# An Effort to reduce the $CO_2$ emission in Computation for Green Computation

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**Abstract**

*This paper analyzes the emission rates of carbon dioxide in the computing field by identifying emission sources. This study is done to highlight the breakdown of the carbon footprint of computing devices, thus suggesting tips to reduce the emission rate. $CO_2$ Emission rates are calculated for devices such as PC, Laptops, Mobile Network Infrastructures, Google Search Engine, Devices involved in Cloud and Fog Computing, wireless access points for WiFi, Raspberry Pi, Air-Conditioners and Solar Panels. In the process of analyzing emission rates, the paper also explores how eco-friendly Solar Panels are. This paper mentions the $CO_2$ emission caused by different devices as a side effect and it affects the environment. Adopting Fog Computing can help us better to achieve Green Computing. This study aims to make the reader aware of the emission rates and suggest ways to reduce their carbon footprint.*

## 1. INTRODUCTION

Earlier, coal plants, heavy industry, and planes were the familiar sources of carbon emission. However, the increasing scrutiny over energy consumption has resulted in the computing sector's discovery as a significant contributor to carbon emission.[1] Global warming is the main reason for climate change. $CO_2$ is one of the leading greenhouse gases which causes global warming. In this paper, many important aspects related to the computing field are discussed. Whenever one uses any sort of computation, for instance, online surfing or even usage of mobile causes $CO_2$ emissions directly or indirectly. The usage rate of the computing field is expanding daily. e.g., The computing industry is said to increase its carbon emission by 6% every year.[1]

Electrical activity and power consumption play a huge role in the computing industry. Earlier, people were oblivious to the increasing emission rate, but they are now aware of the alarming amount of $CO_2$ produced by this sector. The computing industry has and will continue to increase by 6% per year due to an ever-increasing demand for computer hardware, software, and services. There will be 4 billion personal computers by 2020, resulting in an emission rate twice of that in 2008. Based on the above studies and all references referred, few tips are given to reduce the $CO_2$ emission.

Every individual who owns a computing device generates data – it is called their digital footprint. Such kind of data requires a considerable amount of server space for storage and demands a tremendous amount of energy for accessing this data. A part of this digital footprint may be described as digital waste, which depletes the total amount of space and energy available. Large IT companies have been taking steps to grow responsibly, without fueling climate change to prevent harmful consequences. Google is one of the first companies which took a significant step [2] by promoting efficient computing and using renewable energy whenever possible. It is also a member of the Climate Savers Computing Initiative (CSCI).

However, these efforts aren't enough. It is estimated that every second someone browses a simple website, 20 milligrams of $CO_2$ are generated[3]. They were downloading a song, writing an email, streaming a video all result in the same. These simple tasks are performed by almost every user of a computing device, multiple times a day. This makes it crucial to create a Green Internet ecosystem in today's time when every year millions of new users join the internet.

So while IT companies are taking measures to reduce their carbon footprint, there is still a lot that can be done. Antivirus software McAfee reports that 2 million homes could be powered by the amount of electricity used to transmit the trillions of spam mails generated annually [3]. Viessmann, a German manufacturer, has researched that using a mobile phone for just one hour a day for one year produces more carbon emissions than two round trip flights between London and Glasgow. It results in the generation of 1.4 tons of carbon dioxide.[4]

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In this paper, different sources of $CO_2$ emissions are covered and discussed like $CO_2$ emission by PC and Laptops,[5] $CO_2$ emission by Google,[6] $CO_2$ emission by Mobile Network Infrastructures.[7] $CO_2$ emission by cloud and fog computing,[8-11] $CO_2$ generation by wireless access points for WiFi,[12-15] $CO_2$emission by Raspberry Pi [16-19], $CO_2$ emission by Air-Conditioners.[20-22] How eco-friendly are Solar panels?[23-29]

This paper aims to make the user aware of CO2 emission, its side effects, and the primary sources of CO2 generation that user unknowingly contributes. So, by making him understand it, it will reduce the CO2 emission and improve the quality in the environment.

In Fig. 1 [30], the increase in the field of mobile communication is shown. It is almost getting doubled in the year 2020 from the past 10 years. And by the year 2020 it will be responsible to emit 235 Metric tons of $CO_2$ emission. To avoid this, we should use every technology for our betterment and keep in mind that the excess/miss use of these technologies is causing harm to environments.

## 2. $CO_2$ EMISSION BY PC AND LAPTOPS

Daily usage of computing devices results in the emission of carbon dioxide too. A complete desktop's annual consumption of power is much higher as compared to a laptop.

It consumes an average of 200 Watt-hour (Wh) (a computer itself - 171W; Internet modem - 10W; Printer - 5W and loudspeaker - 20W). Assuming a computer is operated for eight hours a day, it would result in annual consumption of 600kWh, corresponding to $CO_2$ emissions of about 175kg per year. On the other hand, a laptop consumes about a third that of a desktop, i.e., 50 to 100 Wh, depending on the model used. Assuming the same usage, it would utilize between 150 and 300 kWh/year, corresponding to $CO_2$ emissions of between 44 and 88 kg per year. Stand-by modes also consume power. A system on the stand-by mode utilizes around one-third of what it would consume when on. Further just putting the monitor on stand-by reduces the consumption by 15%. The internet, although a virtual space, does result in $CO_2$ emission.

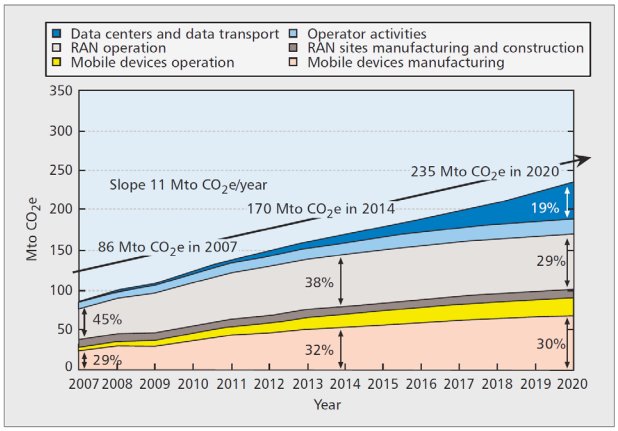


**Fig. 1:** Global carbon footprint of mobile communication projected until 2020

## 3. $CO_2$ EMISSION BY GOOGLE

Every google search comes at the cost of the planet. Google accounts for about 40% of the internet's carbon footprint, as it has an average of 3.5 billion searches a day. There are millions of physical servers, cables, routers, and modems, etc., which require much energy to run. Most of which results in the emission of carbon dioxide. A Simulator [31] analyses real-time Google workload, and it shows the amount of $CO_2$ generated by google per second. Figure 2 shows the amount of $CO_2$ emitted by google servers in few seconds.

## 4. $CO_2$ EMISSION BY MOBILE NETWORK INFRASTRUCTURES

Mobile phones are not a significant source of carbon emissions. However, if you use your phone a lot, i.e. if you use it for an hour a day, it adds up to more than 1 Ton $CO_2$ per year.[32] The amount of $CO_2$ produced in the manufacture of cell phones is about 16 kgs, and if we include the power it consumes in its average lifetime (about 2 years) it comes up to 22 kgs. However, the calls must transmit calls over the network which adds on to the carbon footprint and accounts to almost 94 kgs over the lifetime of the mobile phone. In mobile communication system different components are involved like Base Station Controller (BSC), Master Station Controller (MSC), administrative units and infrastructure based network providers. The amount of $CO_2$ generated by these units in a year are shown in Table 1.

Initially, there was only GSM mobile communication system. But further developments lead to other mobile communications such as WiFi, Wi-Max, HSPA, WLAN protocols and all. Now all these technologies are existing simultaneously with growing number of users. In Fig. 3 the increasing use of data rates showing the increasing need of the technology. And with these the more users using the technology and emitting more and more $CO_2$.

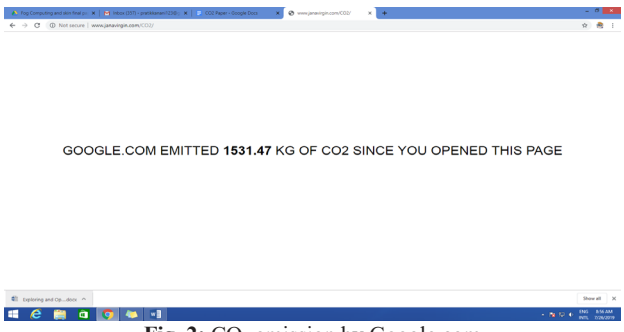


**Fig. 2:** $CO_2$ emission by Google.com

The amount of electricity to charge the phone is small; it is the entire network and infrastructure supporting the cellular network that produces a large amount of $CO_2$. Besides, all smartphones contain hazardous metals like bromine, chlorine, lead, and mercury, and many other chemicals are made of metals like gold, tin, lithium, and tantalum which cause harm to the earth due to land degradation and mining. Also, other factors like the wages of mining employees etc. have to be taken into consideration. Fig. 3 [30] shows, developments in the Mobile network field and is directly proportional to $CO_2$ Emission.

## 5. $CO_2$ EMISSION BY CLOUD AND FOG COMPUTING

Adaptation to cloud computing led to a reduction in the emission of $CO_2$ by saving energy.[33] It is estimated that by the year 2020, cloud computing can reduce the emission of $CO_2$ by 85.7 million metric tons.

From the above infographic shown in Fig. 4, in 2020, 23% of the total $CO_2$ emission in cloud computing was due to network. This includes transmission of data from the end devices to the cloud server and vice-versa for processing or storage purposes. Since fog computing reduces the distance travelled by the data by processing it close to the end devices on the fog nodes this could save energy of transmitting the data and thus reducing the $CO_2$ emission.

Table 2 [29] shows the amount of electricity consumed by cloud giants and their annual carbon debts. The bigger problem is that cloud industry is growing day by day and with that the amount of $Co_2$ emission is also increasing day by day.

### 5.1. So How Much $CO_2$ will can be saved from Fog Computing?

In 2011, According to Cisco 1.8 ZB of data was sent to the cloud data centers so if 5.12 kWh of energy is required to send 1 Gb data across then the total energy required to send 1.8 trillion GB of data is

$1.8 \times 5.12 = 9.216$ trillion kWh of energy

To generate this much amount of energy a total of 5.76 trillion kg of $CO_2$ is emitted.

Inference of the above Statements

9.216 Trillian kWh = 5.76 trillian kg of $CO_2$

9.216 kWh = 5.76 kg of $CO_2$

Therefore

1 kWh= 5.76/9.216 = 0.625 kg of $CO_2$

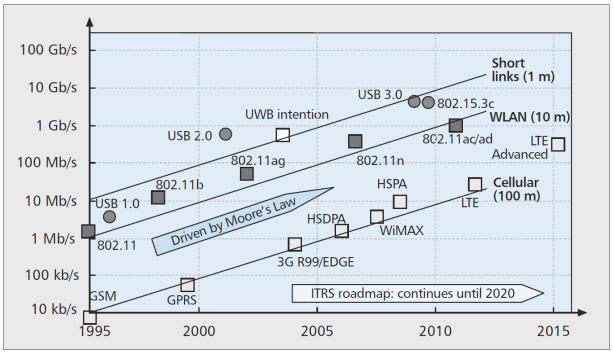


**Fig. 3:** Growth in wireless data rates

**Table 1:** $CO_2$ Emission by different nodes in Mobile Network

| *$CO_2$Generator* | *Amount of $CO_2$ Generation* |
|---|---|
| Base Station | 23.1 kg |
| Administration | 7.1 kg |
| Manufacturer | 6.3 kg |
| Switchboard | 5.6 kg |
| Phone energy | 3.2 kg |
| Transport before sale | 1.6 kg |

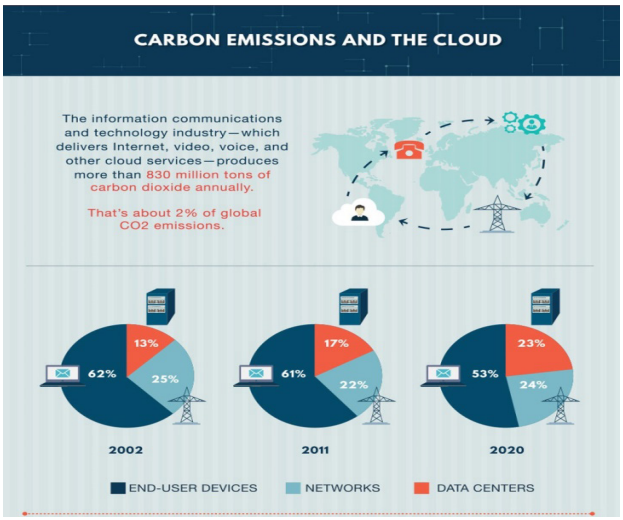


**Fig. 4:** Cloud computing and the Carbon emissions

**Table 2:** Cloud Computing Giants with their Annual Carbon Debt

| *Cloud Provider* | *Estimated annual Electricity consumption (TWh)* | *Annual Carbon Debt (metric tons)* | *Annual Growth* |
|---|---|---|---|
| Amazon Web Service | 20 | 5,150,000 | +46.3% |
| Microsoft Azure | 10 | 150,000 | +75.9% |
| Google Cloud | 20 | 300,000 | +81.7% |
| Alibaba Cloud | 3 | 1,624,500 | +73.8% |


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**Table 3:** Energy consumption and $CO_2$ Emission by Data Centres

| *Different Factors* | *2011* | *2020* |
|---|---|---|
| Data to Cloud Data Centers (in ZB) | 1.8 | 14.1 |
| Energy Consumed (in kWh) | 9.216 trillion | 72.19 trillion |
| Co2 Emitted (in KG) | 5.76 trillion | 45.12 trillion |
| Amount saved (in $) | 60 billion | 470 trillion |

Therefore

1kWh= 5.76/9.216= 0.625 kg of $CO_2$

1GB = 5.12 kWh = 5.12x0.625 kg of co2

Therefore

1GB = 3.2 kg of $CO_2$

Therefore

1 Byte = 3.2/(1024x1024x1024) = 2.98x $e^{-9}$ kg of $CO_2$

= 2.98x $10^{-9}$ x $10^3$ gm of $CO_2$

= 2.98 x $10^{-6}$ gm of $CO_2$

Therefore

1 Byte = 2.98 x $10^{-3}$ mgm of $CO_2$

Now if we adapt to Fog Computing and assume that the data only travels to the data centre only for storage purpose, we can reduce the $CO_2$ emission by 50% the $CO_2$ emission can be potentially reduced by 2.88 billion metric tons. That is almost 34 times that was saved by Cloud Computing.

The data centers run of full performance even though the processing power required by the data is less. In fog computing since the type of data and amount of data at a particular fog node can be assumed and hence we can design a fog node in a way that it can cater to the need of data but not provide large amount of processing so as to waste it. This can also lead to reduction in the amount of $CO_2$ emitted.

Fog computing can also reduce the cost of processing as the transportation is reduced and hence the energy required is also reduced this saving could be up to 60 billion$. These numbers are projected to rise to 14.1 ZB by the year 2020. If the above numbers are calculated for the year 2020 then the result will be as follows.

Table 3. shows the increase in the volume of data flowing across the data centres. With increase in data, it leads to increase in energy and $CO_2$ emission. But if we use Fog Computing then the data flow can be reduced at larger extent and the $CO_2$ emission can be reduced. By reducing $CO_2$ emission, indirectly we are reducing the operational cost of the system.

## 6. $CO_2$ EMISSION BY WIFI ACCESS POINTS

Wireless router, a tool that incorporates the primary tasks of a router as well as that of a wireless access point, which is used to implement services like Inter-network (Internet as we call it) or a private computer network.[12] In computer networking, a hardware device called a wireless access point (WAP) allows other WiFi enabled devices to connect to a wired network. It usually connects to a wired - network router as a standalone device. A router is a device that transmits data packets from one network to another. The router performs the strenuous process of traffic routing and re-routing between different nodes on the internet.

WiFi grew into a popular medium used by many people on an everyday basis, allowing mobile access to the internet. WiFi routers are usually in use 24/7 all year round. We aim at finding out the amount of carbon dioxide generated when a WiFi router is in use. In this study, we have not included the carbon dioxide emissions during the manufacturing, transportation, and waste management phase of the WiFi router. Various traffic loads and conditions being considered, the power measurements of the WiFi access point were conducted to evaluate the power consumption. The results show that a constant current of 150.25 mA was drawn from the power supply for all the different load conditions and a steady supply voltage of 14.78 V. Estimating a power supply efficiency of 80% [13], the overall power consumption of a day results to 66.62 Wh, assuming a typical situation of academic and commercial institutions where the device is always kept powered on. Thus, for usage worth a year, the complete power usage of the access point is 24.32 kWh.[14] In India, the estimated emissions per unit of electricity are in the range of 0.91 to 0.95 kg/kWh for $CO_2$.[15] This implies that the access point's energy usage resulted in 22.13 kg to 23.10 kg of $CO_2$ emissions over one year.

## 7. $CO_2$ EMISSION BY RASPBERRY PI

The Raspberry Pi is a single-board computer used to foster the teaching of computer science among school children. Initially, its sales were expected to be in thousands; however, as of March 2018, it crossed 9 million.[16] This burgeoning demand is being fueled by hobbyists, tinkers, schools, and businesses. The term "using" a Raspberry Pi computer is exceptionally ambiguous. Being the world's 3rd bestselling, the general-purpose computer has a wide variety of applications ranging from being inside laptops, tablets, and robots; to running experiments onboard the International Space Station; to spanning a massive ecosystem of kits for learning about computers.[17] Hence, for the purpose of this paper, we will concentrate on the Raspberry Pi 3 A+ model which was released in 2016. While performing research for this article, most of the articles stated that the


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Raspberry Pi computers comply with European Union regulations regarding the supply of electronic/computer equipment. However, from this, we can only conclude that the manufacturing, recycling and waste management of a Raspberry Pi computer are environmentally friendly. This completely neglects the usage phase of its life cycle. Because of the high flexibility in customization provided by Raspberry Pi, its use phase is highly subjective and varies for each consumer. Most customers utilize the ports on the device for connection, to other devices. Regarding maintenance, updates for security patches and improvements are required for Raspberry Pi's software, although the hardware usually stays intact. Raspberry Pi is like a mini-computer, very user-friendly and just like a standard computer, it works only on electricity. The Raspberry Pi A+ model, which utilizes a minimal amount of electricity, yet it delivers more powerful performance. At best performance, Raspberry Pi A+'s power consumption is 1 Watt, hence effectively, 1kWh energy will be consumed after 1000 hours of its usage. Similarly, a year has 8760 hours, so at its best performance, it will use 18.76 kWh, or 31,536 kilojoules of energy.[18] This is the average running energy consumption of the Raspberry Pi A+ model. Hence just like every other machine, that uses electricity to power itself and it's working, Raspberry Pi is also going to release some detrimental greenhouse gases like nitrogen oxides, carbon monoxide and other particulate materials into the atmosphere due to power production made possible through the fossil fuels. However, due to the rather low consumption of electricity by Raspberry Pi, the overall impact caused is very minimal. The estimate emissions per unit of electricity are in the span of 0.91 to 0.95 kg/kWh for $CO_2$ in India. [19] Based on this, we can estimate that a Raspberry Pi A+ model when in use at maximum power for an entire year will produce 8.322 kilograms (8.76*0.95) of carbon dioxide.

## 8. $CO_2$ EMISSION BY AIR-CONDITIONERS

Air conditioning (often referred to as A/C) is one of the most common methods employed to reduce the amount of heat, moisture, and humidity from a space that is densely engaged by humans and machines likewise. It is used a lot to cool down the rooms in large IT companies that are filled with heat-producing computational devices like servers and power amplifiers.[20] Moreover, due to improving economic conditions in a majority of developing countries and a substantial rise in the per-capita income of the working class, the global market for air-conditioning is likely to grow substantially. This will eventually increase the pollution levels caused by emissions from the air-conditioning industry. The air conditioning market is also heavily driven by the various advancements achieved in developing countries. According to a report by Zion Market Research, the industry was valued at USD 135.2 billion in 2018 and by 2025, it is poised to reach around USD 292.7 billion. This section aims at understanding the amount of carbon dioxide emitted by an air conditioner. This depends on the power consumption of the A/c. Based on research, different types of A/c like split, window, 1 ton, 2 ton, etc. have different rates of power consumption. Hence, for this research, we will only consider the maximum and minimum power consumption of an air conditioner. The power consumption of a 2-ton air conditioner for one-hour usage is 2210 kWh and that of a 0.8-ton air conditioner is 812 kWh.[21] The estimate emissions per unit of electricity are in the span of 0.91 to 0.95 kg/kWh for $CO_2$ in India.[19] Based on this data we can estimate that within one hour an air conditioner emits approximately 738 kg to 2000 kg of carbon dioxide. If the air conditioner is used for 10 hours a day for 365 days, it will produce 26,97,058 kg to 73,00,000 kg of carbon dioxide.

## 9. HOW ECO-FRIENDLY ARE SOLAR PANELS?

Solar Panels produce electricity by transforming solar energy that is, the energy from the sun to electricity. Solar energy has long been sought after as the "Non-polluting renewable" source of energy.[23] However, with increasing awareness about emissions during its manufacturing and difficulties in disposal has piqued scientific curiosity in this matter. In 2016 it was estimated by the International Renewable Energy Agency (IRENA) that there would be around 250,000 metric tons of waste generated by solar panels in the world by the end of the year.[22] Moreover, the agency also projected that this amount could reach a staggering 78 million metric tons by 2050. The industry also faces issues with disposing batteries. Unlike other types of technology, where experts have found ways to recycle or otherwise dispose of them at their life cycle's end, solar batteries have been a bit of a challenge.[25] Furthermore, it has also been found in the life-cycle analysis of such batteries that they are responsible for most of the harmful effects on the environment due to their heavy metal content and a comparatively short life span.[26]

The encapsulant made of ethylene-vinyl acetate and the substrate comprising polyvinyl fluoride are not redeemable and are extracted by employing a thermal process. If this process is not carried out properly, it can lead to the formation of fatal crystalline solar modules from lead solders. Under favorable conditions, the lead can drain and percolate into landfill soils and finally find their way into the water bodies.[27] During the operation of Solar Thermal systems, heat transfer fluids are used as coolants. Due to this reason, they contain chromates, sulfates, sulfites, glycol, nitrates, and nitrites. Applications


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that need even higher temperatures would have to use more complex compounds like CFCs, oils and aromatic alcohols. Since most countries do not have strict disposal stipulations, incidents of water pollution may occur due to leaks of heat transfer fluid [26]. Recycling of panels brings up more significant problems. This is because about 90% of most PV modules are manufactured employing glass, which cannot be replenished as float glass because they contain impurities like plastics, lead, cadmium, and antimony [28]. It was reported by IRENA in 2016,[24] that the value of recovered material if pushed back into the economy, could be more than USD 15 billion by 2050. However, the study also concluded that the expense of recycling is prominently more significant against that of the economic value of the extracted materials. This is the reason because of which most of the solar panels end up in landfills. The dearth of valuable materials plays a vital role, and process costs are the main critical variables.

Moreover, it was reported in 2015 by the United Nations Environment Program (UNEP) [29], that around 60%-90% of electronic waste is used extensively in illegal trade and dumped in developing nations. UNEP also reported that 70% of the collected Electronic Waste (WEEE) ends up in largely unknown and unreported destinations. Thus, rendering the solar panel disposal and recycle process unsustainable.

## 10. TIPS AND TRICKS TO REDUCE THE $CO_2$ EMISSIONS

Certain simple ways, if followed can reduce the Carbon footprint at greater extents.

### 10.1. Tips to Save Energy and reduce $CO_2$ Emissions

1. Turn off the loudspeaker when not in use.
2. Switch off the printer when not needed.
3. Switch off the screen even for short intervals when you are not working on it.
4. Put the computer on stand-by if you are not going to use it for a longer duration of time
5. Using a laptop instead of a desktop helps in reducing power usage.
6. We can turn off the modem when not used, for example at night.

### 10.2. Steps to Reduce the Carbon Footprint left by Your Smart Phone

1. Text over call
2. Buy refurbished phones over new ones
3. Increase your phone life
4. Use modular phones (phones can be reused)

For our conversation through mobile phone is cleaner, we give some tips:

- Unplugging the charger when the phone is not connected to it saves energy and electricity
- Instead of disposing of your phone after you no longer want it, get it recycled or reused.
- Turn off the mobile whenever possible. When you sleep or at a movie, you don't need to keep the phone up. This will help the battery to stay longer.
- The battery will last longer if you reduce the screen brightness to 70 or 80%. Many phones allow you to regulate it.

## 11. CONCLUSION AND FUTURE SCOPE

After analyzing the emission rates of carbon dioxide in the computing field by identifying the sources of emission the paper concludes that a large amount of carbon dioxide is emitted during the process of electricity generation by fossil fuels. PC and laptops emit 175 kg and 88 kg of $CO_2$, respectively. Google emits 0.01 kg of $CO_2$ per request, which ends up to 500 kg of $CO_2$ emissions per second if 47,000 requests are made per second. The mobile network infrastructure emits 94 kg of $CO_2$ over the lifetime of a mobile phone. Wi-Fi Access points generate 23.10 kg of $CO_2$ over a period of one year, whereas Raspberry Pi computers emit only 8.322 kg of $CO_2$ for an entire year when in use at maximum power for 365 days. If an air conditioner is used for 10 hours a day for 365 days it will produce approximately 26,97,058 kg to 73,00,000 kg of carbon dioxide depending on the type of air conditioner in operation. Adaptations to Cloud and Fog computing helps to reduce the $CO_2$ emissions by 85.7 million metric tons. The paper also renders the use of solar panels as unsustainable since it emits a tremendous amount of carbon dioxide during its manufacturing and disposal phase. Finally, the paper suggests other alternatives to reduce the carbon footprint that can be followed by the general population. In Future, we cannot stop the growing need of technology and its energy need. But of course, we can use other technological alternatives to reduce the $CO_2$ footprints like Fog computing and its paradigms. It's better to deploy edge device for automated applications rather using the cloud technology. One more way to reduce the carbon footprint is to send and receive data at certain intervals of time other than continuous data streaming.

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