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The coronavirus disease 2019 (COVID-19) pandemic has triggered the largest drop in greenhouse gas emissions since World War II. Evolving mobility patterns, in particular, have shown the short-term mitigation potential of behavioral change. Sustaining such changes could abate 15% of all transportation emissions with limited net impacts on societal well-being.

As the world holds its breath to rein in the coronavirus disease 2019 (COVID-19) pandemic, global greenhouse gas (GHG) emissions have fallen more rapidly in the space of a few months than they have from years of implementing climate policy. Now that more than half of the global population has been subject to partial or complete lockdowns at different points in time, early estimates suggest that global emission levels will be 6% lower in 2020 than in 2019, the first drop of this magnitude since World War II.¹

The drivers of these emission reductions—forced lockdowns and extensive restrictions on economic activity—are not a viable strategy against climate change. Widespread social hardship and curtailed freedoms are too high a price to pay for reducing carbon emissions when alternative and less disruptive options exist. As Antonio Guterres, Secretary-General of the United Nations, rightly observed, the world “will not fight climate change with a virus.”² Indeed, in regions where efforts to contain the pandemic have been lifted, emissions have already started to rebound to previous levels.

Still, the pandemic response and the changes in human behavior and economic processes it occasioned offer valuable lessons for the collective effort to rein in climate change. For the first time in a generation, deliberate policy choices have resulted in emission reductions at a scale approaching what climate scientists recommend to avoid the worst consequences of climate change. What if some of the observed emission reductions could be sustained without the social and economic disruption experienced during confinement?

As a growing body of literature draws parallels between the pandemic and climate change, revealing dysfunctions that have hampered the societal response to both crises and identifying opportunities for a green recovery, less analysis has sought to systematically dissect the various causes of emission reductions to single out those that might promise lasting climate benefits. We venture such an analysis in this commentary to provide a preliminary estimate of the climate opportunity and point to areas that offer the most potential.

To capture the climate opportunity, we use the heuristic notion of “decarbonization levers.” We do not propose an analysis premised on formal conceptions of social welfare or individual utility. Instead, we identify those behavioral changes witnessed during the pandemic that have yielded large emission reductions, are not a direct result of falling economic output, and have the prospect of being sustained once the contagion ends. These include adjusted practices and processes, such as the increase in local sourcing and telecommuting, as well as evolving preferences, such as a surge in online shopping or biking to avoid crowded trains. Retention (and expansion) of such changes offers potential for emission abatement without necessarily sacrificing societal well-being.

To identify the emission-reduction potential of such “decarbonization levers,” we first break down the emission reductions caused by how governments, companies, and individuals have responded to the pandemic. We then single out those changes in corporate processes and individual behavior that have the potential to be sustained, which are primarily in the transportation sector. We conclude by quantifying the short-term potential for lasting emission abatement and highlighting relevant policy implications.

**Emission Reductions Due to the Pandemic Response**

Early research suggests that lockdown measures will result in the largest emission reductions since the end of World War II. The International Energy Agency (IEA), for instance, has calculated that global CO₂ emissions will decline by 8% in 2020 to levels last seen 10 years ago.³ This represents a year-on-year reduction that is six times larger than the decline caused by the global financial crisis in 2009. These figures are in line with the Energy Information Administration (EIA) forecast of a 7.5% drop for the US in 2020.⁴ Initial academic studies confirm these estimates. Liu et al. estimate an emission decline of 5.8% for the first quarter of 2020,⁵ and Le Quéré et al. expect a decline of 5.7% in 2020 on the basis of the historic carbon intensity of economic activity and the global growth forecast of the International Monetary Fund.⁶ The latter study also applies a bottom-up approach to calculate that global emissions might have dropped by up to 17% at the peak and expect the annual decrease to lie within a range of 4.2%–7.5% depending on the duration of confinement measures.

These early estimates point to the transportation sector as the sector that is experiencing the largest fall in emissions from the pandemic. Le Quéré et al. suggest reductions from surface transportation of 36% by April 7, 2020, in relation to the mean level of emissions in 2019.⁷ Likewise, the IEA observed a steep
decline in demand for personal vehicle use and air travel as a result of restrictions on mobility and work-from-home policies: road transportation dropped between 50% and 75% in regions under lockdown, aviation activity experienced an even larger decline of more than 90% in some regions, and fuel consumption for shipping also dropped as global economic activity slowed down. Other sectors likewise experienced major emission reductions during lockdown phases, but not at the same scale. For instance, lockdowns reduced electricity demand by 20%, and emissions fell by 19% in the industry sector.

Decarbonization Levers in the Transportation Sector

With changes in transportation identified as the largest driver of emission reductions during the pandemic, researchers have suggested that the transportation sector also offers the greatest potential for retaining (and potentially expanding) emission reductions in the short term without negatively affecting societal well-being. Tapping this potential would be particularly beneficial because decarbonization of the transportation sector has proven an intractable challenge: transportation emissions have steadily increased in recent years, SUV sales continue to surge, and demand for air travel over the next two decades is set to double. How difficult it is to decarbonize transportation is evidenced by the fact that the integrated assessment models used to project pathways toward achievement of the 1.5°C temperature target set out in the Paris Agreement still anticipate substantial emissions from the sector even in 2050.

Changes in surface transportation have been found to account for nearly half of all emission reductions during the pandemic response. At the same time, non-fossil or people-powered mobility has soared and contributed to emission abatement and improved air quality. From Athens to Sydney, cities have repurposed public spaces from cars to cyclists and pedestrians, and some of these changes are likely to survive the pandemic. To quantify the climate opportunity, we link emission reductions to behavioral changes. Figure 1 depicts global GHG emissions by sector before the COVID-19 pandemic, highlights the share of transportation within the energy sector, and singles out categories and purposes of travel. On the basis of this breakdown, we explore the lockdown effects. Within air transportation, for instance, the Transportation Security Administration counted up to 96% fewer travelers in the US during some days in April 2020 than on the same day in the previous year, whereas the number of cargo flights remained rather constant. Rail and ship transportation also reveals a heterogeneous picture (e.g., analysts reported that although cruises came to a halt, only 21% of transpacific container sailings were cancelled in May). The second bar of Figure 2 summarizes these lockdown effects. The aggregation shows that lockdown measures might have reduced transportation emissions by more than half, from 7.8 to 3.3 gigatonnes of CO₂ equivalent (GtCO₂e).

At such levels, transport-related emissions would be as low as they last were 45 years ago, lower than the emission levels needed by mid-century to stay on a pathway toward decarbonization in line with the 1.5°C goal. What this unprecedented drop also illustrates is the mitigation potential of behavioral change in transportation, a lever that the integrated assessment models surveyed by the IPCC tend to subordinate to technology substitution projections. Instead, those models suggest that emerging negative-emission technologies will be more viable to address transportation emissions than changes that avoid or shift transportation activity. The scale of emission reductions during the pandemic cautions against underestimating the potential of behavioral change to accelerate decarbonization of the transportation sector.

Going forward, we see two major opportunities for sustained emission reductions. First, commuting and business-related rides accounted for about half of vehicle miles traveled before the pandemic. Retaining work-from-home policies after the COVID-19 pandemic could permanently reduce the frequency and length of such rides. Twitter, for instance, has announced a work-from-home policy that allows 100% of staff to work remotely even beyond the pandemic. Some sectors, such as manufacturing, will be less able to accommodate work-from-home policies, but even there, a sizeable and growing share of the workforce holds desk jobs that could transition to remote working. One example is the car manufacturer BMW, whose workers’ council has formulated the goal of achieving a permanent work-from-home share of 40% after the pandemic. With the service sector accounting for more than 50% of all employment globally, not including administrative or management jobs in other sectors, the potential for structural changes is significant. As the proportion of knowledge-based occupation continues to expand, so will this potential.

Regardless of sector, observed trends such as biking to work and online meetings could further reduce the number of car rides. Another behavioral shift affecting the extent of driving is shopping habits. Shopping was the main purpose of approximately one-fifth of all passenger vehicle miles traveled before the pandemic (see Figure 2). The accelerated trend toward online shopping and stockpiling offers an opportunity to permanently reduce driving for this purpose. In total, we estimate that up to one-third of miles driven by car before the pandemic could be avoided without net losses in societal well-being (see Figure 2). Some sectors (such as brick-and-mortar retail businesses) would see a loss of revenue and employment, whereas others (such as online retail businesses) would see a gain, creating distributional challenges that policymakers might need to address as part of a broader transition strategy.

Second, less business travel might reduce not only the number of car rides but also that of flights. 10% of emissions from passenger flights originated from business travel before the pandemic (see Figure 1). An analysis by airline experts suggests that four out of five flights could become obsolete as video-conferencing solutions have become more accepted during the pandemic. Given that business travelers account for about three-quarters of airline profits, a drop in business travel might disproportionately reduce the number of flights that air carriers can perform profitably. Overall, we estimate that changes to travel patterns offer the opportunity to reduce transportation emissions by 15% from 7.8 to 6.7 GtCO₂e (see Figure 2). Again, impacts on individual sectors—such as aviation—could raise distributional concerns that merit targeted measures, for instance, to mitigate employment effects.
Our calculations provide an estimate of the climate opportunity arising from transportation behavioral changes that do not negatively affect societal well-being. Behavioral changes beyond those we quantify in Figure 2 are feasible. For instance, a trend toward more local sourcing could permanently reduce emissions from trucks, planes, ships, and trains. Also, the number of non-business- or shopping-related automobile rides could be lower after the pandemic if people permanently spend a higher share of their time online than on the road.

At the same time, some rebound or compensation effects have to be considered. The lockdown increased internet usage by 70% and streaming by more than 12%. Working from home results in higher energy consumption at home, which might not be fully offset by reduced consumption in office buildings. Similarly, permanent work-from-home arrangements could incite a trend toward larger homes or additional outbuildings that can better substitute for traditional office spaces, increasing resource use. Local sourcing of food, finally, can sacrifice productivity gains from large-scale centralized agriculture. Such tradeoffs merit further study, and their dynamic nature makes it difficult to accurately estimate them.

**Conclusions and Policy Recommendations**

Notwithstanding uncertainties and data gaps in this rapidly evolving context, our analysis suggests that the transportation sector offers by far the greatest potential to reduce emissions through the type of decarbonization levers we discuss in this commentary: according to our estimate, 15% of all transportation emissions before the pandemic could be abated in the near term if we sustain changes such as increased uptake of work-from-home policies, reduced business-related travel, and altered shopping behavior. By comparison, the potential to abate emissions in other sectors appears much more limited in the short term.

Many of the observed changes driving emission reductions during the lockdown come at a price: reduced convenience, time savings, or even just—in the case of leisure and vacation travel—forgone pleasure and mental stress. However, some changes also come with new benefits, such as improved health due to reduced air pollution and increased physical activity or less productive time lost from commuting and traveling to meetings. Balancing these tradeoffs involves sensitive and often highly personal decisions, which makes any interventions through policy mandates risky and potentially unpopular.

Which of these changes can or cannot be sustained is therefore something only an open and inclusive societal debate can help explore. Governments can play a role by enabling rather than forcing changes and by facilitating deliberation across stakeholders from all parts of society and sectors of the economy. Such deliberation can, in turn, help foster awareness of the choices and their

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**Figure 1. Sectoral Breakdown of Global Greenhouse Gas Emissions**

Emission data from the World Resources Institute (WRI) as of 2016 are presented in gigatonnes of CO₂ equivalents (GtCO₂e); the breakdown of transportation emissions is based on data from the International Energy Agency (IEA), International Council on Clean Transportation (ICCT), Department of Transport, and Office for National Statistics (UK). For further details, data sources, and assumptions, see Table S1.
tradeoffs, as well as build consensus around the desirability of certain changes.

Importantly, such a debate should occur against the backdrop of already committed decarbonization objectives, which will necessitate far-reaching changes and, in some cases, also sacrifices across all parts of the economy. What the collective response to the COVID-19 pandemic has provided is powerful evidence for the mitigation potential of behavioral change: for the first time since climate change has been discussed at the political level, annual emission reductions are likely to be in line with what climate scientists tell us is needed every year for the next decades to limit global warming below 1.5°C. Where climate models assume continued high emissions from the transportation sector even by mid-century—and instead rely on (as yet unproven or fledgling) negative-emission technologies to achieve decarbonization—the pandemic response could prompt reconsideration of untapped opportunities from changes in mobility behavior.

As the recovery from COVID-19 continues to dominate the political agenda in upcoming months, we advocate for a more robust discussion of whether and how observed changes that have contributed to emission reductions can be sustained, especially in the transportation sector. Faced with an economic slowdown and falling consumer spending, however, many governments have reflexively focused their short-term efforts on accelerating a “return to normal,” including pre-pandemic demand levels and consumption patterns. In many cases, they have also faced pressure to relax environmental safeguards as a way to bolster the recovery.

Coupled with deferred investments in clean technologies and infrastructure, as well as a prolonged hiatus of national and international policy processes aimed at advancing decarbonization, the “normal” we return to after the pandemic risks being more carbon intensive than the situation before the pandemic. The last time a global emergency resulted in significant short-term emission reductions—during the economic and financial crisis of 2008—economic recovery also trumped sustainability concerns. In hindsight, many observers described it as a wasted opportunity for decarbonization. We must ensure that, this time around, climate objectives inform our collective choices lest we emerge from one crisis having only exacerbated another crisis.

So far, the debate on how pandemic response efforts might support the struggle against climate change has largely centered on the role of stimulus packages. Despite the moral and political sensitivities, however, an open discussion is also needed on how changes in individual and collective behavior can help progress decarbonization and unlock collateral benefits, such as health improvements. As our analysis of the transportation sector shows, such changes in transportation

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**Figure 2. Global Transportation Emissions before, during, and after the COVID-19 Pandemic**

All numbers are presented in GtCO2e. The GHG level before the pandemic is based on data from the WRI,\(^1\) and the approach to splitting transportation emissions is analogous to that in Figure 1. The GHG levels during the lockdown are based on estimates from the IEA,\(^3\) Le Quéré et al.,\(^1\) and our own further details, data sources, and assumptions, see Table S1. The GHG levels after the pandemic are based on our own estimates derived from expert opinion as described in Decarbonization Levers in the Transportation Sector and are underpinned by empirical data (e.g., the observed increase in basket size and stockpiling during the confinement—online as well as offline—underlines the potential to reduce mileage through fewer store visits and more efficient truck deliveries). For further details, data sources, and assumptions, see Table S1.
patterns offer significant potential for short-term emission reductions in a sector for which decarbonization is particularly challenging.

Mandating restrictions on mobility is unlikely to gain favor with voters. To tap the mitigation potential revealed in the transport sector by the pandemic, changing mindsets and perceptions will matter as much as coercive or enabling policies. Still, the pandemic has also shown that countries watch and learn from each other, such that successful approaches to containing the contagion quickly find uptake elsewhere. Even in an era of diminished multilateral cooperation, countries can learn from each other, and events such as the IEA Clean Energy Summit, held in July 2020 to discuss options for a green recovery, can serve as forums to advance a structured exchange on best practices. If the pandemic is to mark a historic peak in anthropogenic GHG emissions, we need to leverage such lessons and turn them into guardrails against a return to pre-pandemic emission growth.

EXPERIMENTAL PROCEDURES

Resource Availability

Lead Contact
Requests for further information and resources should be directed to Christian Stoll (cstoll@mit.edu).

Materials Availability

This study did not generate new unique materials.

Data and Code Availability

All data analyzed for this commentary have been included in Table S1. The data are also available at Mendeley Data: https://doi.org/10.17632/d7sty33h5g.1.

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at https://doi.org/10.1016/j.oneear.2020.09.003.

AUTHOR CONTRIBUTIONS

C.S. conceived of the study. Both authors contributed to the design of the study and data acquisition. C.S. aggregated and analyzed the data. Both authors drafted the manuscript.

REFERENCES

1. Le Quéré, C., Jackson, R.B., Jones, M.W., Smith, A.J.P., Abernethy, S., Andrew, R.M., DeCecchis, A.L., Willis, D.R., Shan, Y., Canadell, J.G., et al. (2020). Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. Nat. Clim. Chang. 10, 647–653.

2. United Nations (2020). Press conference by Secretary-General António Guterres at United Nations headquarters. SG/SM/20003, March 10, 2020. https://www.un.org/press/en/2020/sgsm20003.doc.htm.

3. International Energy Agency (2020). Global Energy Review 2020. https://www.iea.org/reports/global-energy-review-2020.

4. Energy Information Administration (2020). Short-Term Energy Outlook. https://www.eia.gov/outlooks/steo/.

5. Liu, Z., Ciais, P., Deng, Z., Lei, R., Davis, S.J., Feng, S., Zheng, B., Cui, D., Dou, X., He, P., et al. (2020). Near-real-time data captured record decline in global CO2 emissions due to COVID-19. https://arxiv.org/abs/2004.13614.

6. International Air Transport Association (2016). IATA forecasts passenger demand to double over 20 years. Press release, October 18, 2016. https://www.iata.org/en/pressroom/pr/2016-10-18-02/.

7. Intergovernmental Panel on Climate Change (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. https://www.ipcc.ch/sr15/.

8. Transportation Security Administration (2020). TSA checkpoint travel numbers for 2020 and 2019. https://www.tsa.gov/about/the-tsa/system/uploads/attachment_data/file/823068/national-travel-survey-2018.pdf.

9. The Economist (2020). Has covid-19 killed globalisation? May 14, 2020. https://www.economist.com/leaders/2020/05/14/has-covid-19-killed-globalisation.

10. Ge, M., and Friedrich, J. (2020). 4 charts explain greenhouse gas emissions by countries and sectors. World Resources Institute blog, February 6, 2020. https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector.

11. International Energy Agency (2019). Transport sector CO2 emissions by mode in the Sustainable Development Scenario, 2000-2030. https://www.iea.org/data-and-statistics/charts/transport-sector-co2-emissions-by-mode-in-the-sustainable-development-scenario-2000-2030.

12. Graver, B., Zhang, K., and Rutherford, D. (2019). CO2 emissions from commercial aviation, 2018. International Council on Clean Transportation Working Paper 2019-16. https://icct.org/publications/co2-emissions-commercial-aviation-2018.

13. Evans, A., Kelly, A., and Slocombe, M. (2019). National Travel Survey: England 2018. Department for Transport Statistical Release, July 31, 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/823068/national-travel-survey-2018.pdf.

14. Office for National Statistics (2019). Travel trends: 2019. https://www.ons.gov.uk/peoplepopulationandcommunity/leisureandtourism/articles/traveltrends/2019.

15. Harrell, E. (2020). Looking to the future of air travel. Harvard Business Review, May 4, 2020. https://hbr.org/2020/05/looking-to-the-future-of-air-travel.

16. Beech, M. (2020). COVID-19 Pushes up internet use 70% and streaming more than 12%, first figures revel. Forbes, March 25, 2020. https://www.forbes.com/sites/markbeech/2020/03/25/covid-19-pushes-up-internet-use-70-streaming-more-than-12-first-figures-revel/#31af866e63104.

17. Peters, G.P., Marland, G., Le Quéré, C., Boden, T., Canadell, J.G., and Raupach, M.R. (2012). Rapid growth in CO2 emissions after the 2008–2009 global financial crisis. Nat. Clim. Chang. 2, 2-4.

18. Hepburn, C., O’Callaghan, B., Stern, N., Stiglitz, J., and Zenghelis, D. (2020). Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? Oxf. Rev. Econ. Policy 36, https://doi.org/10.1093/oxrep/graa015.