbon [9]. Therefore, the increased rate of video conferencing across the globe results in vast amounts of carbon being emitted [11]. The report also indicated that individuals with weekly conferencing hours of around 15 hours would reduce their carbon footprint by over 9 kilograms [9]. This rate equals an individual charging a smartphone every night for three years [15]. Therefore, the carbon footprint resulting from digital concepts is a growing issue. This is associated with the increased electricity use over the past few years. Thus, the ever-increasing global changes contribute to increased effects in the atmosphere due to increased carbon emissions. Digitization affects carbon footprint can be seen effectively by examining digital services organizations [16]. Simple digital services like video conferencing and website hosting contribute to an increased impact on the planet. This influence is specially developed from the size of these organizations [17]. A good example is an organization like Microsoft. The employees in the company and the services the company offers significantly impact the planet due to increased carbon emissions.

Several digitization services and developments have majorly contributed to carbon emissions across the globe. These services and developments have especially impacted the US, increasing carbon emissions worldwide. The internet generates 1.6 billion tons of greenhouse gas emissions per year [16]. These impacts have all contributed to several changes experienced across the planet. These changes are associated with increasing developments, and more people appreciate these technologies [18]. The overall changes related to such changes have contributed to the daily rising carbon emissions. Below are several digitization concepts that have resulted in an increased impact on carbon footprint across the globe. Each of the factors described showcases a development in technology associated with technology usage and increased carbon emission. Most of the activities described as using electricity are found on the internet. The activities range from e-payment methods, e-commerce, streaming and entertainment services, and finance systems, among many others [16]. Each of these factors has been described below as a potential effect on the available carbon emissions resulting from digital services.

3.1. Search engines

With over 4.66 billion active internet users globally, accounting for over 60% of the global population, we can make a difference. Search engines have become indispensable in today's environment, and Google's expanding growth demonstrated edits reliance on search engines. The company's profits from the ad system have continued to rise, and serving these clients has a more significant influence on the earth's ecological [16]. People using their electronic gadgets to obtain these searches have contributed to this. According to Jens Gröger, senior researcher at the ko-Institute, the estimated carbon emission from an individual's query is 1.45 grams of CO2 [9]. Assuming that a person conducts 50 search queries per day, approximately 26kg of CO2 emissions per year [9]. According to the study, Google's environmental report described a carbon footprint of 2.9 million tons of CO2 in 2016 [9]. The 2017 report also told the energy consumption by the company to stand at 6.2 terawatt-hours (TWh) [9].

3.2. Music and video streaming

Research by The Shift Project found that 80% of data moves through the internet in the form of images [9]. This means that online videos on different platforms contributed significantly towards a large portion of the carbon footprint from the internet. The above report indicated that 60% of the global data transfer was downloaded videos. The images require vast amounts of data, which requires a considerable amount of electricity to transfer. The development of higher resolution devices has increased the available data amount on the internet [19]. The Shift Project described that the average CO2 consumption of streaming online video is over 300 million tons every year [9]. This was showcased in the measurement included in 2018. The CO2 emission represents the overall CO2 emission recorded by Spain in the same year [9]. This show cases how music and video streaming impact the environment tremendously.

Streaming a Netflix video was also described as the power consumption of 0.12-0.24 kWh of electricity per hour. These figures are estimated since people use different devices and require different resolutions for the videos they are streaming. The network connection has also been described as influencing the exact amount of power consumed. This creates a challenge in determining how Netflix streaming has contributed to the CO2 emissions across the globe [19]. Music streaming has also been described as having a significant effect on the environment through its greenhouse gas emissions. Jungblut [9] indicated that music streaming resulted in around 200 to 350 million kilograms of greenhouse gases being emitted into the atmosphere. The report suggested that streaming services like Spotify and Apple music also contributed to the effects on the environment. The disposal of CDs and music records also resulted in an

environmental impact. This was especially experienced when the records were burnt, which pushed even more carbon into the atmosphere.

3.3. Internet usage through mobile Apps

Mobile phones account for a significant portion of total daily electricity consumption due to mobile phones' wireless network connection. Since buildings, vegetation and weather weaken the electromagnetic network connections, more power is always included to ensure that the networks have reached their destination. Jungblut [9] suggests that copper lines and fiber optic cables also contribute to the power consumption from the need to amplify the signal through electricity. The power coverage is therefore affected by the distance associated with every individual. This aspect also affects mobile users' current carbon emissions and power usage [20]. They, however, contribute significantly to the carbon footprint of digital technology.

3.4. Cloud Computing

The carbon footprint has significantly been associated with the increased use of cloud computing applications. Cloud computing is among the digitization processes related to an increased rise in carbon emissions. Cloud computing has become a recently appreciated technology over the past few years. Jungblut [9] describes it as being a significant power guzzler. By definition, cloud computing refers to the technology associated with storing data in computers where they can be accessed remotely from any location [20]. It typically refers to the technology where specific software and data have been backed up for people to access from any location (Kessel et al., 2008). A good example of cloud computing technology is how people can access their emails anywhere. The emails have been backed up over the internet, allowing people from different locations to access these data.

Although cloud computing has been described as an effective method of saving power and storage for people, it has also been very power consumptive. Cloud computing requires that servers are always connected to the internet to ensure that people can access their information. Cloud computing companies and services have been described to be very lucrative. According to recent trends, many organizations overuse digitalized services to process Big data and analytics for data-driven insights [22]. Also, the digitalized trend is at its highest during this COVID-19 pandemic. This aspect, therefore, suggests that more servers always remain plugged in, ensuring safety has been achieved. Thus, this aspect can increase the carbon footprint associated with cloud computing. Cloud computing technologies are being appreciated daily. Technology has been described as an essential part of many organizations. The increased adoption of cloud computing services can therefore be described as a contributing factor to the rise of cloud computing. The increased growth associated with cloud computing services creates a larger digital CO2 footprint across the globe [23].

The servers and users of the cloud computing services can be described as part of the growing digital footprint associated with cloud computing. Microsoft and Amazon are leading cloud computing service companies. They have recorded steady growth for the respective cloud computing applications [23]. Continued growth is another concept indicating the increased growth within the growth associated with the cloud computing service. The steady development has significantly impacted CO2 within the nation [24]. The steady increase of users means that the servers are being used more. This usage, in turn, results in a continued influence across the community. This rise indicates that more efforts are required since the digital carbon footprint is developing significantly, which risks the state of the globe in general.

3.5. Blockchain and cryptocurrency technologies

One of the breakthroughs in finance has been the concept of cryptocurrency. Cryptocurrency technology has been described as being the future of finance. Jungblut [9] illustrates that cryptocurrency is among the leading causes of a rise in the digital carbon footprint. Cryptocurrencies work by allowing different machines to hold records for all transactions, making them more secure and reliable [23]. However, ensuring many devices save this data has created a challenge for the current carbon footprint. The appreciation of more computers increases power usage across different parts of the universe [25]. More people continue to abuse the power they have been provided with, which increases the overall risk associated with a high carbon footprint [26]. The high carbon footprint of cryptocurrency can be seen in the increase of crypto miners across the globe. Mining has been described as another way people can gain some profits off crypto. This method has been described as being very power-consuming. Crypto miners are, therefore, the leading people engaging in digital carbon footprint.

The issue of crypto mining has been abolished in several states. This has been associated with the high-power consumption and how it affects the power grids of these states. Jungblut [9] described that a report by the Bitcoin Energy Consumption Index (2018) explained that a single Bitcoin transaction consumes around 819 kWh. Reports indicate that there are a lot of transactions associated with bitcoin in a single day. This has also created a significant issue, and hundreds of cryptocurrencies have developed [27]. Each of these currencies has contributed to an increased power usage which influences the current global carbon footprint. Therefore, cryptocurrency has been described as a leading caron emitter regarding the new world order. The development of other blockchains has contributed to increased power consumption, resulting in more carbon in the atmosphere.

According to Jungblut [9], a single bitcoin account's amount of energy utilized equals a refrigerator's total energy consumption for almost eight months. This factor, therefore, showcases that the issue of digital carbon footprint is more in comparison to the carbon footprint which people had before the risen digital carbon footprint. The above study [9] also indicated that a report by the Technical University of Munich determined the entire system of bitcoin procedures around 22 megatons of carbon dioxide per year. The increased power usage represents a high amount of carbon emitted to the atmosphere resulting in different impacts on the earth. CO2 emissions have therefore been a leading aspect associated with increased effects on the globe through cryptocurrency impact. The consequences associated with the digital carbon footprint have been recorded to be associated with an increased number of global effects. These effects all promote a continued impact on the planet. The environment continues to experience several effects through the issue of cryptocurrency and blockchain technologies. Miners have also contributed significantly to the rise of power usage, making this a leading influence on environmental development.

4. THE DIGITAL CARBON FOOTPRINT

A study by Gani [28] found that political stability, the rule of law, and control of corruption are negatively associated with CO2 emissions. The above analysis showcases that the leading issue with technology development has been power consumption, which is the ultimate effect of increased technology development [28]. Technology and data centers have contributed to a significant rise in power consumption. This power consumption greatly influences the CO2 included in the atmosphere [29]. Therefore, this has been the main factor associated with an increased carbon footprint from digital technology. The rise of these technologies has all been described to have particular impacts on the environment due to the available increase in carbon

emissions. The overall increase in carbon emissions is estimated to be primarily contributed by the rise in data centers by most companies today [30]. Most of the digital methods described above showcase an increased cause of energy consumption as the cause of CO2 emissions. The influence of data centers showcases a growing issue that requires an effective solution. Resolving the power consumption issue across most data centers will reduce their carbon footprint [20]. Finding effective and better methods to cool the server system better will promote the carbon footprint associated with digital technology.

Although energy consumption is a leading cause of carbon emission for technology companies, the cooling systems in some data centers have also been recorded to release various chemicals into the atmosphere [31]. These chemicals contribute to the overall amount of carbon in the atmosphere. Therefore, the increased number of data centers results in more chemical substances being subjected to the atmosphere. These substances continue to influence the carbon footprint of these data centers. Finding effective methods of cooling the data centers would reduce their carbon emissions. The analysis showcases an increased issue associated with several technologies and their carbon footprint [32]. Each of these issues requires that an effective solution has been created to resolve the subject available. Focusing on these issues will promote the necessary developments globally [33]. It will also limit most of the effects associated with global warming due to increased carbon emissions. The analysis proves that digital methods create an increasing impact on the planet which must be resolved. The increased technology production from practices such as coal electricity production, in turn, increases carbon emissions across the atmosphere.

The move to finding practical solutions which reduce CO2 emissions due to digitalization is an effective and required area of focus. The effects of carbon emissions affect people's livelihood, indicating the need for developing a practical solution that avoids these impacts and promotes people's lives. This solution will significantly reduce the effects associated with carbon emissions [34].

5. DIGITAL FINANCIAL DEVELOPMENT AND CO2 EMMISIONS

In the past few years, a new empirical study has emerged to investigate the relationship between digital financial development and CO2 emissions in various nations. Another study looked at income, financial development, and trade on carbon emissions in the global economy. The dynamic vector correction model was used; the empirical data demonstrated a favorable relationship between financial development and carbon release. Furthermore, the Granger causality test [35] established the unidirectional relationship between continuous expansion in financial development and carbon release. Below is an association of financial growth (FG) and CO2 emission using the Nonlinear Auto-Regressive Distributed Lag (NARDL) model.

$$CO2t=\gamma 0+\gamma 1FGt+\gamma 2EUt+\gamma+3FD+t+\gamma-4FD-t+\varepsilon t \quad ---(1)$$

Here, CO2 denotes carbon emissions of order one, FG denotes financial growth of order one, EU denotes energy use of order one, FD is financial development of order one, and $\gamma=(\gamma 0, \gamma 1, \gamma 2, \gamma, +3, \gamma+4)$ is a vector of unknown long-run factors. The findings (Table 1) of this model show that the relationship between financial development versus CO2 emissions shows a positive correlation for developing nations, whereas, for developing countries, it shows a neutral or negative trend.

Table 1.

Country	Findings
Nigeria	FD negatively affects CO2 emissions.
China	FD positively affects CO2 emissions. It causes CO2 emissions to surge further.
Turkey	No relationship was found.
Indonesia	FD negatively affects CO2 emissions.
India	FD has a positive effect on CO2 emissions.
Pakistan	FD has a positive effect on CO2 emission.
UAE	FD positively affects CO2 emissions.
USA	FD negatively affects CO2 emissions.

Source: Summary of studies on the financial development vs. CO2 emissions relationship [35].

6. DEVELOPING CARBON-FREE DIGITALIZATION

Attaining global sustainability and greener growth targets is a problem for all countries, particularly developing ones. As technology has been researched to have a growing effect on increasing carbon emissions, it has been described as increasing global warming, which has, in turn, affected more people both in the short and long term. Therefore, the need to explain effective solutions is associated with the need to ensure people across the globe have been protected. Finding practical solutions will make people worldwide safer. The government and related profit and non-profit organizations should implement measures that reduce the carbon footprint associated with technology [36]. To promote people's safety and wellbeing, reducing digitization's CO2 footprint requires that people across the globe work together toward reducing these numbers.

Recent strategies by some larger organizations have been described to reduce carbon emissions. Data centers by Google and Amazon have focused on environment-effective methods, ensuring they have better managed their carbon emissions [37]. The main focus has predominantly been on the power consumption associated with these data centers has contributed to the level of carbon emitted by these organizations [25]. Therefore, the focus on these issues has promoted effective management associated with these data centers, creating a promise of a practical solution implemented across the globe.

An excellent example of a solution implemented by larger companies is the solution implemented by Facebook. The company moved part of its data centers to Sweden, reducing the energy used to cool the systems [38]. Sweden experiences cooler temperatures than the US, making a move effective in saving a considerable amount of power. The immediate solution that could be implemented is to ensure that companies focus on powering their digital services through climate-friendly solar solutions [39]. The move toward solar power has significantly reduced the carbon footprint by a significant percentage [40]. Reports also indicate that solar energy is estimated to reduce the world's global carbon footprint by over 20%. Reducing electricity as a form of carbon emitter across the globe will significantly contribute to more people benefitting from the required growth [41]. Companies that manage data centers should consider changing their primary power usage, therefore participating in reducing carbon emissions around the globe.

According to an EY study, the German Federal Environment Agency (UBA) predicts rebound effects wipe out 10% to 30% of the potential savings from energy-efficient technologies via

innovative digital services [42]. According to the same EY study, 'sustainable digitalization' can help decarbonization and foster an eco-friendly future by 2030. Individual users are also encouraged to consider their impact on the globe from their technology usage. The use of a mobile phone increases the carbon footprint [43]. Therefore, the need to resolve this issue is that phone charging and usage should be limited only when needed. Focusing on conserving electricity is the easiest and safest way to manage the digital carbon footprint [44]. People should strive to focus on these approaches. This will contribute to their carbon footprint. With the rise of technology, developers and innovators should focus on effectively reducing the digital carbon footprint. The development of effective devices with consideration to the carbon footprint could help with saving many lives.

7. CONCLUSION

In conclusion, globalization and digitalization have contributed to a spike in the carbon footprint. The paper highlights some of the technologies that have been associated with a considerable increase in the carbon footprint. These challenges have all contributed to increasing the carbon footprint. The world has been affected by the rise in greenhouse gases. The effects of global warming have begun affecting many people across the globe. Studies indicate that technological products are expected to increase significantly in the coming years. Technology is a part of this problem; it creates a growing challenge and issue. Each of the technologies described above promotes people's lives to become more accessible. Therefore, the solution to the above problem will be to resolve this issue by finding a solution. The research paper includes several solutions that could be adopted. Companies that have implemented solutions have showcased a considerable reduction in their carbon emissions. Relevant organizations and governments should implement laws and regulations for better solutions to reduce the growing carbon footprint due to technology. It should be the top priority for preventing global warming and human sustainability.

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