nature climate change

ARTICLES
https://doi.org/10.1038/s41558-020-0797-x

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Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement

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Government policies during the COVID-19 pandemic have drastically altered patterns of energy demand around the world. Many international borders were closed and populations were confined to their homes, which reduced transport and changed consumption patterns. Here we compile government policies and activity data to estimate the decrease in CO_2 emissions during forced confinements. Daily global CO_2 emissions decreased by –17% (–11 to –25% for $\pm1\sigma$) by early April 2020 compared with the mean 2019 levels, just under half from changes in surface transport. At their peak, emissions in individual countries decreased by –26% on average. The impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2 to –7%) if prepandemic conditions return by mid-June, and a high estimate of –7% (–3 to –13%) if some restrictions remain worldwide until the end of 2020. Government actions and economic incentives postcrisis will likely influence the global CO_2 emissions path for decades.

Before the COVID-19 pandemic of 2020, emissions of carbon dioxide were rising by about 1% per year over the previous decade[1–3], with no growth in 2019[3,4] (see Methods). Renewable energy production was expanding rapidly amid plummeting prices[5], but much of the renewable energy was being deployed alongside fossil energy and did not replace it[6], while emissions from surface transport continued to rise[3,7].

The emergence of COVID-19 was first identified on 30 December 2019[8] and declared a global pandemic by the World Health Organization on 11 March 2020. Cases rapidly spread, initially mainly in China during January, but quickly expanding to South Korea, Japan, Europe (mainly Italy, France and Spain) and the United States between late January and mid-February, before reaching global proportions by the time the pandemic was declared[9]. Increasingly stringent measures were put in place by world governments in an effort, initially, to isolate cases and stop the transmission of the virus, and later to slow down its rate of spread. The measures imposed were ramped up from the isolation of symptomatic individuals to the ban of mass gatherings, mandatory closure of schools and even mandatory home confinement (Table 1 and Fig. 1). The population confinement is leading to drastic changes in energy use, with expected impacts on CO_2 emissions.

Despite the critical importance of CO_2 emissions for understanding global climate change, systems are not in place to monitor global emissions in real time. CO_2 emissions are reported as annual values[1], often released months or even years after the end of the calendar year. Despite this, some proxy data are available in near-real time or at monthly intervals. High-frequency electricity data are available for some regions (for example, Europe[10] and the United States[11]), but rarely the associated CO_2 emissions data. Fossil fuel use is estimated for some countries at the monthly level, with data usually released a few months later[1,12]. Observations of CO_2 concentration in the atmosphere are available in near-real time[13,14], but the influence of the natural variability of the carbon cycle and meteorology is large and masks the variability in anthropogenic signal over a short period[15,16]. Satellite measurements for the column CO_2 inventory[17] have large uncertainties and also reflect the variability of the natural CO_2 fluxes[18], and thus cannot yet be used in near-real time to determine anthropogenic emissions.

Given the lack of real-time CO_2 emissions data, we devise an alternative approach to estimate country-level emissions based on a confinement index (CI) conceived to capture the extent to which different policies affect emissions, and available daily data of activity for six economic sectors (Table 1 and Fig. 2). The change in CO_2 emissions associated with the confinement is informative in multiple ways. First, the changes in emissions are entirely due to a forced reduction in energy demand. Although in this case the demand disruption was neither intentional nor welcome, the effect provides a quantitative indication of the potential limits that extreme measures could deliver with the current energy mix (for example, a higher rate of home working or reducing consumption). Second, during previous economic crises, the decrease in emissions was short-lived with a postcrisis rebound that restored emissions to their original trajectory, except when these crises were driven by energy factors such as the oil crises of the 1970s and 1980s, which led to substantial shifts in energy efficiency and the development of alternative energy sources[19]. For example, the 2008–2009 Global Financial Crisis saw global CO_2 emissions decline of –1.4% in 2009, immediately

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Table 1 | Definition of the CI

Level	Description	Policy examples
0	No restrictions	
1	Policies targeted at long distance travel or groups of individuals where outbreak first nucleates	Isolation of sick or symptomatic individuals
		Self-quarantine of travellers arriving from affected countries
		Screening passengers at transport hubs
		Ban of mass gatherings >5,000
		Closure of selected national borders and restricted international travel
		Citizen repatriation
2	Regional policies that restrict an entire city, region or ~50% of society from normal daily routines	Closure of all national borders
		Mandatory closure of schools, universities, public buildings, religious or cultural buildings, restaurants, bars and other non-essential businesses within a city or region
		Ban of public gatherings >100
		Perhaps also accompanied by recommended closures at a broader or national level
		Mandatory night curfew
3	National policies that substantially restrict the daily routine of all but key workers	Mandatory national 'lockdown' that requires household confinement of all but key workers
		Ban public gatherings and enforce social distancing >2 m

The CI categorizes the level of restrictions to normal activities that have the potential to influence CO_2 emissions. It is based on the policies adopted by national and subnational governments.

followed by a growth in emissions of +5.1% in 2010[20], well above the long-term average. Emissions soon returned to their previous path almost as if the crisis had not occurred.

The economic crisis associated with COVID-19 is markedly different from previous economic crises in that it is more deeply anchored in constrained individual behaviour. At present it is unclear how long and deep the crisis will be, and how the recovery path will look, and therefore how CO_2 emissions will be affected. Keeping track of evolving CO_2 emissions can help inform government responses to the COVID-19 pandemic to avoid locking future emissions trajectories in carbon-intensive pathways.

Results

In this analysis, we used a combination of energy, activity and policy data available up to the end of April 2020 to estimate the changes in daily emissions during the confinement from the COVID-19 pandemic, and its implications for the growth in CO_2 emissions in 2020. We compared this change in emissions to the mean daily emissions for the latest available year (2019 for the globe) to provide a quantitative measure of relative change compared to pre-COVID conditions.

Changes in CO_2 emissions were estimated for three levels of confinement and for six sectors of the economy, as the product of the CO_2 emissions by sector before confinement and the fractional decrease in those emissions due to the severity of the confinement and its impact on each sector (equation (1) in Methods). The analysis is done over 69 countries, 50 US states and 30 Chinese provinces, which represent 85% of the world population and 97% of global CO_2 emissions.

The confinement index (CI) is defined on a scale of 0 to 3 and allocates the degree to which normal daily activities were constrained for part or all of the population (Table 1). Scale 0 indicates no measures were in place, scale 1 indicates policies targeted at small groups of individuals suspected of carrying infection, scale 2 indicates policies targeted at entire cities or regions or that affect about 50% of society and scale 3 indicates national policies that substantially restrict the daily routine of all but key workers (Supplementary Extended Methods). During the early confinement phase around Chinese New Year in China (starting 25 January 2020), around 30% of global emissions were in areas under some confinement (Fig. 1). This increased to 70% by the end of February, and over 85% by mid-March when confinement in Europe, India and the United States started, as China relaxed confinement (Fig. 1). At its peak in early April, 89% of global emissions were in areas under some confinement.

The six economic sectors covered in this analysis are: (1) power (44.3% of global fossil CO_2 emissions), (2) industry (22.4%), (3) surface transport (20.6%), (4) public buildings and commerce (here shortened to 'public', 4.2%), (5) residential (5.6%) and (6) aviation (2.8% (Methods)). We collected time-series data (mainly daily) representative of activities that emit CO_2 in each sector to inform the changes in each sector as a function of the confinement level (Fig. 2). The data represent changes in activity, such as electricity demand or road and air traffic, rather than direct changes in CO_2 emissions. We made a number of assumptions to cover the six sectors based on the available data and the nature of the confinement (Table 2, Methods and Supplementary Tables 1–11). Changes in the surface transport and aviation sectors were best constrained by indicators of traffic from a range of countries, which included both urban and nationwide data. Changes in power-sector emissions were inferred from electricity data from Europe, the United States and India. Changes in industry were inferred mainly from industrial activity in China and steel production in the United States. Changes in the residential sector were inferred from UK smart meter data, whereas changes in the public sector were based on assumptions about the nature of the confinement. All the activity changes are relative to typical activity levels prior to the COVID-19 pandemic (Supplementary Extended Methods).

Activity data show that the changes in daily activities at the country, state or provincial level were largest in the aviation sector, with a decrease in daily activity of −75% (−60 to −90%) during confinement level 3 (Table 2). Surface transport saw its activity reduce by −50% (−40 to −65%), whereas industry and public sectors saw their activity reduce by −35% (−25 to −45%) and −33% (−15 to −50%), respectively. Also during confinement level 3, power saw its activity decrease by a modest −15% (−5 to −25%) and the residential sector saw its activity increase by +5% (0 to +10%). Activity data also show substantial decreases in activity during confinement level 2, and only small decreases during confinement level 1 (Table 2).

Daily changes in CO_2 emissions

The effect of the confinement was to decrease daily global CO_2 emissions by −17 (−11 to −25) $MtCO_2\,d^{-1}$, or −17% (−11 to −25%)

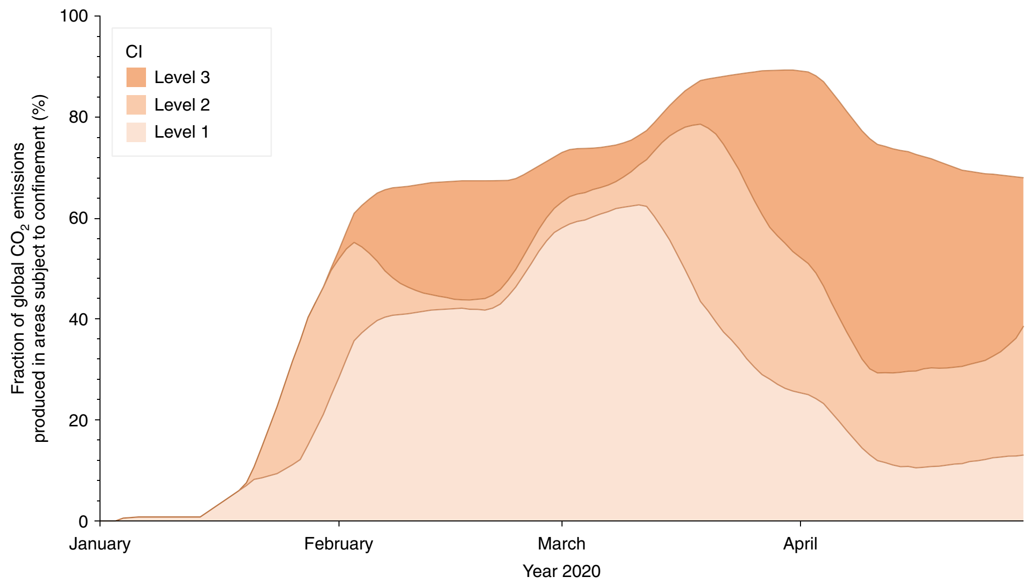

Fig. 1 | Fraction of global CO_2 emissions produced in areas subject to confinement. CO_2 emissions from countries, states and provinces in each confinement level (Table 1) aggregated as a fraction of global CO_2 emissions. CO_2 emissions are from the Global Carbon Project[1] (Methods).

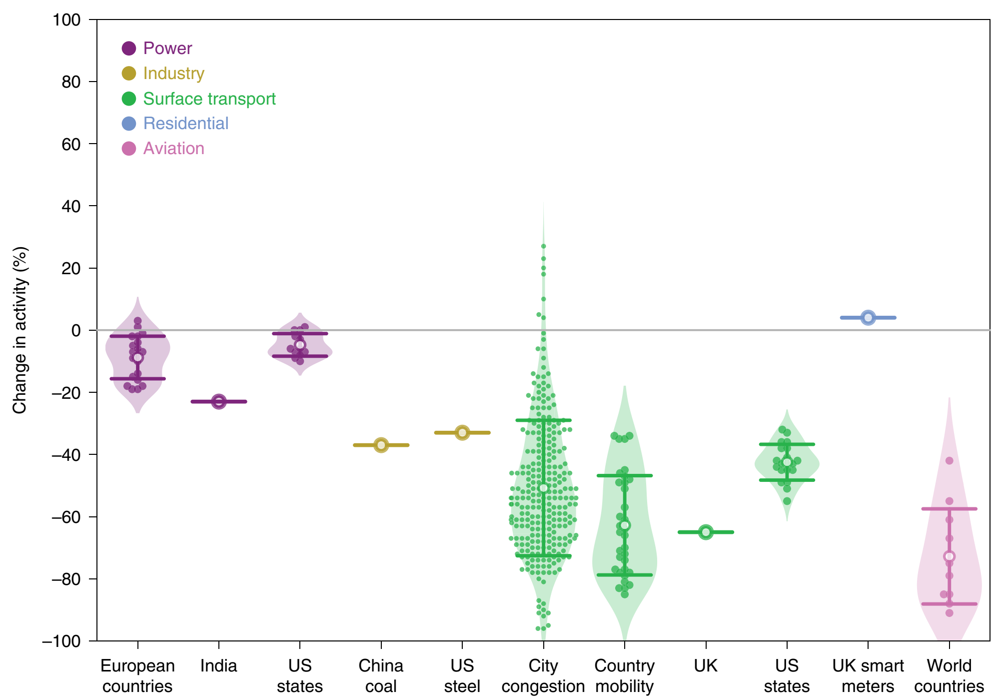

Fig. 2 | Change in activity by sector during confinement level 3 (percent). The data includes: for the power sector, temperature-adjusted electricity trends in Europe[10], India[38] and the US[11]; for the industry sector, coal use in industry in China[22] and US steel production[39]; for the surface transport sector, city congestion[40], country mobility[41], UK[42] and US state[43] traffic data; for the residential sector, UK smart meter data[44]; and for aviation, aircraft departures[45]. Each data point (filled circles) represents the analysis of a full time series and shows the changes in activity compared to typical activity levels prior to COVID-19, corrected for seasonal and weekly biases. These changes along with the nature of the confinement were used to set the parameters in equation (1) in Methods. The data are randomly spaced to highlight the volume of some data streams. Open points represent the mean value among the sample of data points, whereas the whiskers mark the standard deviation from the mean. The plotted violins represent the kernel density estimate of the probability density function for each sample of data points.

by 7 April 2020 (Table 2 and Supplementary Table 12), relative to the mean level of emissions in 2019. The change in emissions on 7 April was the largest estimated daily change during 1 January to 30 April 2020. Daily emissions in early April are comparable to their levels of 2006 (Fig. 3). The values in $MtCO_2\,d^{-1}$ are close to the value in percent coincidentally, because we currently emit about 100 $MtCO_2\,d^{-1}$. For individual countries, the maximum daily decrease averaged to −26% (±7% for ±1σ). The maximum daily decrease did not occur during the same day across countries, and hence the country decreases are more pronounced than the global

Table 2 | Change in activity as a function of the confinement level (%)

	Change in activity as a function of confinement level (equation (1))[a]			Results[b]
	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 shown. [a]Parameters used in equation (1) for each sector (ΔA^s). [b]Change in emissions for each sector for the globe on the day with the maximum change (7 April 2020). The change is estimated relative to the mean level of emissions in 2019 (Methods).

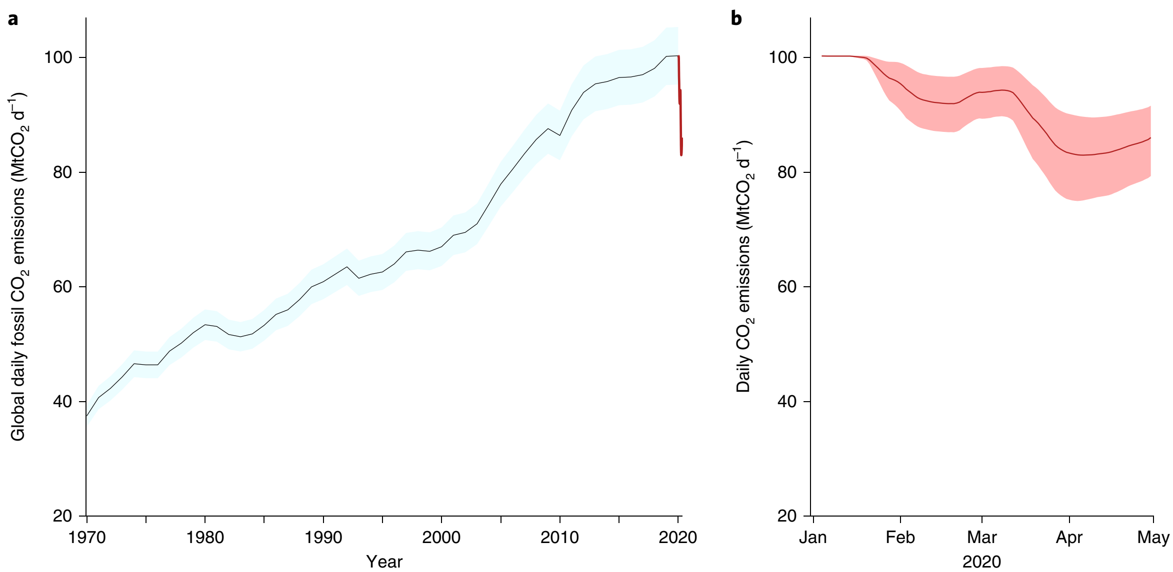

Fig. 3 | Global daily fossil CO_2 emissions ($MtCO_2\,d^{-1}$). a, Annual mean daily emissions in the period 1970–2019 (black line), updated from the Global Carbon Project[1,3] (Methods), with uncertainty of ±5% (±1σ; grey shading). The red line shows the daily emissions up to end of April 2020 estimated here. **b**, Daily CO_2 emissions in 2020 (red line, as in **a**) based on the CI and corresponding change in activity for each CI level (Fig. 2) and the uncertainty (red shading; Table 2). Daily emissions in 2020 are smoothed with a 7-d box filter to account for the transition between confinement levels.

maximum daily decrease. Estimated changes quantify the effect of confinement only, and are relative to underlying trends prior to the COVID-19 pandemic. The daily decrease in global CO_2 emissions during the pandemic is as large as the seasonal amplitude in emissions estimated from data published elsewhere[21] (−17 $MtCO_2\,d^{-1}$; M.J.W., manuscript in preparation), which results primarily from the higher energy use in winter than in summer in the Northern Hemisphere. The range in estimate reflects the range of parameter values (Table 2) based on the spread in the underlying data (Fig. 2).

Global emissions from surface transport fell by −36% or −7.5 (−5.9 to −9.6) $MtCO_2\,d^{-1}$ by 7 April 2020 and made the largest contribution to the total emissions change (−43%; Fig. 4, Table 2 and Supplementary Table 12). Emissions fell by −7.4% or −3.3 (−1.0 to −6.8) $MtCO_2\,d^{-1}$ in the power sector and by −19% or −4.3 (−2.3 to −6.0) $MtCO_2\,d^{-1}$ in the industry sector. Emissions from surface transport, power and industry were the most affected sectors in absolute values, accounting for 86% of the total reduction in global emissions. CO_2 emissions declined by −60% or −1.7 (−1.3 to −2.2) $MtCO_2\,d^{-1}$ in the aviation sector, which yielded the largest relative anomaly of any sector, and by −21% or −0.9 (−0.3 to −1.4) $MtCO_2\,d^{-1}$ in the public sector. The large relative anomalies in the aviation sector correspond with the disproportionate effect of confinement on air travel (Table 2), although the sector contributed only 10% of the decrease in global CO_2 emissions. A small growth in global emissions occurred in the residential sector, with +2.8% or +0.2 (−0.1 to +0.4) $MtCO_2\,d^{-1}$ and only marginally offsets the decrease in emissions in other sectors.

The total change in emissions until the end of April is estimated to amount to −1,048 (−543 to −1,638) $MtCO_2$ (Supplementary Table 13), equivalent to a −8.6% decrease over January–April 2019. Of this, the changes are largest in China, where the confinement started, with a decrease of −242 (−108 to −394) $MtCO_2$, then in the United States, with −207 (−112 to −314) $MtCO_2$, then Europe, with −123 (−78 to −177) $MtCO_2$, and India, with −98 (−47 to −154) $MtCO_2$. These changes reflect both that these regions emit high levels of CO_2 on average and that their confinements were severe in the period through end of April. The integrated changes in emissions over China are comparable in magnitude with the estimate of −250 $MtCO_2$ of Myllyvirta (2020)[22] up to the end of March. The global changes in emissions is also consistent with global changes in the NO_2 inventory from satellite data, although the concentration data are complex to interpret (Supplementary Figs. 1 and 2).

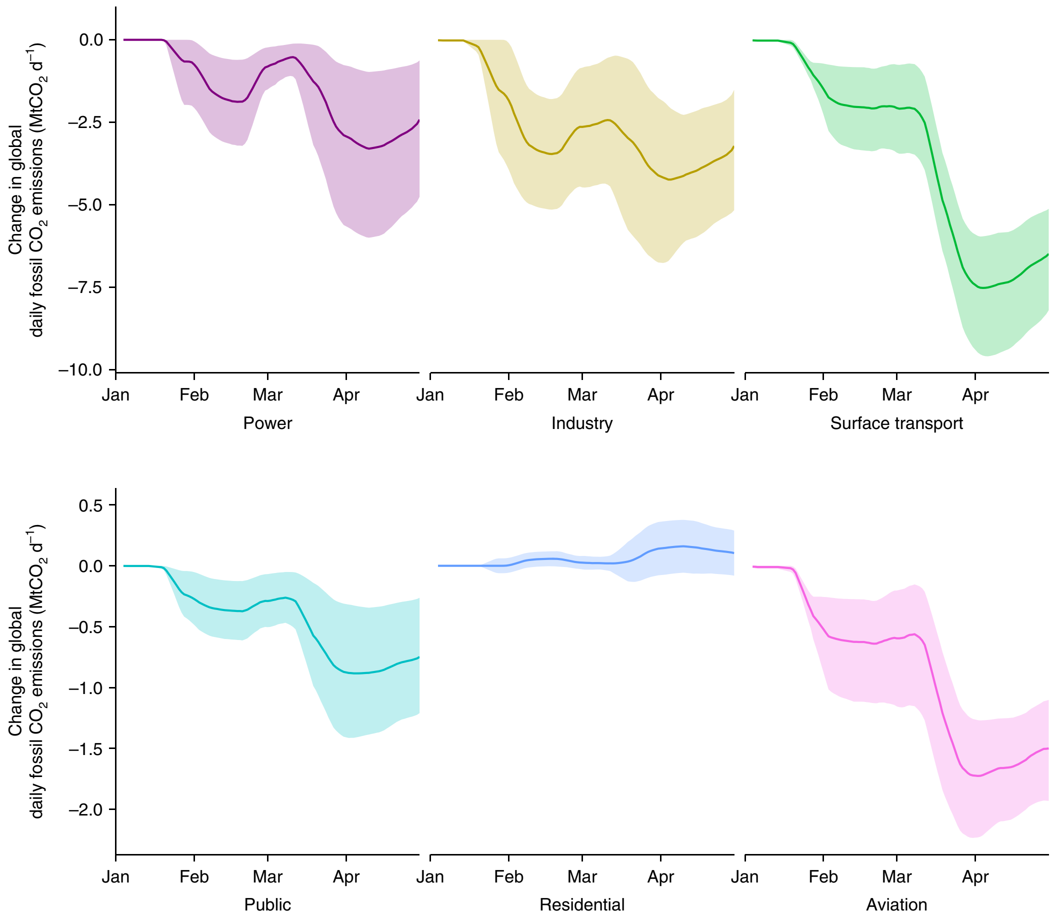

Fig. 4 | Change in global daily fossil CO_2 emissions by sector ($MtCO2\ d^{-1}$). The uncertainty ranges represent the full range of our estimates. Changes are relative to annual mean daily emissions from those sectors in 2019 (Methods). Daily emissions are smoothed with a 7-d box filter to account for the transition between confinement levels. Note the different ranges on the *y* axes in the upper and lower panels.

Implications for global fossil CO_2 emissions in 2020

The change for the rest of the year will depend on the duration and extent of the confinement, the time it will take to resume normal activities and the degree to which life will resume its preconfinement course. At the time of press, most countries that were in confinement level 3 had announced dates when they anticipated some confinement would be lifted. Dates ranged between mid-April and mid-May. We used those dates where available, and for other countries we assumed an end of confinement that corresponded to those neighbouring regions or states (Supplementary Tables 14 and 15). It is possible that the end of confinement will be delayed in some countries and therefore these dates are probably the earliest possible dates. Nevertheless, the mounting social[23,24] and economic pressure[25], along with the improving management of healthcare, means a systematic postponement is unlikely.

We assessed the effect of the recovery time by conducting three sensitivity tests. Our sensitivity tests are not intended to provide a full range of possibilities, but rather to indicate the approximate effect of the extent of the confinement on CO_2 emissions. Before COVID-19, we expected global emissions to be similar to those in 2019[2], so the effect of confinement on CO_2 emissions provided above might be approximately equivalent to the actual change from 2019 emissions. Our sensitivity tests do not attempt to quantify the effects of multiple confinement waves, or of deeper and sustained changes in the economy that could result from either the collapse of tens of thousands of small and medium businesses or government economic stimulus packages.

In the first sensitivity test, we assumed that after the announced dates for initial deconfinement, activities will return to precrisis levels within six weeks (around mid-June), as observed for coal use in industry in China[22] (Supplementary Fig. 3). In this case, the decrease in emissions from the COVID-19 crisis would be −1,524 (−795 to −2,403) $MtCO_2$ or −4.2% (−2.2 to −6.6%). In the second sensitivity test, we assumed it takes 12 weeks to reach preconfinement levels (towards the end of July), because of the low productivity that results from social trauma and low confidence. This longer period is more aligned with the announcements of gradual deconfinements, for example, in France, the UK and Norway, where a gradual deconfinement is planned over the coming months, and with timescales for the expected progression of the illness[26]. In this case, the decrease in emissions from the COVID-19 crisis would be −1,923 (−965 to −3,083) $MtCO_2$ or −5.3% (−2.6 to −8.4%).

In the third sensitivity test, we made the same assumption as in the second test, but further assumed that confinement level 1 remains in place in all the countries examined until the end of the year. This is consistent with the situation in China in general, where, although measures were lifted at the end of February in most provinces, there are still some restrictions on specific activities, such as a restricted international travel. It is also more aligned with the latest understanding of the dynamics of transmission of the disease, which suggests prolonged or intermittent social distancing may be necessary into 2022[27]. In this case, the decrease in emissions from the COVID-19 crisis would be −2,729 (−986 to −4,717) $MtCO_2$ or −7.5% (−2.7 to −13%).

At the regional levels, the low sensitivity test led to mid-point decreases in emissions for year 2020 of −2.6%, −6.7%, −5.1% and −5.2% respectively for China, the US, Europe (EU27 + UK) and India, while the high sensitivity test led to midpoint decreases of −5.6%, −11%, −8.5% and −8.7% for those same countries (Supplementary Table 14). For comparison, for the United States alone, the Energy Information Administration (EIA) provides a forecast of a decrease in emissions of −7.5% in 2020[28], which takes into account all projected economic factors, and is between our sensitivity tests 1 and 2.

In spite of the broader effects on the economy that are not included in our analysis, our 2020 estimates are similar to those that can be inferred based on the projections of the International Monetary Fund for 2020 of −3% reduction in global Gross Domestic Product[29] combined with an average CO_2/GDP improvement of −2.7% over the past decade[2,30], which gives a −5.7% reduction in CO_2 emissions in 2020. These independent global and US projections are similar to the middle sensitivity test 2 of confinement that we present in this publication (see Supplementary Table 14), while the projection of the International Energy Agency (IEA) of −8% decrease in CO_2 emissions in 2020 aligns with our high-end test 3[31]. The International Monetary Fund and EIA further forecast that emissions will rebound by +5.8 and +3.5% in 2021, respectively, for the world and US economies.

Discussion

The estimated decrease in daily fossil CO_2 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 associated annual decrease will be much lower (−4.2 to −7.5% according to our sensitivity tests), which is comparable to the rates of decrease needed year-on-year over the next decades to limit climate change to a 1.5 °C warming[32,33]. These numbers put in perspective both the large growth in global emissions observed over the past 14 years and the size of the challenge we have to limit climate change in line with the Paris Climate Agreement.

Furthermore, most changes observed in 2020 are likely to be temporary as they do not reflect structural changes in the economic, transport or energy systems. The social trauma of confinement and associated changes could alter the future trajectory in unpredictable ways[34], but social responses alone, as shown here, would not drive the deep and sustained reductions needed to reach net-zero emissions. Scenarios of low-energy and/or material demand explored for climate stabilization explicitly aim to match reduced demand with higher well-being[34,35], an objective that is not met by mandatory confinements. Still, opportunities exist to set structural changes in motion by implementing economic stimuli aligned with low carbon pathways.

Our study reveals how responsive the surface transportation sector's emissions can be to policy changes and economic shifts. Surface transport accounts for nearly half the decrease in emissions during confinement, and active travel (walking and cycling, including e-bikes) has attributes of social distancing that are likely to be desirable for some time[27] and could help to cut back CO_2 emissions and air pollution as confinement is eased. For example, cities like Bogota, New York, Paris and Berlin are rededicating street space for pedestrians and cyclists to enable safe individual mobility, with some changes likely to become permanent. Follow-up research could explore further the potential of near-term emissions reductions in the transport sector that could be delivered with minimal or positive impact on societal well-being.

Several drivers push towards a rebound with an even higher emission trajectory compared with the policy-induced trajectories before the COVID-19 pandemic, which include calls by some governments[36] and industry to delay Green New Deal programmes and to weaken vehicle emission standards[37], and the disruption of clean energy deployment and research from supply issues. The extent to which world leaders consider the net-zero emissions targets and the imperatives of climate change when planning their economic responses to COVID-19 is likely to influence the pathway of CO_2 emissions for decades to come.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-020-0797-x.

Received: 9 April 2020; Accepted: 1 May 2020;
Published online: 19 May 2020

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Methods

Changes in emissions. Changes in emissions $\Delta CO_2^{c,s,d}$ ($MtCO_2\,d^{-1}$) for each country/state/province (c), sector (s) and day (d) are estimated using equation (1):

$$\Delta CO_2^{c,s,d} = CO_2^{c} \times \delta S^{c} \times \Delta A^{s,d(\mathrm{CI},c)} \quad (1)$$

where CO_2^c ($MtCO_2\,d^{-1}$) is the mean daily emissions for the latest available year (2017–2019) updated from the Global Carbon Project for world countries[1] (Supplementary Extended Methods), EIA[46] for the United States and updated national statistics[47] for Chinese provinces. International aviation and shipping is allocated to each country using data from IEA[48]. δS^c is the fraction of emissions in each sector calculated using data from the IEA[48] for world countries, EIA[46] for the United States and national statistics[47] for Chinese provinces. $\Delta A^{s,d(\mathrm{CI},c)}$ is the fractional change in activity level for each sector compared with pre-COVID levels (Fig. 2 and Table 2) as a function of the CI for each day of the year and each country, state or province (Supplementary Tables 15 and 16). The combination of CO_2 emissions data from the Global Carbon Project and sector distribution from IEA enabled the use of a country's own reported emissions to the UNFCCC (United Nations Framework Convention on Climate Change), building on our previous work[1], and means that more recent emissions could be used. Our analysis is done for 69 countries, which accounts for 97% of global emissions. We do not estimate the changes in other countries.

Parameter choices. The choice of parameters by sector is based on data that represent changes in activity rather than directly changes in CO_2 emissions, and on assumptions about the nature of the confinement. Most data are available daily up to 15 April 2020. All the data (Fig. 2) are representative of changes compared to a typical day prior to confinement, taking into account seasonality and day of the week. The changes were calculated differently depending on the data availability and the causes of the seasonality and weekly variability. The uncertainty represents approximately $\pm 1\sigma$. Sectors and parameter choices are described in detail in Supplementary Extended Methods with the key elements summarized here.

The power sector (44.3% of global CO_2 emissions) includes energy conversion for electricity and heat generation. The change in electricity and heat assumes this sector follows the change observed in electricity demand data for the United States[11], selected European countries[10] and India[38]. The analysis accounts for cooling degree-days so that the effect of the confinement alone is isolated.

The industry sector (22.4%) includes the production of materials (for example, steel) and of cement, and manufacturing. The change in industry is based on coal consumption from six coal producers in China[22] and on steel production in the United States[39].

The surface transport sector (20.6%) includes cars, light vehicles, buses and trucks, as well as national and international shipping. The change in transport is based on Apple mobility data[41] for world countries, MS2 corporation for US state data[43] and the UK government[42] for traffic data, and urban congestion data from TOMTOM[40]. The changes in shipping are based on forecasts by the World Trade Organization.

The public sector (4.2%) includes public buildings and commerce. The change in the public sector is based on surface transport for the upper limit, assuming it is proportional to the change in the workforce. It is based on electricity changes for the lower limit, with the central value interpolated between the two.

The residential sector (5.6%) represents mostly residential buildings. The changes in residential sector is based on reports of residential use monitored with UK smart meters from Octopus Energy[44].

The aviation sector (2.8%) includes both domestic and international aviation. It is based on the total number of departing flights by aircraft on ground[45].

Data availability

Global Carbon Project CO_2 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/. CO_2 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-has-temporarily-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/.

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Acknowledgements

We thank P. Hunter for insights on the evolution of the pandemic. C.L.Q. and D.R.W. were funded by the Royal Society (grant no. RP\R1\191063). P.F., A.J.D.-G., R.M.A. and G.P.P. were funded by the European Union Horizon 2020 (H2020) '4C' project (no. 821003), M.W.J. and A.J.P.S. by the H2020 'VERIFY' project (no. 776810), G.P.P. by the H2020 PARIS REINFORCE project (no. 820846), and M.W.J. by the H2020 'CHE' project (no. 776186). R.B.J. was funded by the Gordon and Betty Moore Foundation (GBMF5439). J.G.C. was funded by the Australian National Environmental Science Program—Earth Systems and Climate Change Hub. This collaboration was made possible by prior funding from the UK Natural Environment Research Funding International Opportunities Fund (no. NE/I03002X/1), and by the Global Carbon Project. We thank the UEA HPC team for support. This analysis is based in part on data from the IEA, http://www.iea.org/statistics.

Author contributions

C.L.Q., R.B.J., J.G.C., P.F. and G.P.P. conceived and designed the project. C.L.Q. and A.J.P.S. conceived the CI and, together with Y.S., produced it. C.L.Q., R.B.J., M.W.J., S.A., R.M.A., A.J.D.-G., D.R.W. and F.C. provided and analysed data. C.L.Q. produced the analysis. All the authors contributed to the interpretation of the results and wrote the paper.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information is available for this paper at https://doi.org/10.1038/s41558-020-0797-x.

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Peer review information *Nature Climate Change* thanks Hannah Ritchie and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.