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Climate lessons from the global response to COVID-19

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The strictest versions of lockdowns during the pandemic changed the daily rhythms of millions of people around the world, reducing the burning of fossil fuels from vehicular traffic and the aviation industry by over 50% and temporarily halting manufacturing and industrial activities. As a result, scientific evidence is now mounting on the short-term improvements this 'natural experiment' of lockdowns has had on levels of carbon dioxide and pollutants typically used as air quality indicators.

Introduction

It has been over one year since many governments around the world declared a state of emergency and initiated lockdowns to limit the spread of the coronavirus SARS-CoV-2, which has resulted in the death of more than 2.3 million people worldwide.[1] A 'lockdown' is a euphemism for halting normal business, educational, and social practices, 'locking' humans down into their homes so as to reduce physical contact between potentially contagious persons, and unaffected persons. With drastically reduced mobility, the strictest versions of lockdowns changed the daily rhythms of millions of people around the world, reducing the burning of fossil fuels from vehicular traffic and the aviation industry[2] by over 50% and temporarily halting manufacturing and industrial activities. As a result, scientific evidence is now mounting on the short-term improvements this 'natural experiment' of lockdowns has had on levels of carbon dioxide and pollutants typically used as air quality indicators.[3] In other words, lockdowns have provided us with an unanticipated experiment into what happens when we suddenly stop burning fossil fuels *en masse*. Another result considered to be 'positive' from an environmental or health standpoint is the heightened awareness of the general public on how the lockdown's 'go home and stay home' orders, and associated public health measures on wearing masks and keeping physical distance, are saving lives and reducing contagion. There is a growing recognition that individual compliance, albeit difficult, is necessary for both personal and the common good of communities. These unanticipated effects raise an important question, however: Will the public's heightened sense of awareness of our shared health future continue once the coronavirus pandemic is under control? Or, will we simply return to dangerous past practices, such as burning fossil fuels, polluting the air we breathe, and letting individual behaviors negatively affect the shared public commons? This paper addresses these questions in two ways. First, it will provide a concise summary of how scientific knowledge affected the governance and policy-decisions of major global environmental challenges of the past, including policy decisions on air pollution, the ozone hole, and climate change. Second, the paper reviews how scientific knowledge shaped and informed past policies, such as Clean Air legislation and the Montreal Protocol. Using these two insights, the paper concludes by articulating future trajectories of air quality and climate in a post COVID-19 world that is aiming for a net-zero carbon by 2050.

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[1] Covid-19 dashboard by the center for systems science and engineering at johns hopkins university (accessed february 7, 2021). https://coronavirus.jhu.edu/map.html

[2] *Report on the effects of novel coronavirus (covid-19) on civil aviation: Economic impact analysis*; Economic Development – Air Transport Bureau, International Civil Avaiation Organization (ICAO) Montréal, Canada, 2021.

[3] Amigo (analysis of emissions using observations). https://amigo.aeronomie.be/index.php/covid-19-publications/peer-reviewed

Air Pollution as a Global Public Health Issue

According to the World Health Organization (WHO)[4] and the Global Alliance on Health Pollution[5], outdoor and indoor air pollution is the cause of nearly 8 million deaths annually, with about 92% of pollution-related deaths occurring in low and middle-income countries. Over one third of deaths result from stroke, lung cancer, and chronic respiratory disease, and one quarter of the deaths stem from ischemic heart disease. Air pollution is also responsible for the premature deaths of millions around the world, causing a significant reduction in life expectancy. The largest and most susceptible groups are the young and elderly, as well as those with chronic asthma and compromised immune systems. In Canada, for example, it is estimated that 14,600 premature deaths per year can be linked to air pollution, with a total economic valuation of the health impacts of $114B annually.[6] The WHO, the World Bank, and a majority of nations recognize air pollution as an 'invisible killer' and a major public health issue that requires sustained monitoring and preventative action to safeguard the health of citizens. Naturally, the weakening of immune systems causes spillover effects: a recent study estimated that 15% of COVID-19 deaths worldwide could be attributed to air pollution.[7] Another US study showed an association between long term exposure to air pollution and higher COVID-19 mortality rate.[8] Yet, despite the clear ramifications for the health and welfare of all citizens in every nation, projects aimed at understanding sources and solutions to air pollution remain under-funded, with outdated policies that do not give enough incentives for large-scale implementation of existing technologies to improve air quality, particularly in low and middle-income countries.[5] We know that air pollution will get worse as climate change intensifies, and this is compounded by our current 'business-as-usual' mentality that promotes carbon-intense lifestyles based on consumption, which are commonly assumed to fuel the engine of the global economy.[9] This suggests that air pollution is a global health issue with a myriad of indicators and disastrous effects, yet it has not received the attention it deserves.

The Link between Air Pollution and Climate Change

Although the two concepts are commonly conflated, air pollution and climate change are different phenomena, despite being linked in the context of emission sources, atmospheric properties, processes,

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[4] Air pollution by the world health organization (accessed februay 7, 2021). https://www.who.int/health-topics/air-pollution#tab=tab_1
[5] The lancet report on pollution and health (accessed february 7, 2021). https://gahp.net/the-lancet-report-2/
[6] *Health impacts of air pollution in canada: Estimates of morbidity and premature mortality outcomes*; Health Canada: Ottawa, ON, 2019; pp http://publications.gc.ca/collections/collection_2019/sc-hc/H144-51-2019-eng.pdf.
[7] Air pollution as co-factor of covid-19 mortality (2020). https://www.mpic.de/4768451/air-pollution-as-co-factor-of-covid-19-mortality
[8] Wu, X.; Nethery, R. C.; Sabath, M. B.; Braun, D.; Dominici, F., Air pollution and covid-19 mortality in the united states: Strengths and limitations of an ecological regression analysis. *Sci. Adv.* **2020,** *6* (45), eabd4049 (1-6).
[9] Watts, N.; Adger, W. N.; Agnolucci, P.; Blackstock, J.; Byass, P.; Cai, W.; Chaytor, S.; Colbourn, T.; Collins, M.; Cooper, A.; Cox, P. M.; Depledge, J.; Drummond, P.; Ekins, P.; Galaz, V.; Grace, D.; Graham, H.; Grubb, M.; Haines, A.; Hamilton, I.; Hunter, A.; Jiang, X.; Li, M.; Kelman, I.; Liang, L.; Lott, M.; Lowe, R.; Luo, Y.; Mace, G.; Maslin, M.; Nilsson, M.; Oreszczyn, T.; Pye, S.; Quinn, T.; Svensdotter, M.; Venevsky, S.; Warner, K.; Xu, B.; Yang, J.; Yin, Y.; Yu, C.; Zhang, Q.; Gong, P.; Montgomery, H.; Costello, A., Health and climate change: Policy responses to protect public health. *The Lancet-Elsevier* **2015,** 10.1016/S0140-6736(15)60854-60856.

chemistry, and mitigation options.[10] The root cause of air pollution is chemicals emanating from the burning of fossil fuels that include nitrogen oxides, sulfur dioxide, ozone, and fine particulate matter. Human-induced climate change is the long-term effect of this burning of fossil fuels, which also releases carbon dioxide. This gas has a much longer lifetime in the atmosphere, amplifying the 'greenhouse effect' that makes life on earth possible by trapping heat in the atmosphere instead of radiating outwards into space. With the global increase in the burning of fossil fuels, levels of other greenhouse gases such as methane[11] and nitrous oxide[12] have also been steadily increasing globally, particularly from the agricultural and waste sectors. Increasing temperatures lead to increased emissions of volatile organics from the biosphere and that, in turn, increase ground-level ozone formation. The latter is known to be damaging to crops, hence reducing the capacity of trees to take up carbon dioxide from the atmosphere. In addition, emissions of particulate matter and chemicals that lead to the formation of clouds in the atmosphere alter a cloud's 'lifetime' and its properties impacting the hydrological cycle. The latter would affect water quality and quantity (floods in some areas and drought in others), infrastructure and sanitary systems, and the spread of diseases such as Lyme disease. Changes to temperature and the hydrological cycle also lead to a loss of biodiversity and wildlife habitats, which in turn increases encounters of humans with wildlife, raising the risk of new pandemics.[13] The projected increases in intensity and frequency of wildfires[14] would also lead to worsening air quality and an increase in atmospheric temperature because of black particles released through fires that trap heat. Ironically, particles that form in the atmosphere from sulfur dioxide can cause acid rain and may also have a cooling effect, because of their ability to scatter solar light back to space depending on where they are in the atmosphere. In general, if the particles are in the air we breathe, then they could also act as vehicles for transmitting airborne diseases, as we now know from the transmission of the SARS-Cov-2 virus.[15]

This all paints a seemingly dire picture for the state of the planet. Are we forever consigned to a hothouse-Earth, where increasing air pollutants and greenhouse gases send our world further spiraling into crisis? Alternatively, is there a way to test or evaluate how the Earth could respond to a sudden cessation of the burning of hydrocarbons? It is here where the lockdowns wrought by COVID-19 provide some unanticipated, yet fascinating, insights.

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[10] von Schneidemesser, E.; al., e., Chemistry and the linkages between air quality and climate change. *Chem. Rev.* **2015,** *115* 3856-3897.
[11] Global methane emissions have risen nearly 10 percent over last 20 years (accessed february 7, 2021). https://futureearth.org/2020/07/15/global-methane-emissions-have-risen-nearly-10-percent-over-last-20-years/
[12] Tian, H.; al., e., A comprehensive quantification of global nitrous oxide sources and sinks. *Nature* **2020,** *586* 248-256.
[13] Cadham, J. Covid-19 and climate change. https://www.cigionline.org/articles/covid-19-and-climate-change
[14] Covington, W. W.; Pyne, S., Fire in our future. *Science* **2020,** *370* (6512), 13.
[15] Prather, K. A.; Wang, C. C.; Schooley, R. T., Reducing transmission of sars-cov-2. *Science* **2020,** *368* (6498), 1422-1424.

Air Quality, Carbon Emissions, and the Response to COVID-19

The effect that COVID-19 lockdowns have had on air quality globally was reported from different cities.[3] Venter *et al.*[16] analyzed data from 37 countries and reported population-weighted drop in nitrogen dioxide and fine particulate matter levels to be 60% and 31%, respectively, with a 4% marginal increase in ozone levels, relative to the 2017-2019 average. Le Quere *et al*[17] quantified daily global carbon dioxide emission decreases to be 17% by early April 2020 compared with the 2019 mean levels, where just under half of these decreases was attributed to changes in land transportation. We recently reported significant short-term reductions in nitrogen dioxide and carbon monoxide of about 20% relative to 2017-2019 levels, experienced by the majority of cities in Southern Ontario, home to 35% of Canada's population.[18] However, levels of ozone and fine particulate matter did not experience significant reductions during the same period in the majority of sites in Southern Ontario. Gettelman *et al*[19] reported a small net warming effect in Spring 2020 due to reductions in particulate matter and their precursor chemicals that cause a cooling effect (namely sulfate particles). The above drops were temporary, and levels rose with phased opening of economies around the world. The amount of carbon dioxide reached record levels in 2020 (417 parts per million in May) making 2020 the hottest year on record tied with 2016.[20] This finding is not surprising as scientists know that (1) the lifetime of carbon dioxide from fossil fuels in the atmosphere lasts a few centuries, and hence, drops in emissions for a few months would not stop climate change[21], and (2) light scattering aerosols that have a net cooling effect on the climate have been masking the 'real' warming effect of greenhouse gases and black particles that absorb heat.[22] Higher temperatures in 2020 led to earlier snowmelt, a longer fire season, and drier vegetation, especially by August and September. The fires in California and western US in 2020 became the state's worst ever fire season where millions of acres were burnt, and a few dozen people died.[23] As stated in many media reports, the link to climate change was made by examining research over the past 15 years that shows amplification of the risk of many conditions that help wildfires ignite and spread.[24]

The above analysis provides a quantitative picture of the short-term experience of the general public in the context of improved air quality during the COVID-19 lockdowns. It also helps us to reflect on what it

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[16] Venter, Z. S.; Aunan, K.; Chowdhury, S.; Lelieveld, J., Covid-19 lockdowns cause global air pollution declines. *Proc. Nat. Acad. Sci. USA* **2020,** *117* (32), 18984-18990.
[17] Le Quere, C., Temporary reduction in daily global co2 emissions during the covid-19 forced confinement. *Nature Climate Change* **2020,** *10* 647-653.
[18] Al-Abadleh, H. A.; Lysy, M.; Neil, L.; Patel, P.; Mohammed, W.; Khalaf, Y., Rigorous quantification of statistical significance of the covid-19 lockdown effect on air quality: The case from ground-based measurements in ontario, canada. *J. Haz. Mater.* **2021,** In press, https://doi.org/10.1016/j.jhazmat.2021.125445.
[19] Gettelman, A.; et.al., Climate impacts of covid-19 induced emission changes. . *Geophys. Res. Lett.* **2021,** *48* e2020GL091805 (1-10).
[20] 2020 tied for warmest year on record, nasa analysis shows (accessed february 7, 2021). https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows
[21] Inman, M., Carbon is forever. *Nature Climate Change* **2008,** *1* 156-158.
[22] Aerosols and Incoming Sunlight (Direct Effects). https://earthobservatory.nasa.gov/features/Aerosols/page3.php
[23] California's wildfire hell: How 2020 became the state's worst ever fire season (accessed february 7, 2021). https://www.theguardian.com/us-news/2020/dec/30/california-wildfires-north-complex-record
[24] What's behind the 'unprecedented' wildfires ravaging california (accessed february 7, 2021). https://www.cbc.ca/news/technology/california-wildfires-climate-change-1.5659909

would take to reduce climate change. Notably, this experience would not have happened in a world without the reconsideration of traditional and taken-for-granted behavioral patterns and practices that the COVID-19 lockdowns engendered. The general public witnessing first-hand how sudden reductions in carbon-intense human activities impact the quality of the air we breathe, and how carbon-intensive connectivity is correlated with the likelihood of being infected with a deadly disease, provide a unique opportunity for advancing progressive policies aimed at mitigating carbon emissions in the future. In other words, COVID-19 lockdowns have demonstrated that the capacity to, and the positive results expected from, the cessation of fossil-fuel combustion, are within the grasp of our societies. This task is more urgent than ever today, particularly in the wake of the 2019 Emissions Gap Report by the United Nations Environment Program.[25] This report shows that the world is heading towards 2.8-3.2 degrees Celsius of warming by the end of this century with current policy scenarios, and that technically, it is still possible to keep global warming to well below 2 degrees Celsius. However, governments will need to make much bolder commitments to reduce their emissions of greenhouse gases now for a 66% chance of staying within this threshold.

On the path to net zero carbon by 2050: Lessons from the response to the ozone hole story

Countries around the world are continuously urged to come together and show leadership on the climate change issue as they did when signing the Montreal Protocol in 1987 and its follow up amendments to close the ozone hole over Antarctica.[26] This protocol was signed nearly 20 years after the science of how chlorofluorocarbons (CFCs) could destroy stratospheric ozone was discovered in the lab. The Montreal Protocol called for a global phaseout on the production and consumption of ozone depleting substances, including CFCs, by 2010. Phasing out these substances has saved millions of lives, and health-related expenses from diseases caused by harmful ultraviolet radiation (UV). Also, pressure from political agreements and environmental activism forced industries to innovate to find practical and profitable alternatives to CFCs. First signs of recovery of the ozone layer were reported in 2014.[27] The positive side of this story is that political action taken to close the ozone hole also slowed the impacts of climate change.[28] This is because CFCs are longer-lived and more potent greenhouse gases than carbon dioxide. Phasing out CFCs in 2010 is analogous to removing about two billion cars from the streets per year. We also now know that hydrofluorocarbons (HFCs) — alternatives to CFCs — are also potent greenhouse gases. As a result, the latest amendment to the Montreal Protocol, the Kigali Accord signed in 2016, could contribute to avoiding half a degree Celsius of global warming through reducing production and consumption of HFCs over the next 30 years. Scientists are now calling for a Kigali-plus Amendment to accelerate the phasing out of HFCs to avoid exceeding 2 degrees Celsius of warming.[26]

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[25] United nations environment program, emissions gap report (accessed February 7, 2021). https://www.unenvironment.org/resources/emissions-gap-report-2019
[26] Solomon, S.; al., e., Unfinished business after five decades of ozone-layer science and policy. *Nature Comm.* **2020,** *11* (4272), 1-4.
[27] International action against ozone depleting substances yields significant gains (2014). https://www.nasa.gov/content/goddard/international-action-against-ozone-depleting-substances-yields-significant-gains
[28] Velders, G. J. M.; Anderson, S. O.; Daniel, J. S.; Fahey, D. W.; McFarland, M., The importance of the montreal protocol in protecting climate. *Proc. Nat. Acad. Sci. USA* **2007,** *104* (12), 4814-4819.

One would argue that it was easier from a policy point of view to deal with the ozone hole problem than climate change. On the one hand, as noted by Solomon *et al.*[26], the reasons for the success of the Montreal Protocol can be attributed to three key features: (1) a manageable number of sources of ozone depleting substances and the narrow industrial sector that uses them, (2) financial assistance from OECD nations that might have encouraged all countries to participate, and (3) the "flexibility and openness of the Parties to adapt to changing political climates and new knowledge provided by the Protocol's technical panels". On the other hand, it is argued that our industrial civilization and all sectors of the global economy are powered by fossil fuels, and hence the problem is more complicated from a policy innovation point of view than just finding an alternative for harmful chemicals. It is this very last argument that has derailed any meaningful and impactful progress on the politics of climate change when technological advances in generating clean energy[29] and removing carbon from the atmosphere[30] do exist. Although challenges facing the clean technology and green energy sector for widescale implementation to replace fossil fuels remain entrenched, they are weakening, and there are concrete - and *impactful* – steps towards real climate action that can be taken today.

On the path to net zero carbon by 2050 in a post COVID-19 world

It was welcome news to see political leaders in developed nations aiming to power-up their economies to weather the storm of COVID-19, with investments worth billions of dollars made in green and clean technology. Decoupling economic growth from fossil fuels will not be straightforward or pain-free. It starts with phasing out dirty fossil fuels such as coal, embedding the true value of nature's services into performance models, and recognizing that recovery from a pandemic depends on ecological health, and not simply economic health.[31] This effort also calls for a new treaty[32] on fossil fuel prohibition that draws parallels from the success of the Montreal Protocol and the non-proliferation of the nuclear weapons treaty, and addresses the limitations of the 2015 Paris Agreement. A recent article by the Environmental Defense Fund outlined three strategies that Wall Street can adopt to turn this aspiration into actionable plans under three main themes: integrate climate into core business, align proxy voting with climate goals, and support regulations and policies required to decarbonize.[33] To this end, several countries, including Canada, have introduced targets to achieve net-zero emissions by 2050.[34,35]

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[29] Rand, T., *Kick the fossil fuel habit: 10 clean technologies to save our world*. Eco Ten Publishing: Toronto, Canada, 2010.
[30] Bourzac, K., We have the technology. *Nature* **2017**, *550* S66-S69.
[31] Editorial, Embed nature in strategies to reboot economies. *Nature* **2020**, *581* 119.
[32] The fossil fuel non-proliferation treaty. https://fossilfueltreaty.org
[33] How wall street can win on climate in 2021 (accessed february 7, 2021). https://www.forbes.com/sites/edfenergyexchange/2021/01/11/how-wall-street-can-win-on-climate-in-2021/?sh=152b1d527788
[34] Climate action tracker global update: Paris agreement turning point (accessed february 7, 2021). https://newclimate.org/2020/12/01/cat-global-update-paris-agreement-turning-point/
[35] World energy outlook-achieving net-zero emissions by 2050 (accessed february 7, 2021). https://www.iea.org/reports/world-energy-outlook-2020/achieving-net-zero-emissions-by-2050

Within the Canadian context, there are a number of policy implications to consider in a post COVID-19 world as outlined by Fitz-Gerald[36] and Cadham.[13] Of direct relevance to this short paper, Ontario – as Canada's most populous province – was the first in North America to phase out coal-fired electricity in 2014 for health and environmental reasons.[37] The current Canadian government announced in December, 2020, that Canada's climate plan includes hiking the federal carbon tax to $170 a tonne by 2030 and investing over $10 billion in clean technology, mitigation, and adaptation efforts.[38] Prior to the announcement of this plan, more than 490 Canadian municipalities declared a climate emergency in response to the UN report on closing the emissions gaps.[39] The Climate Science 2050 report[40] was also published late 2020 as a "national synthesis to better understand the breadth of Canadian climate change science and knowledge gaps and guide science and knowledge producers, holders, and funders as they advance the collaborative and interdisciplinary efforts needed to inform climate action." The publication of this report is timely as "it encompasses the natural, social, and health sciences, and recognizes the need to mobilize the full spectrum of Indigenous leadership, participation, and knowledge systems." To date, this report has informed the creation of the Climate Action and Awareness Fund (CAAF)[41] that will "invest $206 million over five years to support Canadian-made projects that help to reduce Canada's greenhouse gas emissions."

What lessons do the lockdowns of COVID-19 teach us about fighting climate change? For 'green' efforts and policies to bear their desired fruits over time, it suggests that there must be: (1) a widespread and long-term conviction that action on the climate is a non-partisan issue that deserves continuity and funding stability irrespective of the government of the day; (2) that jobs that will build a clean future capitalizing on the transferrable skills of workers, who were laid off from the oil and gas sector, are essential; (3) that long term investments in monitoring and the open reporting of greenhouse gas emissions and air quality indicators at the city-level, which fully engage citizens by quantifying the impact of their actions on carbon and air pollution in real time, make a real difference. These initiatives require collaboration among experts from different fields, different levels of government, and communities engaged in citizen science projects aimed at climate action and air quality improvement. The short-term benefits will be felt by citizens in the form of better air to breathe, leading to cost savings on health-related expenses. The long-term benefit would be to stabilize the climate system for resilient future generations, which will inherit an earth that is ecologically different than the one we are living in at present.

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36 Fitz-Gerald, A., In the aftermath of covid-19: Policy implications for canada. *Balsillie Papers* **2020,** *1* (3), 1-11.
37 The end of coal. https://www.ontario.ca/page/end-coal
38 Canada's climate plan (accessed february 7, 2021). https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan.html
39 A tale of two emergencies by the canadian urban institute (accessed february 7, 2021). https://canurb.org/citytalk-news/a-tale-of-two-emergencies/
40 Canada's climate science 2050 report (accessed february 7, 2021). https://www.canada.ca/en/services/environment/weather/climatechange/climate-science-2050.html
41 Canada's climate action and awareness fund (caaf) (accessed february 7, 2021). https://www.canada.ca/en/services/environment/weather/climatechange/funding-programs/climate-action-awareness-fund.html

Conclusions

For multiple generations of humans, the year 2020 was like no other. No age, culture, religion, or socioeconomic status was spared from the shock that the social, economic, and political systems received as a result of the COVID-19 pandemic. This shock exposed cracks in the above systems and challenged humanity at large to rethink what is 'essential' in everyday life, and what type of world they have created based on the consumption of fossil fuels. The pandemic came at a time when declaring climate emergencies around the world was in full force, and taking central stage in the public eye. As we have noted, because of the wide-scale lockdowns aimed at limiting the spread COVID-19, there was unprecedented interest in quantifying the impact of these lockdowns on pollutant levels emitted from the industrial and transportation sectors. Temporary drops in these pollutant levels were observed around the world, which dramatically improved air quality, particularly in heavily polluted metropolitan cities. While a temporary reduction in carbon dioxide levels was observed, the reduction in light scattering sulfate particles resulted in a small net warming effect, highlighting the complexity of how the atmospheric system responds to lowering levels of pollutants in the short-term.

As the world emerges from the pandemic, therefore, humanity has an unprecedented opportunity to create a new 'normal' that incorporates lower GHG emissions into a healthier daily lifestyle. Such efforts should learn from the successful stories in history that addressed air pollution through Clean Air Acts and the Antarctic ozone hole with the Montreal Protocol and its amendments. New government policies should empower communities to 'think global and act local', businesses to incorporate nature (and its limits) into their economic models and accelerate the use of clean energy generation and carbon removal technologies.

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