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Climate Change Perspective: The Advantage and Disadvantage of COVID-19 Pandemic

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Abstract: Government initiatives during the COVID-19 outbreak had a significant impact on global energy consumption patterns. Many international borders were blocked, and individuals were confined to their homes, restricting mobility and changing social habits. The lockdowns introduced economic, physical, and social pastimes to a halt. However, as an advantage, the world had a good effect on air quality, the environment, and greenhouse gases (GHGs), in particular CO2 emissions. When compared to the mean 2019 levels, daily worldwide CO2 emissions had fallen by –17 % (–11 to –25 % for 1) by early April 2020, with changes in surface transportation accounting for little under half of the decline. The total global CO2 reduction from January to April 2020 was predicted to be more than 1749 Mt CO2 (a 14.3 % decline), with the transportation sector contributing the most (58%) followed by coal power generation (29%), and industry (10%). As a result, transportation was identified as the primary source of more than half of the emissions reduction during the epidemic. As of August 23, 2021, 193 countries produced 8.4 million tons of pandemic-related plastic waste, with 25.9 thousand tons dumped into the ocean, accounting for 1.5 percent of total riverine plastic discharge globally. As a result of China and India's record-breaking confirmed cases, MMPW generation and discharge are projected to be more skewed toward Asia. The study found that hospital trash accounts for 73% of global discharge and that Asia accounts for 72% of global discharge, indicating the need for better medical waste management in emerging countries. This review highlights the brief lessening in GHG outflows and expanded request for single-use plastics, including the weight of an as of now out-of-control worldwide plastic squander emergency caused by the COVID-19 widespread. This review also will be helpful for people to understand the COVID-19 impact on climate change point of view. There is advantage and disadvantage brought by this pandemic and it's the best time to change the new normal of globalization. Global policies makers should consider the acute need to change the policies for a circular economy with the best environment sustainable, both during the pandemic and, more significantly, thereafter. The authors of the reference articles on the COVID-19 pandemic hope their findings will aid attempts to better understand the disease's relationship to climate change. If lessons from both global crises are learned, the world may be better prepared to deal with global climate change, which has local consequences.

Keywords: *CO2, Covid-19, GHG, MMPW, Plastic Pollution*

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1. Introduction

Global warming and its impact on Earth's weather patterns are now considered part of climate change. Climate change has occurred in the past, but the current changes are faster and are not caused by natural factors (IPCC, 2018). The cause of these phenomena is the release of greenhouse gases, primarily carbon dioxide (CO2) and methane. In sunlight, greenhouse gases are transparent, allowing them to penetrate the Earth's surface and heat it. This heat is radiated off the Earth as infrared radiation, which is absorbed by the gases, causing the heat to be trapped close to the Earth's surface. Changes in the planet's climate, such as the decrease of sunlight-reflecting snow cover, hasten global warming (IPCC, 2022). Many of these impacts can already be felt as the earth warms by 1.2 degrees Celsius (2.2 degrees Fahrenheit). More ramifications will follow, and there may be tipping points, such as the melting of the Greenland ice sheet (IPCC, 2021).

GHGs, or greenhouse gases, absorb and emit electromagnetic radiation within the infrared range, which results in the greenhouse effect (IPCC, 2021). Water vapor (H2O), carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and ozone are the five principal greenhouse gases found in the Earth's atmosphere (O3). Anthropogenic greenhouse gas emissions have steadily increased from the pre-industrial era, owing primarily to economic and population expansion, and are presently at their highest levels ever. Anthropogenic greenhouse gas emissions have steadily increased from the pre-industrial era, owing primarily to economic and population expansion, and are presently at their highest levels ever (IPCC, 2014). Carbon dioxide (CO2) is one of the most significant greenhouse gases created by human activities. CO2 is an atmospheric gas that is naturally present as part of Earth's carbon cycle (the way that carbon is transferred between the atmosphere, oceans, soil, plants, and animals. The carbon cycle is being altered by anthropogenic activities, both by adding more CO2 to the atmosphere and by interfering with the ability of natural carbon sinks, such as forests and soils, to remove and store carbon (GHG and Sinks: 2012). Even though there is a range of natural sources of CO2, human-related CO2 emissions are to blame for the rise in atmospheric CO2 levels since the industrial revolution. On the other hand, any human-caused climate change will be layered on a background of natural climatic variations that occur over a wide range of space and time ranges (IPCC, 2014). Increased concentrations of greenhouse gases (CO2, CH4, N2O, and others) have ensued, trapping heat and causing the Earth to warm while simultaneously diminishing the efficiency with which the Earth cools to space (IPCC, 2020). Without greenhouse gases, the average temperature of Earth's surface would be about −18 °C (0 °F),(Lacis, 2010) rather than the present average of 15 °C (59 °F) (Karl & Trenberth, 2003). By 2050, given current greenhouse gas emission rates, temperatures might rise by 2 degrees Celsius (3.6 degrees Fahrenheit), exceeding the top limit set by the United Nations' Intergovernmental Panel on Climate Change (IPCC) to avoid "dangerous" levels (Cowtan et al., 2015). As part of the 2015 Paris Agreement, countries agreed to keep global warming "well below 2°C." Even though pledges made under the Agreement are likely to restrict warming to roughly 2.7 degrees Celsius by the end of the century, global temperatures are expected to reach around 4.9 degrees Celsius (Environment, 2021). If we are to limit global warming to 1.5 °C, we must halve emissions by 2030 and achieve net-zero emissions by 2050 (IPCC, 2018).

Most people aren't aware that plastic is made from fossil fuels. Because of the energy-intensive procedures required in extracting and distilling oil, plastic manufacturing produces a significant amount of greenhouse emissions. The majority of these emissions are caused by fossil fuels used for energy generation, with agriculture, steelmaking, cement manufacture, and forest loss as additional contributors (Ritchie, H., & Roser, 2018). Globally, plastic consumption makes up about 6% of oil consumption, and it is expected to reach 20% by 2050. Plastic pollution occurs when plastic objects and particles accumulate in the environment, causing harm to humans, wildlife, and their ecosystem (e.g., plastic bags, plastic bottles, and microbeads) (Parker, 2018). Plastics that pollute the environment are classified as micro-, meso-, or macro- trash, depending on their size. (Hammer et al., 2012). Plastics are affordable and durable, making them ideal for a variety of applications; as a result, producers prefer plastic to other materials (Hester, 2011). Most plastics, on the other hand, have a chemical structure that makes them resistant to a variety of natural breakdown processes, thus they disintegrate slowly (Guern, 2018). These two variables work together to allow significant amounts of plastic to enter the environment as Mismanaged Plastic Waste (MMPW) and persist in the ecosystem. Land, rivers, and oceans are all susceptible to plastic pollution. Each year, 1.1 to 8.8 million tons of plastic garbage from coastal towns is expected to enter the ocean (Jambeck et al., 2015).

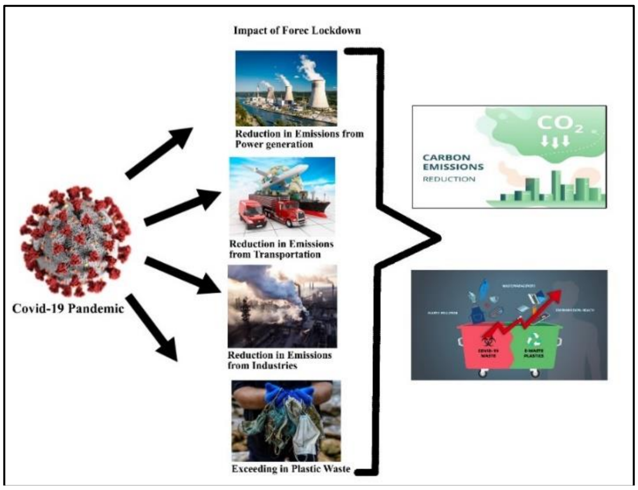

Figure 1: Graphical abstract of the review

The coronavirus 2019 (COVID 19, or SARS-CoV-2) widespread, which may be a sort of pneumonia, started in Wuhan, Hubei Province, China, in December 2019 (Gautam, 2020; Huang et al., 2021). Over 81.5 million occasions had been archived all-inclusive in 223 nations as of December 2020, counting autonomous, subordinate regions, and self-declared countries (WHO Coronavirus, 2021). On March 11, 2020, the WHO declared the COVID-19 outbreak a worldwide pandemic. The COVID-19 pandemic has been one of the worst of its kind in the last century in terms of global deaths, and in the lack of any effective treatment, governments around the world have mandated lock-down measures, as well as residents voluntarily minimizing non-essential trips and activities. In many places across the world, the pandemic wanted intense countering techniques like as social isolation, wearing face masks, and implementing strict lockdowns. The lockdowns introduced economic, physical, and social pastimes to a halt (Chikaire, Ajaero, & Atoma, 2022).

However, as an advantage, the world had a good effect on air quality, the environment, and greenhouse gases (GHGs), in particular CO2 emissions (Naderipour et al., 2020). When compared to the mean 2019 levels, daily worldwide CO2 emissions had fallen by –17 % (–11 to –25 % for 1) by early April 2020, with changes in surface transportation accounting for little under half of the decline. As a result, transportation was identified as the primary source of more than half of the emissions reduction during the epidemic. This strongly suggests that changing typical working patterns, such as reducing commuting to work, working from home, and doing online meetings or site visits, can have a real impact on GHG emissions. The resulting yearly decline will be much smaller (–4.2 to –7.5%, according to our sensitivity studies), but it will be comparable to the annual reductions required over the next decades to keep global warming to 1.5 degrees Celsius (IPCC, 2018; UNEP, 2019). These figures highlight both the rapid increase in global emissions over the last 14 years and the magnitude of the task we face in limiting climate change by the Paris Climate Agreement.

After one use, the majority of the million tons of plastic manufactured each year is discarded. Plastic bag, bottles, food containers, and cups that end up in landfills and the environment could survive hundreds of years or more. Furthermore, the COVID-19 would worsen global plastic pollution since personal protective equipment (PPE, such as gloves and masks) is now required to prevent the virus from spreading (Khanal, Sondhi and Giri, 2021). As a disadvantage the COVID-19 pandemic has raised the demand for single-use plastics, putting pressure on a worldwide plastic waste crisis that is already out of control (Peng et al., 2021a). In particular, pandemic epicenters struggle to handle the waste (UNEP, 2020), and not all old personal protective equipment (PPE) and packaging materials are handled or recycled (CNN, 2020), (UNCTAD, 2020). This mismanaged plastic waste (MMPW) is subsequently released into the environment, with some of it ending up in the ocean. (Woodall et al., 2014). The unleashed plastics can travel large distances in the water, collide with marine life, and cause injury or death. (Laist, 2009). The number of confirmed cases is expected to reach 280 million by the end of 2021, according to conservative estimates. The total MMPW generated by the pandemic will be 11 million tons, culminating in a global riverine discharge of 34,000 tons into the ocean. Plastic discharged to the ocean as a result of the pandemic accounts for 1.5% (+/- 0.2%) of total riverine plastic discharges (Peng et al., 2021b). A considerable amount of the outflow is medical waste, which increases the risk to the environment and human health (Hirsch, 1988) or even the COVID-19 virus is spreading (Nabi & Khan, 2020). This demonstrates how waste management necessitates structural modifications.

2. Materials and methods

This review paper used the Global Carbon Project CO2 emissions data, International Energy Agency IEA World Energy Balances (IEA) data, Power System Operation Corporation Limited data, EIA, American Iron and Steel Institute data for CO2 emission analysis. TOMTOM Traffic Index, MS2 Corporation traffic data, Apple Mobility Trends data, Octopus Energy Tech smart meter data, Aircraft on Ground OAG data were used for Transportation sector analysis according to Le Quéré et al., (2020), Sikarwar et al., (2021), Tiseo, (2021), Peng et al., (2021) and Ray et al., (2022). Global plastic production 1950-2019 data were taken from United States Environmental Protection Agency, 2019. Documentation for the Waste Reduction Model (WARM) were taken from Waste Reduction Model (WARM) | US EPA. On a scale of 0 to 3, Le Quéré et al., (2020), described the confinement index. Scale 0: no limitations; 1: isolation of sick or symptomatic individuals; 2: partial or complete lockdown in certain places; 3: mandated countrywide lockdown in 2020. To assess the influence of COVID-19 on CO2 emissions globally, the study employed the SMAP L4C product (Net Ecosystem CO2 Exchange (NEE) and EC flux tower data to quantify the cumulative effects of lockdown measures on overall carbon emissions in the targeted locations.

3. Results

3.1. Effect of temporal reduction of global fossil CO2 emissions in 2020

During the Covid-19 pandemic, the six economic sectors were reduced the CO2 emission from the total percent of global fossil CO2 emissions as follow: Power (44.3%), Industry (22.4%), Surface transportation (20.6%), Residential (5.6%), Public buildings and commerce (here shortened to 'public', 4.2%), and Aviation (2.8%). Changes in inactivity, such as power demand or road and air traffic, are represented by the statistics rather than direct changes in CO2 emissions. Based on the available data and the nature of the confinement, many assumptions were made to cover the six economic sectors (Table 1). All of the activity variations are in comparison to normal levels prior to the COVID-19 pandemic. At the national, state, and provincial levels, the aviation sector experienced the biggest decreases in daily activities, with a reduction of –75 % (–60 to –90 %) during confinement level 3 (Table 1). Surface transport activity decreased by –50% (–40 to –65 %), while industrial and government activity decreased by –35% (–25 to –45 %) and –33% (–15 to –50%), respectively. (Le Quéré et al., 2020). Furthermore, power activity declined by a small –15 % (–5 to –25 %) at confinement level 3, although residential activity grew by +5 % (0 to +10 %). Activity data demonstrates that during confinement level 2, there are large reductions in activity, but only moderate reductions in activity during confinement level 1 (Table 1).

By 7 April 2020, the confinement had reduced daily worldwide CO2 emissions by –17 (–11 to –25) MtCO2 d-1, or –17 % (–11 to –25 %), compared to the mean level of emissions in 2019 (Table 1). From 1st January to 30th April 2020, the change in emissions on 7 April was the biggest estimated daily change. In early April, daily emissions are comparable to those of 2006 (Figure 2). Because we currently emit roughly 100 MtCO2 d-1, the values in MtCO2 d-1 are close to the amount in %. The maximum daily reduction averaged 26 % (7% for 1) for specific countries. Because the highest daily decline did not occur on the same day in every country, the country decreases are larger than the worldwide maximum daily decrease. The estimated changes are compared to underlying trends previous to the COVID-19 pandemic and only take into consideration the effect of incarceration. The estimated changes are compared to underlying trends previous to the COVID-19 pandemic and only take into consideration the effect of incarceration. During the epidemic, the daily decline in global CO2 emissions is equivalent to the seasonal amplitude in emissions derived from data published elsewhere -21 (–17 MtCO2 d-1; M.J.W., manuscript in progress), owing to the Northern Hemisphere's higher energy use in winter compared to summer (–43%; Figure 3 and Table 1). In the electricity sector, emissions decreased by –7.4 %, or –3.3 (–1.0 to –6.8) MtCO2 d-1, while in the industry sector, emissions decreased by –19 %, or –4.3 (–2.3 to –6.0) MtCO2 d-1. In absolute terms, emissions from surface transportation, power, and industry were the most impacted, accounting for 86 % of the total reduction in global emissions. CO2 emissions fell by –60 % in the aviation industry, or –1.7 (–1.3 to –2.2) MtCO2 d-1, and by –21 % in the public sector, or –0.9 (–0.3 to –1.4) MtCO2 d-1. Although the aviation industry provided only 10% of the global CO2 reduction, the substantial relative anomalies in the sector correspond to the disproportionate effect of confinement on air travel (Table 1) (Le Quéré et al., 2020).

Emissions will almost probably rebound once the economy recovers, as prior crises have demonstrated. The changes in the environment (e.g., fewer carbon emissions) are only temporary because they are the product of imposed lockdowns rather than fundamental changes in the economic, energy, or transportation systems. There are, nevertheless, some lessons to be learned from this horrible time. Significant and long-term emissions reductions are required to reach the IPCC's Paris Agreement target (Agreement & Nations, 2015). The COVID-19 outbreak may present an opportunity to resurrect the economy through low-carbon and environmentally beneficial approaches. The economy's rebuilding path should be smart, with a bigger emphasis on renewables, to achieve greater energy security. Governments all throughout the world must avoid overreacting and cutting corners.

Figure 4 and Figure 5 show that the transportation sector contributed the most to the reduction in CO2 emissions (1020 Mt CO2) when compared to the other sectors. Many passenger flights were grounded as the confinement was enforced, and people were advised or even ordered to stay at home, depending on domestic countermeasures. As a result, a significant decrease in emissions can be expected in this sector (58 % of overall reduction by sector for January to April 2020) (IEA, no date). From January to April 2020, CO2 emissions from coal power generation decreased by 508 Mt CO2 compared to the same period in 2019. Lower electricity consumption, as stated in earlier sections, resulted in a 10% reduction in coal power generation, accounting for 29% of the total emissions reduction. In addition, industrial businesses were either closed or had their output decreased. This resulted in a CO2 reduction of 179 Mt from industry, accounting for 10% of total emissions decrease. Overall, a total reduction of 1749 Mt CO2, or 14.3%, was calculated, with the COVID-19-induced lockout from January to April 2020 accounting for the majority of the decrease. The number for worldwide emissions reduction was extrapolated from the four major emitters (which account for about a quarter of global emissions). As a result, a small overestimation is feasible. The aforementioned extrapolation imparts a realistic model because practically all large CO2 emissions contributors (90–95 %) (CO2 emissions - Our World in Data, 2021), were economically able to apply lockdown measures. A scenario in which 10% of CO2 emitters did or did not properly enforce lockout measures was also investigated. This would result in a total CO2 decrease of 1575 Mt (12.8%) (Sikarwar et al., 2021a). Surface traffic began to decline in February (third week) and peaked at 63.2 % by the end of April, a loss of 25.2 % on average. In addition, as shown in Figure 5. b, CO2 emissions from the sector decreased by 5.5 % in February.

Changes/differences in the spatial distribution of annual CO2 emissions were compared between 2019 and 2020 and 2016 and 2019, as indicated in Figures 6 (a) and (b). To understand the spatial distribution ranges of CO2 emissions globally, the discrepancies were categorized into nine classes. Carbon emissions in the northern hemisphere (North America, Europe, and Asia) were greater in 2019 than in 2016 (1–100 g C m-2 yr-1). Most of the southern hemisphere (South American and African continents, save Australia) had higher carbon uptakes (from 0 to 299 g C m-2 yr-1). However, carbon emissions on the Australian continent were higher in 2019 than in 2016, ranging from 1 to 300 g C m-2 yr-1. In contrast, most of the northern hemisphere (continents of North America, Europe, and Asia) had higher carbon uptakes in 2020 than in 2019 (0 to 9 g C m-2 yr-1), although carbon emissions in the north-western region of South America and Africa were higher (1–300 g C m-2 yr-1). In addition, in 2020, the majority of Australia's continent had significantly lower carbon emissions (1 to 100 g C m-2 yr-1) than in 2019 (Ray et al., 2022).

Overall, in 2020, there was a regional drop in carbon emissions and an increase in carbon uptakes compared to previous years, which could be attributable to reduced traffic and industrial activities or the worldwide influence of lockdown measures. Annual carbon emissions and uptakes fluctuated across different continents before and throughout the COVID-19 pandemic, as illustrated in

Figure 7. a. While Asia and South America absorbed carbon from 2016 to 2020, North America absorbed carbon from 2016 to 2017 and 2019 to 2020, but emitted carbon in 2018. Europe, on the other hand, had carbon emissions every year except 2016, when it had carbon uptakes. Interestingly, except in 2016 and 2017, Australia, which has a lower COVID-19 impact, had carbon emissions every year. Figure 7 (b) shows the difference in annual carbon emissions in each continent from 2016 to 2019, and from 2019 to 2020. In comparison to 2019, yearly carbon emissions in Asia, North America, and Europe decreased in 2020, while all other continents increased. Carbon emissions in Asia, North America, and Europe decreased significantly in 2020 compared to 2019. In contrast, whereas carbon emissions in Oceania and Australia increased significantly, carbon emissions in Africa, South America, and Antarctica increased marginally. In terms of the difference in yearly carbon emissions between 2016 and 2019, North America, Europe, and Australia saw a major increase in annual carbon emissions, whereas Africa, South America, Oceania, and Antarctica saw a significant decrease. However, in Asia, carbon emissions decreased somewhat in 2019 as compared to 2016. Between 2016 and 2019, the continents of North America, Europe, and Australia, which constitute the majority of developed countries, had an increase in annual carbon emissions. Annual carbon emissions, on the other hand, have been falling in South Africa, Asia, and South America, which include developing and least-developed countries, as well as Antarctica and Oceania.

Table 1: Change in activity as a function of the confinement level (%) (Le Quéré et al., 2020)

	Change in activity as a function of confinement level (equation (1))			**Results**
	Level 1	**Level 2**	**Level 3**	**Daily change 7 April 2020**
Power	0 (0 to 0)	–5 (0 to –15)	–15 (–5 to –25)	–7.4 (–2.2 to –14)
Industry	–10 (0 to –20)	–15 (0 to –35)	–35 (–25 to –45)	–19 (–10 to –29)
Surface transport	–10 (0 to –20)	–40 (–35 to –45)	–50 (–40 to –65)	–36 (–28 to –46)
Public	–5 (0 to –10)	–22.5 (–5 to –40)	–32.5 (–15 to –50)	–21 (–8.1 to –33)
Residential	0 (0 to 0)	0 (–5 to +5)	+5 (0 to +10)	+2.8 (–1.0 to +6.7)
Aviation	–20 (0 to –50)	–75 (–55 to –95)	–75 (–60 to –90)	–60 (–44 to –76)
Total				–17 (–11 to –25)

The mean and range are exhibited. aParameters used in equation (1) for each sector (ΔAs). Changes in emissions by sector for the entire world on the day with the greatest change (7 April 2020). The change is calculated as a %age of the average level of emissions in 2019. (Methods)

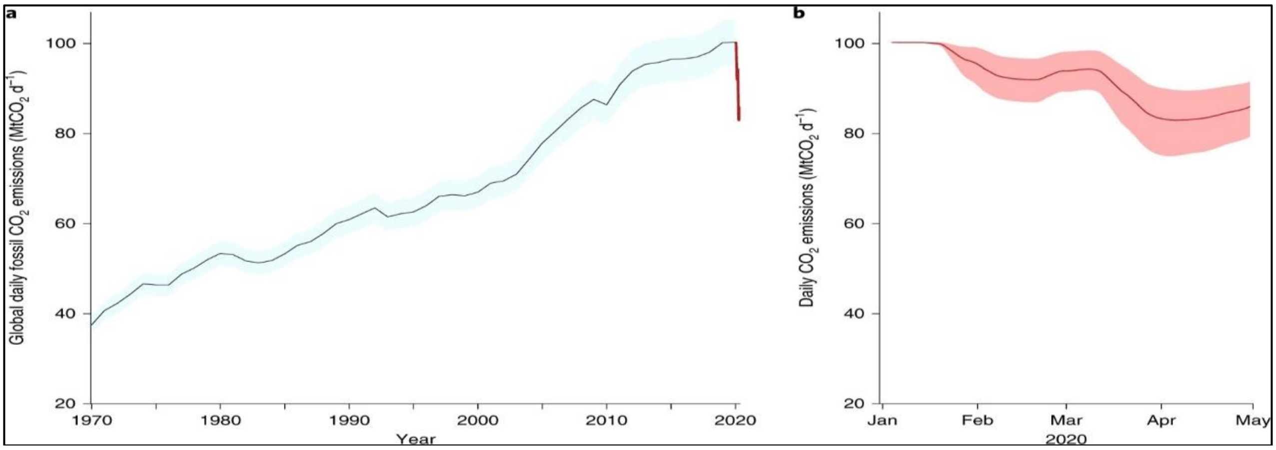

Figure 2: Global daily fossil CO2 emissions (MtCO2 d-1). (a) Annual mean daily emission from 1970 to 2019 (black line), updated from the Global Carbon Project1,3 (Methods), with ±5% (±1σ; grey shading) uncertainty. From now through the end of April 2020, the red line indicates projected daily emissions. (b), Daily CO2 emissions in 2020 (red line, same as in a) based on the CI and associated activity change for each CI level (Fig. 2), as well as the uncertainty (red shading; Table 1).(Le Quéré et al., 2020)

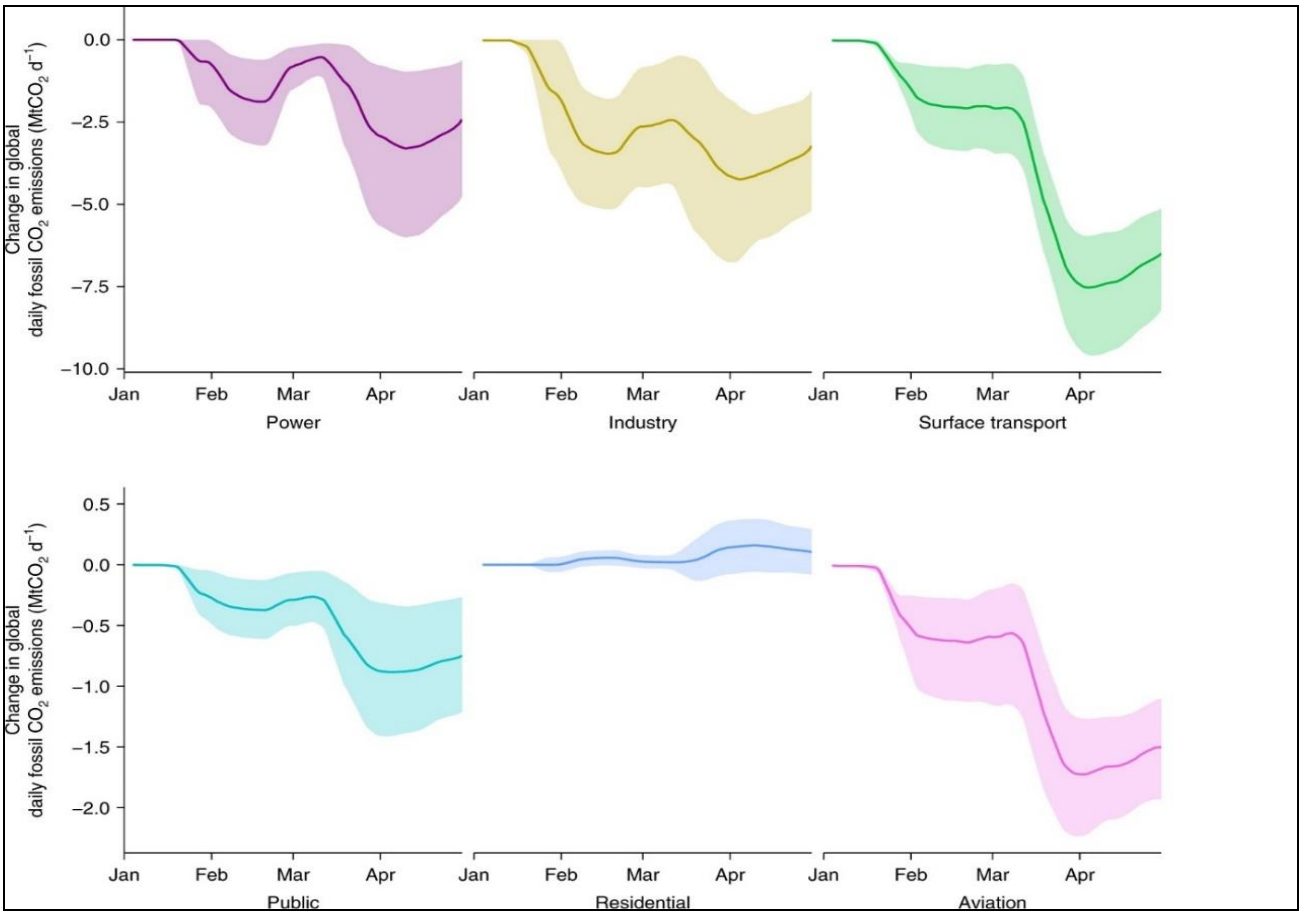

Figure 3: Change in global daily fossil CO2 emissions by sector (MtCO2 d-1). The graph depicts changes in annual mean daily emissions from several sectors in 2019. (Methods). Daily emissions are smoothed with a 7-d box filter to account for the transition between confinement levels. The upper and lower panels' y-axes have different ranges. (Le Quéré et al., 2020)

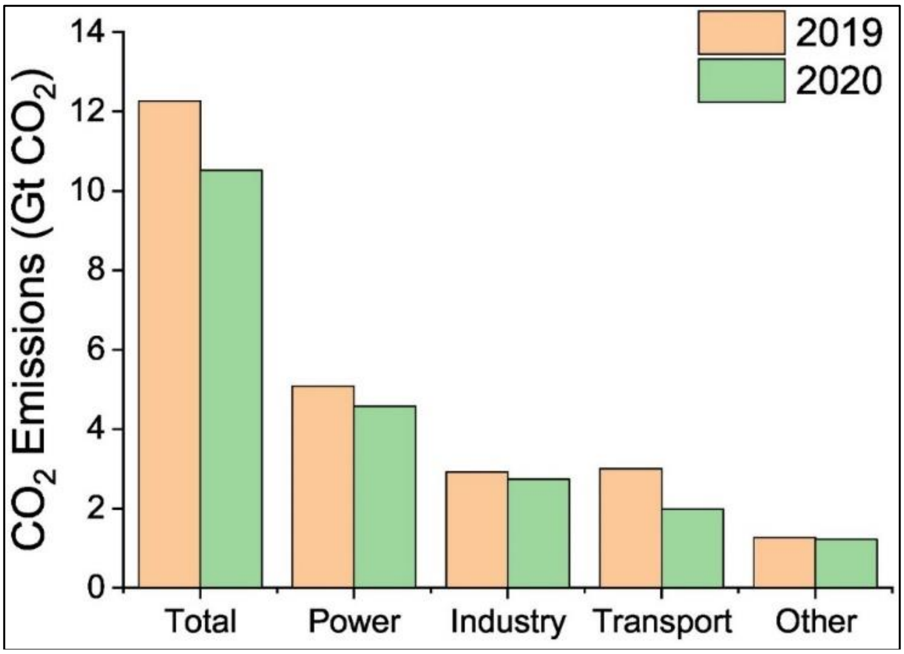

Figure 4: Sector-wise absolute CO2 emissions globally from January to April 2020 concerning January to April 2019. (Sikarwar et al., 2021b).

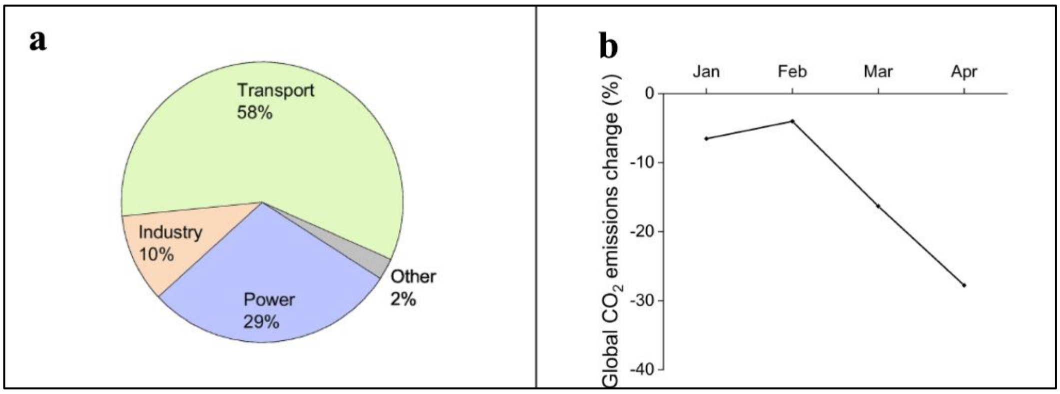

Figure 5: (a). Sector-wise contribution to the reduction in CO2 emissions and (b). Global change in CO2 emissions for Q1 2020 relative to Q1 2019. (Sikarwar et al., 2021b)

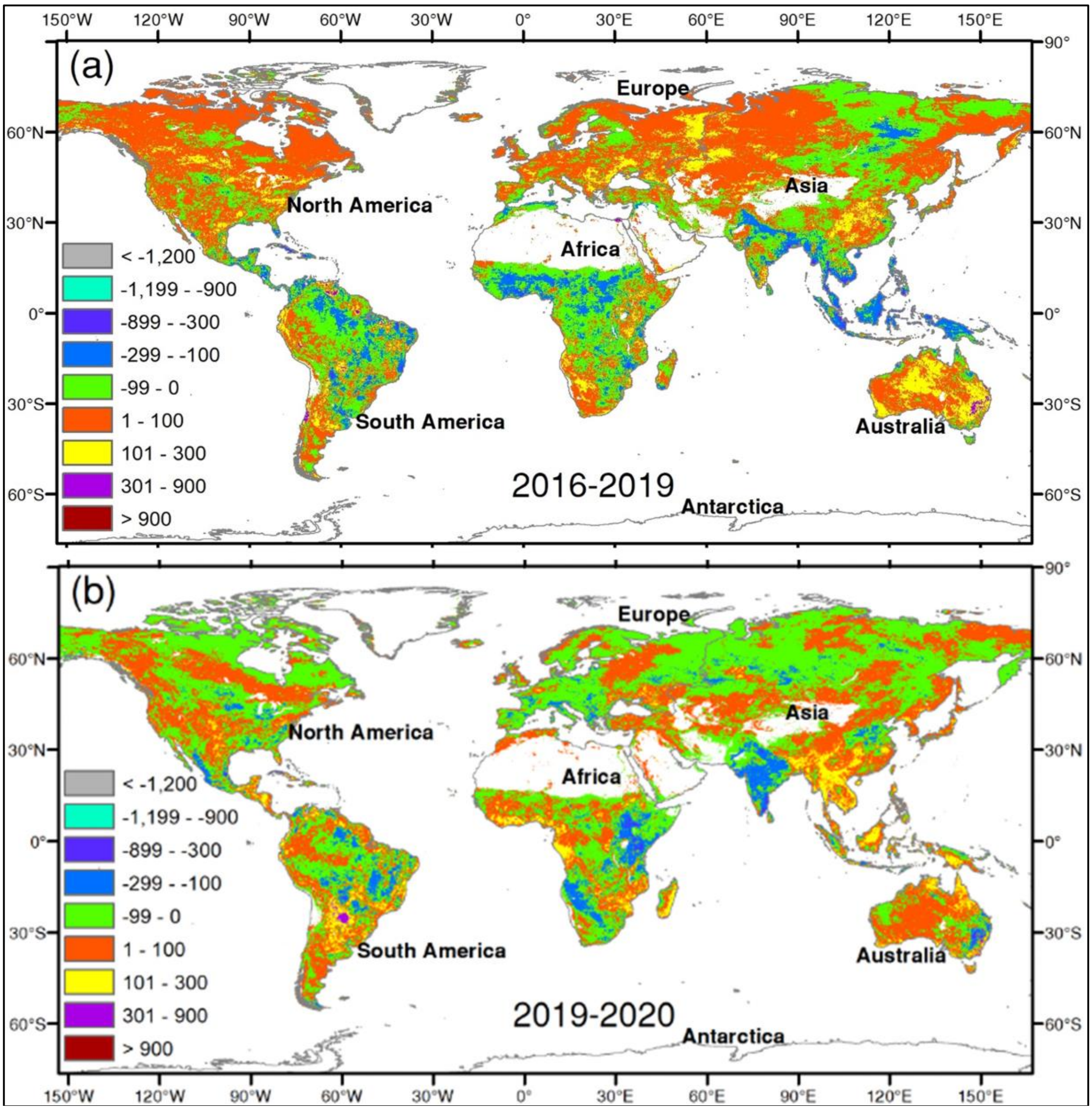

Figure 6: From (a) 2016 to 2019 and (b) 2019 to 2020, changes in the global spatial distribution of annual CO2 emissions (g C m2 yr1). Carbon inputs are denoted by a negative number, while carbon outputs are denoted by a positive number.(Ray et al., 2022)

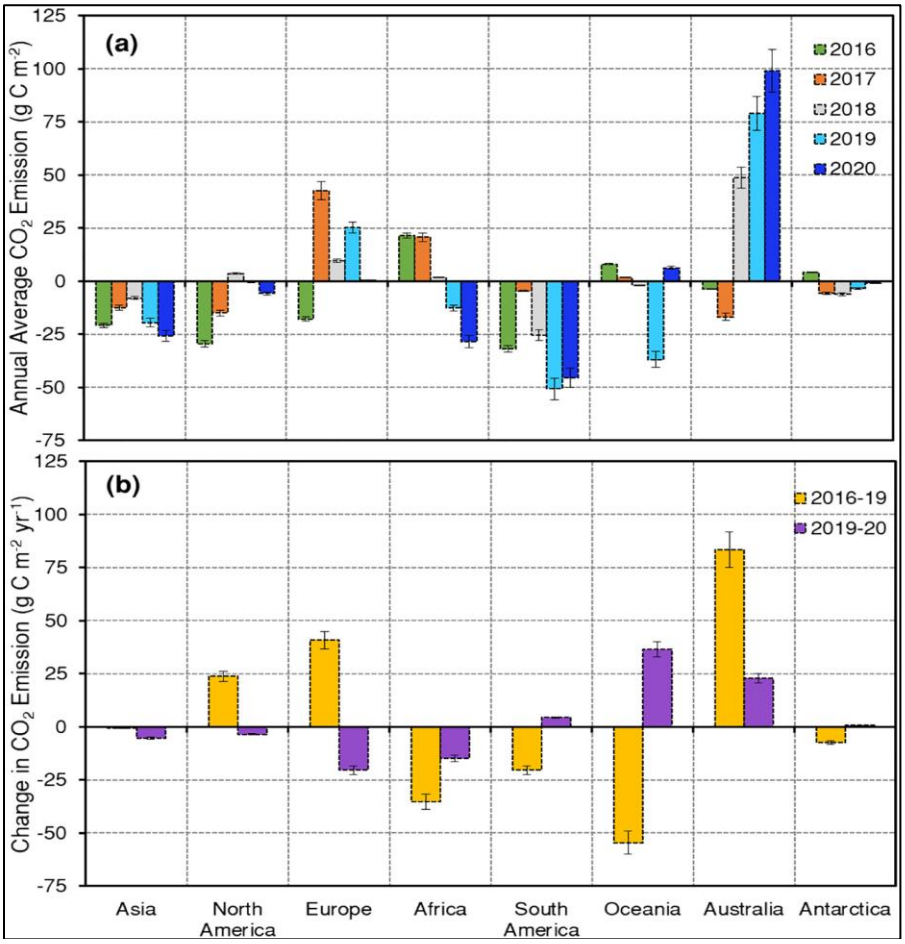

Figure 7: At the continental level, (a) annual average CO2 emissions, and (b) change in yearly CO2 emissions between 2016 and 2019, and 2019 and 2020. Annual carbon emissions differences were computed by subtracting 2019 yearly emissions from 2020 annual emissions. A standard error is indicated by the straight line in each bar (SE).(Ray et al., 2022)

3.2. Double plastic waste disposal

After one use, the majority of the million tons of plastic manufactured each year is discarded. Bottles, bags, gloves, and cups made of plastic that end up in landfills and the environment have the potential to last hundreds of years or longer. The COVID-19 pandemic has raised demand for single-use plastics, putting to the pressure on a worldwide plastic waste crisis that is already out of control (Peng et al., 2021a). Pandemic epicenters, in particular, struggle with waste management (UNEP, 2020), and not all obsolete personal protective equipment (PPE) and packaging materials are handled or recycled. Mismanaged plastic waste (MMPW) is then released into the environment, with some of it eventually ending up in the ocean (Woodall et al., 2014). Plastics that have been released into the sea can travel great distances, clash with marine life, and cause injury or death (Laist, 2009). According to conservative predictions, the number of confirmed cases would reach 280 million by the end of 2021. The pandemic will generate 11 million tons of MMPW, culminating in a global riverine discharge of 34,000 tons into the ocean. As of August 23, 2021, 193 countries had produced 8.4 (+/-1.4) million tons of pandemic-related plastic waste, with 25.9 (+/- 3.8) thousand tons of waste were discharged into the world's oceans, amounting for 1.5 % (+/-0.2%) of total riverine plastic discharge on a worldwide scale (Peng et al., 2021a). MMPW generation and discharge are expected to be more skewed toward Asia as a result of India's record-breaking confirmed cases (WHO Coronavirus (COVID-19) Dashboard). The pandemic's plastic outflow to the ocean contributes for 1.5 % (+/- 0.2 %) of overall riverine plastic discharges (Lebreton et al., 2012; Schmidt et al., 2017b). Medical waste accounts for a significant portion of the outflow, posing a concern to the environment and human health (Hirsch, 1988), and the COVID-19 virus is spreading. (Nabi & Khan, 2020). This is an illustration of the need for structural improvements in waste management.

Understanding the many aspects of the plastic production, distribution, and waste management chains is necessary to comprehend the volume of plastics input to the natural environment and the world's oceans. This is critical not just for determining the scope of the problem, but also for adopting the most effective reduction strategies. From 1950 to 2015, the graph depicts the increase in worldwide plastic output, estimated in tonnes per year Figure 8. In 1950, the world's annual production was only 2 million tonnes. Annual production has nearly doubled since then, hitting 381 million tonnes in 2015. To put this in perspective, this is about equal to two-thirds of the world's population (Hannah Ritchie and Max Roser, 2018). The COVID-19 pandemic, which was triggered by a novel severe acute respiratory syndrome coronavirus (SARS-Cov-2), has brought single-use plastics back into fashion. Hypothetical past, present, and future worldwide plastic production. Plastic production is predicted to increase to 600 million tons in 2040 based on the data available of plastic production rate between 2008 and 2019 (Tiseo, 2021) and assuming a linear trend. However, based on (Shams, Alam, and Mahbub's, 2021)'s research data, it has been estimated that COVID-19 caused a drastic increase in plastic production to around 698 million tons in only 2020 Figure 9.

Figure 10 depicts time-series increases in FW, PW, and municipal solid waste (MSW) generation in Bangkok between 2003 and 2020, based on data collected in the study (Liu et al., 2020a) and officially published statistics by the BMA's Department of Environment. MSW is solid trash collected and handled by BMA from municipal activities (such as households, supermarkets, retail shops, enterprises, service providers, marketplaces, and institutions). After the COVID-19 pandemic, the amount of MSW generated reduced by roughly 1000 tonnes per day in early 2020, owing to the closure of hotels and restaurants, after a steady growth in the decade leading up to the pandemic. Food waste accounts for 50–60% of total MSW, whereas plastic waste accounts for 20–30%, although COVID-19 has resulted in a decrease in food waste and an increase in plastic trash at the city level. Similarly, other worldwide plastic waste sources are increasing year by year, although at a faster rate, as the Covid-19 impact shows in 2020 (Liu et al., 2020b).

Food waste (FW) includes unavoidable items like peels, stems, and bones, as well as leftovers and other avoidable items, but it excludes commercial excess food as well as reused and recycled food such as animal feed, which developed dramatically in the late 2010s as a result of increased tourism and lifestyle changes. The total weight of MSW has decreased dramatically since the COVID-19 epidemic and subsequent lockdowns, owing to a large reduction in food waste from hotels and restaurants. Before the COVID-19 epidemic, however, the amount of plastic garbage generated grew and dropped in a gradual curve, averaging 2115 tonnes per day in 2019, then increasing dramatically by 62 % in 2020, reaching an average of 3432 tonnes per day between January and June (Figure 10) (Liu & Bunditsakulchai, 2021).

The plastic waste (PW) may also aid in the invasion of species and the transmission of pollutants such as the COVID-19 virus (Carlton et al., 2017; Mol and Caldas, 2020). Despite the potential consequences, nothing is known about the entire volume of pandemic-related plastic garbage and its environmental and health consequences. The total excess mismanaged plastic waste (MMPW) generated during the epidemic is estimated to be 4.4 to 15.1 million tons as to August 23, 2021 (Figure 11).

The majority of this excess waste (87.4%) comes from hospitals, as determined by the number of COVID-19 inpatients (Coronavirus (COVID-19) Dashboard, 2021) and per-patient medical waste generation for each country (Minoglou, 2017). Individuals' use of personal protective equipment accounts for only 7.6% of overall excess waste. Surprisingly, we discover that the rise in online purchasing leads to an increase in packaging material consumption. Packaging and test kits, on the other hand, are negligible sources of plastic waste, accounting for only 4.7 % and 0.3 %, respectively.

Cases of COVID-19 have been found all over the world (Asia, Europe, North America, South America, Oceania, and Africa). North and South America, as well as Asia, account for over 70% of COVID-19 cases. MMPW production does not match the case distribution, with the majority of MMPW produced in Asia (46%) followed by Europe (24%), and finally North and South America (22%) (Figure 12E). This reflects the lower level of medical waste treatment in many developing nations, such as India, Brazil, and China (low- and high-end estimates range from 11.5 to 76 %) compared to industrialized countries with significant numbers of cases, such as North America and Europe (e.g., the United States and Spain) (0 to 5% of total) (Figure 12A). Because of the huge mask-wearing populace, the MMPW generated from individual PPE is considerably more skewed toward Asia (Figure 12C) (YORK, 2019). Similarly, online-shopping packaging generates the highest MMPW in Asia (Figure 12D). China (58%), the United States (14.9 %), and Japan (10.3 %) are the top three countries in the express delivery business by global share, followed by the United Kingdom (4%) and Germany (4%) (Peng et al., 2021b).

Plastic garbage has been generated at a pace of 1.6 million tonnes per day since the pandemic began. According to (Benson et al., 2021), roughly 3.4 billion single-use facemasks or face shields are discarded daily due to the COVID-19 pandemic. China, which has the world's largest population, is expected to produce almost 702 million wasted facemasks per day, and 108 million tonnes of plastic garbage by the end of 2020. According to our calculations, Asia will generate the most wasted facemasks per inhabitant every day (1.8 billion). Europe has 445 million people, Africa has 411 million people, Latin America and the Caribbean has 380 million people, North America has 244 million people, and Oceania has 22 million people (Figure 13 and 14). The mandated use of single-use facemasks (face shields) could significantly increase PPE waste creation due to existing policies and COVID-19 guidelines in several countries. For example, the daily facemasks generated in China (1.4 billion people), India (1.3 billion people), the United States (331 million people), Brazil (212 million people), Nigeria (206 million people), and the United Kingdom (67 million people) are estimated to be at least 702, 386, 219, 140, 75, and 45 million contaminated masks per day, respectively. If the masks are abandoned into the environment and not properly managed, they may disintegrate into smaller particles, aggravating the already existing problem (Fred-Ahmadu, 2020: Prata et al., 2020; Patrício Silva et al., 2022).

The significant growth in PPE waste has overburdened waste management programs around the world, as spent plastic PPE must be properly disposed of to avoid cross-contamination. Indeed, recycling centers are restricting possibly tainted plastics, implying that incineration and landfilling are being favored. Such disposal methods are clearly incompatible with the goals of the plastic circular economy and sustainable development (You, Sonne, and Ok, 2020), and incineration can also cause major air quality problems by emitting volatile pollutants (such as dioxins and furans) and greenhouse gases over time (Juliano Calil, 2021).

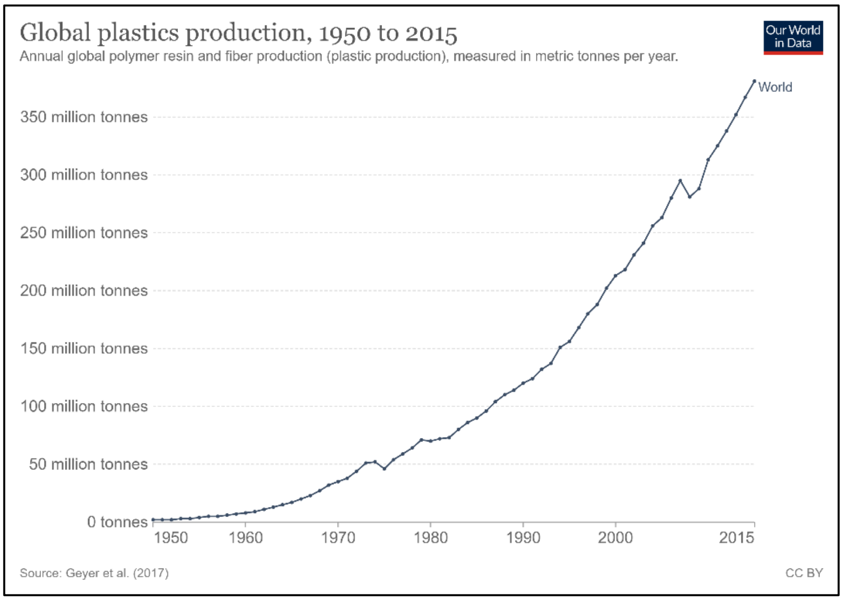

Figure 8: Annual global polymer resin and fiber production (plastic production), measured in metric tonnes per year.

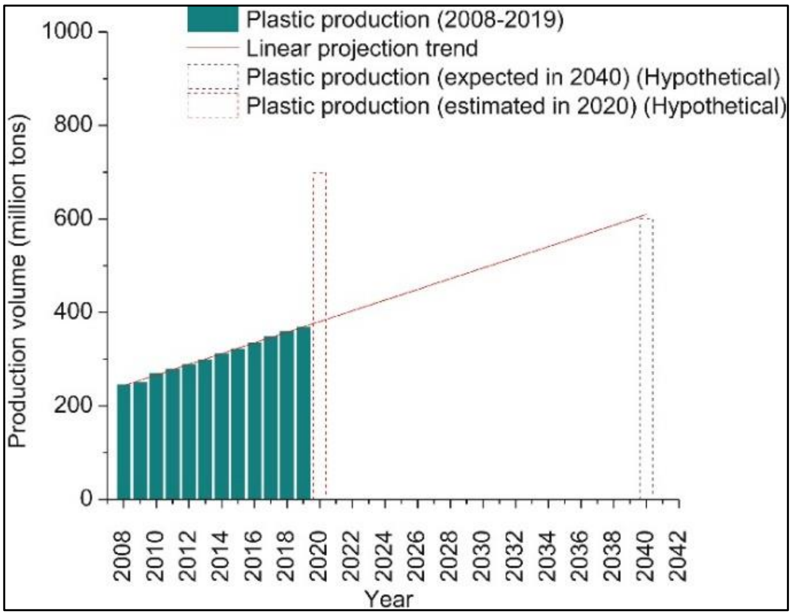

Figure 9: Hypothetical past, present, and future worldwide plastic production. Plastic production is predicted to increase to 600 million tons in 2040 based on the data available of plastic production rate between 2008 and 2019 (Tiseo, 2021) and assuming a linear trend. However, based on (Shams, Alam, and Mahbub's, 2021)'s research data, it has been estimated that COVID-19 caused a drastic increase in plastic production to around 698 million tons in only 2020.

Figure 10: The Bangkok metropolitan area generates food trash, plastic waste, and municipal solid waste. Note: According to the BMA's Department of Environment, the average of PW and MSW generation in 2020 is between January and April. There are no food waste data available for 2019 or 2020.

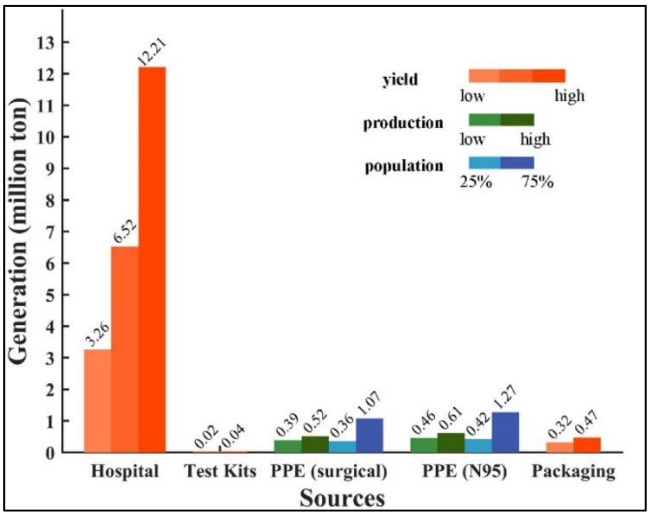

Figure 11: The COVID-19 epidemic has resulted in a global generation of unmanaged plastics from several sources (hospital medical waste, test kits, personal protective equipment, and internet packaging). For each source, high- and low-yield scenarios are evaluated (Methods).

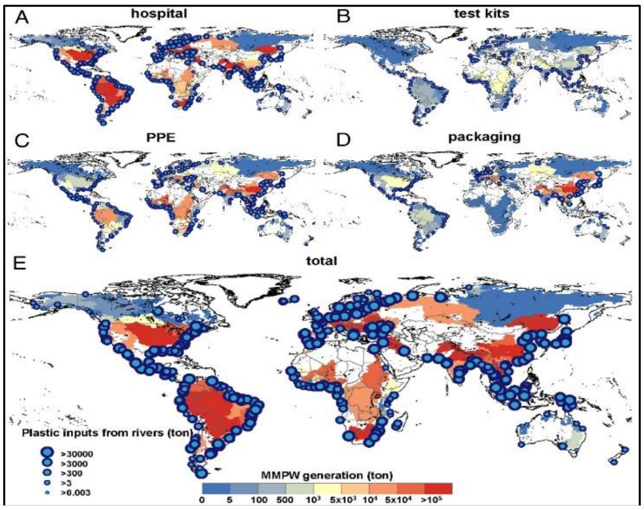

Figure 12: Unmanaged plastics from pandemic-related riverine discharge have amassed in the global ocean. Panels illustrate the discharges caused by (A) hospital medical waste, (B) COVID-19 viral test kits, (C) personal protective equipment, (D) online-shopping packing material, and (E) all of them. The MMPW formed in each watershed is represented by the background color, while the sizes of the blue circles represent river mouth discharges.

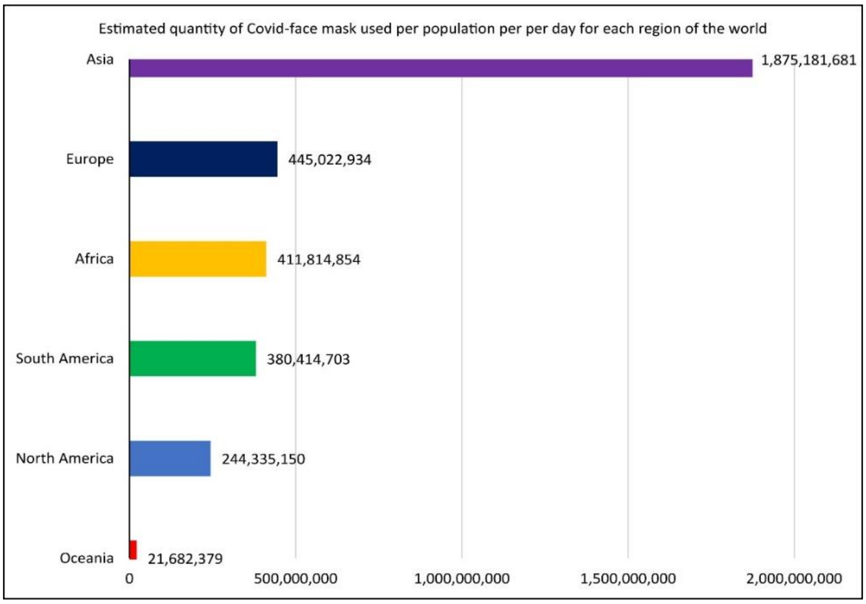

Figure 13: Estimated daily single-use facemasks (face shields) discarded by each continent

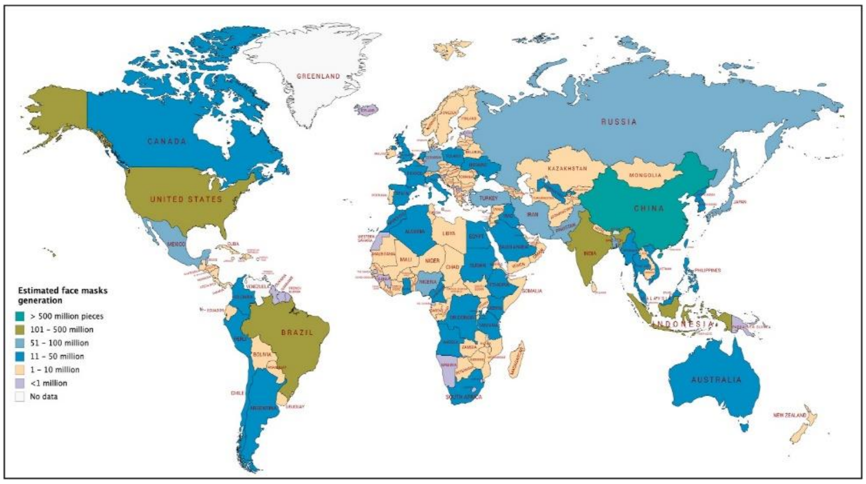

Figure 14: Estimated global share of face masks discarded as COVID-waste generated from a given. Country.

4. Discussion

The estimated decrease in daily fossil CO2 emissions from the severe and forced confinement of world populations of –17% (–11 to –25%) at its peak are extreme and probably unseen before. Still, these only correspond to the level of emissions in 2006. The resulting yearly decline will be much smaller (–4.2 to –7.5 percent, according to our sensitivity studies), but it will be comparable to the annual reductions required over the next decades to keep global warming to 1.5 degrees Celsius. (IPCC, 2018; UNEP, 2019). These figures highlight both the rapid increase in global emissions over the last 14 years and the magnitude of the task we face in limiting climate change in accordance with the Paris Climate Agreement. Furthermore, because most of the changes observed in 2020 do not reflect structural changes in the economic, transportation, or energy sectors, they are likely to be transient. The social pain of confinement and the changes that accompany it could influence the future trajectory in unanticipated ways34, but social responses alone, as shown here, would not be sufficient to achieve the deep and long-term reductions required to achieve net-zero emissions. Low-energy and/or material demand scenarios investigated for climate stabilization expressly aim to link lower demand with increased well-being (Creutzig et al., 2017; McCollum et al., 2020), an ambition that coercive confinements do not meet. Still, by applying economic stimulus that are linked with low-carbon paths, there are potential to set structural changes in motion. Our research illustrates how sensitive the emissions from the surface transportation sector are to policy and economic adjustments. Surface transportation accounts for nearly half of the reduction in emissions during confinement, and active travel such as walking and cycling, including electric vehicles, has social distancing qualities that are likely to be desirable for some time, as well as the potential to help reduce CO2 emissions and air pollution as confinement is eased (Kissler et al., 2020). Cities such as Bogota, New York, Paris, and Berlin, for example, are repurposing roadway space for walkers and bikes in order to promote secure individual mobility, with some alterations likely to be permanent. Further research could look into the possibility of near-term emissions reductions in the transportation industry that have little or no negative impact on social well-being.

Several factors, including calls from some governments, are pushing for a rebound with an even greater emission trajectory than the policy-induced trajectories before to the COVID-19 epidemic and Green New Deal programs will be delayed, and automobile emission requirements will be weakened (Leyen, 2020), and supply issues are causing a halt to clean energy implementation and development. The extent to which world leaders consider net-zero emissions targets and climate change imperatives while developing their COVID-19 economic policies is predicted to have a long-term impact on CO2 emissions.

Many containment tactics will likely continue to be imposed as the epidemic is not expected to be entirely contained in the next few years (Egypt Independent, 2020.). The number of confirmed cases is expected to reach 280 million by the end of 2021, according to conservative estimates (IHME:,2021.). The total MMPW generated by the pandemic will be 11 million tons, culminating in a global riverine discharge of 34,000 tons into the ocean. According to India's record-breaking confirmed cases, MMPW produce and discharge may be projected to be more in Asia. (WHO, 2021.). The destiny and transport of newly generated plastic discharge can be deduced from our existing results, given the linearity between discharge and ocean plastic mass. The destiny and transport of newly generated plastic discharge can be deduced from our existing results, given the linearity between discharge and ocean plastic mass.

Due to a lack of good data, our estimate of pandemic-related MMPW emission is subject to significant uncertainty (e.g., under overcapacity conditions, the number of used masks and online order packets, as well as the fraction of mismanaged waste). For example, based on survey data, a person uses a single mask daily and that a mask lasts for 6 days (Chowdhury et al., 2021) our estimate for the discharge from face mask use is substantially lower than that. As a result, we analyze a variety of scenarios to limit the actual occurrences. Plastic discharged to the ocean as a result of the pandemic accounts for 15 percent of total riverine plastic discharges. (Lebreton et al., 2012; Schmidt et al., 2017a). A large portion of the discharge is medical waste that also elevates the potential ecological and health risk (Hirsch, 1988) or even the spreading of the COVID-19 virus (Nabi & Khan, 2020.). This offers lessons waste management requires structural changes. The revocation or postponement of SUP bans may make it more difficult to manage plastic garbage after the outbreak. Public understanding of the environmental impact of PPE and other plastic items must be raised around the world. Innovative technology, as well as the development of more environmentally friendly materials, must be fostered in order to improve plastic waste collection, categorization, treatment, and recycling (Bondaroff, 2020; Bellou et al., 2021). Better management of medical waste in epicenters, especially in developing countries, is necessary.

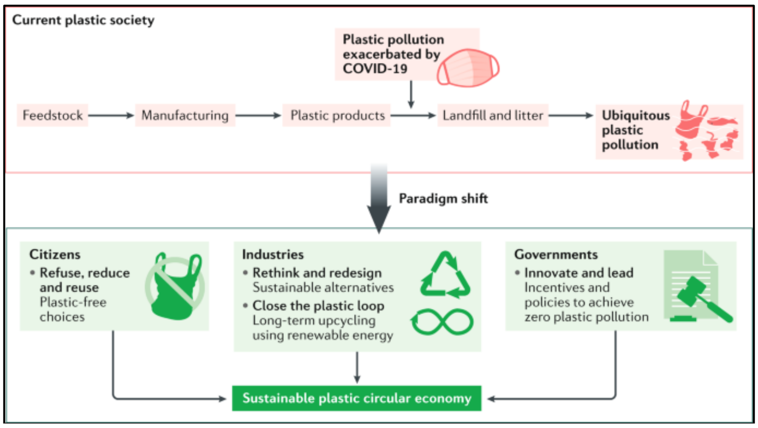

Figure 15: A proposed shift towards a circular plastic economy. Global plastic pollution has been exacerbated by the COVID-19 pandemic. Sustainable plastic use should be prioritized, to create a circular plastic economy

As a result, governments must coordinate the collection, segregation, and disposal of plastic garbage generated during the COVID-19 pandemic. Potentially contaminated waste should be collected in specially labeled reusable containers for simple separation and treatment, and waste treatment facilities should have real-time information on incoming PPE waste volume, types, and hotspots of creation. In the near future, an integrated mechanical and chemical recycling process will be required for the disposal of plastic PPE (Coates et al., 2020). Hydrocracking, for example, has the potential to be a sustainable process because to its low carbon emissions and energy consumption, as well as the ease with which related pollutants may be controlled (Davidson, Furlong, and McManus, 2021). More effective use of current waste management technologies should be linked with government incentives to attain the goal of zero plastic pollution. Instead of being mishandled, end-of-life plastic

PPE should be intended to be totally degraded or correctly repurposed for value-added uses.

During the COVID-19 pandemic, a balance must be achieved between safeguarding public health and minimizing environmental harm. Even if capacity is increased, present plastic waste management schemes will not be able to keep up with the expected increases in plastic trash creation in the long run. COVID-19 has exacerbated the problem, but it is not the underlying cause – single-use plastics were already widespread and poorly disposed of before the pandemic. There is an acute need to change to a circular economy for plastics, both during the pandemic and, more significantly, thereafter. Consumers, researchers, governments, and industries must all work together to achieve this aim Figure 15. Plastics that are inappropriately disposed of in the oceans and on land endanger marine life and, as a result, human lives. Plastic waste is already causing environmental damage in both the marine and terrestrial habitats, but it will eventually degrade into micro and nanoscale plastics. We also looked at how increasing plastic pollution will worsen the micro- and nanoscale plastic problem, which has recently become a serious concern. This review will help people understand how plastic is used and how it affects the environment in the event of a pandemic like COVID-19.

5. Conclusion and recommendation

This paper has evaluated and analyzed past studies on how the COVID-19 pandemic has influenced or is anticipated to influence global climate action. The study found that the several big cities and countries with extensive carbon emissions-related operations and long-term lockdown measures dramatically reduced carbon emissions in 2020. In comparison to 2019, some big cities and countries that were either little impacted by COVID-19 or did not take severe lockdown measures had a minor or no impact on carbon emissions in 2020. Furthermore, because most of the changes observed in 2020 do not reflect structural changes in the economic, transportation, or energy sectors, they are likely to be transient. The social trauma of confinement and the changes that accompany it could modify the future trajectory in unanticipated ways, but social responses alone, as shown here, would not be sufficient to achieve the deep and long-term reductions required to achieve net-zero emissions. Low-energy and/or low-material demand scenarios investigated for climate stabilization specifically attempt to match reduced demand with increased well-being, an objective that is not satisfied via mandatory confinement. Still, by applying economic stimulus that are linked with low-carbon paths, there are potential to set structural changes in motion. The extent to which world leaders consider net-zero emissions targets and climate change imperatives while developing their COVID-19 economic policies is predicted to have a long-term impact on CO2 emissions.

People should be mindful of the long-term repercussions of their plastic usage and disposal, since the COVID-19 epidemic has compounded the problem of plastic pollution. According to the summary data and hypothetical estimates, the COVID-19 epidemic has resulted in a massive amount of plastic being produced over the world. During the pandemic, poor plastic waste management and unlawful dumping will have both short and long-term repercussions on biological, ecological, and human health. Plastic trash is currently damaging the marine and terrestrial environments, but it will also disintegrate in the future into minuscule micro and nanoscale plastics. These micro and nanoscale plastics have the potential to harm humans and the environment even more irreversibly. Public understanding of the environmental impact of PPE and other plastic items must be raised around the world. Better plastic trash collection, categorization, treatment, and recycling, as well as the development of more environmentally friendly materials, require the promotion of innovative technology. Because current technologies are overwhelmed, new plastic waste management strategies are required to deal with this plastic overflow. As a result, it is critical to establish plastic usage laws and to educate people on how to minimize, reuse, recycle, and manage plastic trash. Contingency preparations for future plastic pollution and plastic waste management in critical scenarios should be the focus of future effort.

During the first wave of the pandemic, the respondents' opinions were reflected in the article. It should be interesting to repeat the study after a year. The authors anticipate that the data and patterns presented in the research will aid attempts to better understand the COVID-19 pandemic's relationship to climate change. The development of COVID-19 vaccinations will help to limit the disease's spread. However, climate change will continue to be an issue long after COVID-19 has been eliminated. If the present lessons from both global crises are learned and the appropriate policies and measures are implemented, the world may be better prepared to deal with global climate change, which has local consequences. This review will also assist individuals in comprehending the influence of COVID-19 on climate change. This epidemic has both advantages and disadvantages, and now is the greatest time to shift the new globalization normal. Global policymakers should take into account the urgent necessity to shift policies toward a circular economy with the best possible environmental sustainability, both during the epidemic and, more importantly, thereafter. The authors of the COVID-19 pandemic reference articles expect that their findings will benefit efforts to better understand the disease's relationship to climate change. If the world learns from both global crises, it may be better prepared to deal with global climate change, which has local implications.

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Data Availability

Global Carbon Project CO2 emissions data are available at https://www.icos-cp.eu/global-carbon-budget-2019 . International Energy Agency IEA World Energy Balances 2019@IEA are available at http://www.iea.org/statistics/. European Network of Transmission System Operators Electricity Transparency Platform are available at https://transparency.entsoe.eu/. Power System Operation Corporation Limited data are available at https://posoco.in/reports/daily-reports/ . EIA data are available at https://www.eia.gov/realtime_grid/ and https://www.eia.gov/environment/emissions/ state/ . CO2 emissions data for China are available at https://doi.org/10.1038/s41597-020-0393-y/. Coal changes from China industry are available at https://www.carbonbrief.org/analysis-coronavirus-hastemporarily-reduced-chinas-co2-emissions-by-a-quarter/ . American Iron and Steel Institute data are available at https://www.steel.org/industry-data/. TOMTOM Traffic Index are available at https://www.tomtom.com/en_gb/traffic-index . MS2 Corporation traffic data are available at https://www.ms2soft.com/traffic-dashboard . Apple Mobility Trends data are available at https://www.apple.com/covid19/mobility/. UK traffic data from the Cabinet Office Briefing are available at https://www.gov.uk/government/collections/slides-and-datasets-to-accompany-coronavirus-press-conferences . Octopus Energy Tech smart meter data are available at https://tech.octopus.energy/data-discourse/2020-social-distancing/index.html. Aircraft on Ground OAG data are available at https://www.oag.com/coronavirus-airline-schedules-data/.Global plastic production 1950-2019 data are taken from United States Environmental Protection Agency, 2019. Documentation for the Waste Reduction Model (WARM) and available at https://www.epa.gov/warm.

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