Literature Review

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The Nexus of COVID-19 and Climate Change: A Systematic Literature Review

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Abstract: Since the onset of the COVID-19 pandemic, many studies have appeared on how it will affect climate change and policy, and vice versa. In this study, we systematically review the literature about this relationship. We obtained a sample of 204 articles published in the period from February 2020 to March 2022. Using topic modelling and qualitative analysis, we identify seven main topics on the nexus of COVID-19 and climate change: (1) impacts of COVID-19 on climate change and policy; (2) sustainable recovery after COVID-19; (3) public concern about climate change and COVID-19; (4) lessons from COVID-19 for climate change action; (5) effects of COVID-19 and climate change on the economy, food security and poverty; (6) collective responses to crises and (7) similarities and differences between COVID-19 and climate change. We discuss lessons derived from each of these topics and identify key policies and strategies for a sustainable recovery from COVID-19. Investments in low-carbon technologies and carbon taxation are the most commonly suggested policy solutions. If climate targets are to be met, climate action needs to be the focus of COVID-19 recovery.

Keywords: coronavirus; pandemic; sustainable recovery; climate policy; climate strategies; crisis

JEL Classification: I15; O13; O44; Q56

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1 Introduction

In 2020, the entire world came to a halt due to the COVID-19 pandemic. As of July 2022, more than 566 million cases and over six million deaths have been reported (Worldometer 2020). In her State of the Union speech in September 2020, president of the European Commission Ursula von der Leyen addressed the effects of the COVID-19 pandemic and stated that the virus "laid bare the strains on our health systems and the limits of a model that values wealth above well-being. It brought into sharper focus the planetary fragility that we see every day through melting glaciers, burning forests and now through global pandemics" (von der Leyen 2020).

The virus originated in Wuhan, China, and then spread across the world over the course of two years, producing different variants and threatening individuals as well as health systems (Markard and Rosenbloom 2020). In response to the pandemic, governments imposed strict lockdown measures that reduced human activity, simultaneously limiting economic activity too. This, in turn, resulted in a decrease of greenhouse gas (GHG) emissions and air pollution (Forster et al. 2020).

The multiple changes have raised questions about the relationship between the two global crises of climate change and COVID-19. Some have argued that the destruction of natural habitats has moved humans closer to animal locations, thus increasing the risks of pandemics caused by zoonotic diseases, such as COVID-19 (McNeeley 2021; Yan Yam 2020). In addition, some suggest that the two crises require coordinated responses by policymakers, experts and society as a whole (Markard and Rosenbloom 2020). However, they also have clear differences: while COVID-19 showed an almost immediate direct impact on individuals and global health, climate change is slower and more subtle in the way it affects ecological and human systems (ibid).

This paper attempts to analyse the main questions posed by the recent literature on the nexus of COVID-19 and climate change. The high uncertainty and urgency about handling the pandemic encouraged many studies in a variety of disciplines. Some of these examine the interconnection between climate action and policy on the one hand, and COVID-19 experiences and opinions on the other. For instance, Drews et al. (2022) investigate the way in which COVID-19 changed public perceptions of climate change, action and policy. The authors find that people who believe that climate change contributed to the COVID-19 outbreak have increased their support for climate policies. However, on average, climate concern decreased during the first wave of the COVID-19 pandemic (ibid). In addition, people are found to be rather pessimistic regarding future climate actions by citizens and the government. Some tend to be concerned about scarce financial resources for climate action and government mismanagement of the COVID-19 pandemic (Savin et al. 2022a).

Prior reviews of this recent literature are not systemic but selective (Fuentes et al. 2020) or mini-reviews (Amnuaylojaroen and Parasin 2021). Some of these reviews focus on the similarities and differences between COVID-19 and climate change (Amnuaylojaroen and Parasin 2021; Fuentes et al. 2020; Gupta, Rouse and Sarangi 2021; Joshi et al. 2021). Other reviews examine the impacts of COVID-19 on climate change (Rieder 2020; Tan et al. 2021). Due to the short time span between the start of the pandemic and their publication, these cover a limited literature (between a few dozen and hundred). Through the present systematic review, we are able to synthesise a larger set of studies and broader range of themes on the nexus of COVID-19 and climate change. This covers the period February 2020 until March 2022. We analyse the studies both qualitatively and quantitatively – employing statistics and methods from computational linguistics. The research questions for this work are what are the main topics discussed on the relationship between COVID-19 and climate change? What are the main policy implications of the studies?

To sample relevant studies, we followed an eligibility process according to the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al. 2009). Sampled articles were categorised into topics, methods used, world region and specific application (e.g. focus on policy or the economy). We generate descriptive statistics for publication time, country focus, methods used and journal publication rates. Next, through a combination of qualitative analysis and computational linguistics, we derive seven topics that are recurring in the literature concerning climate change and COVID-19. We use these topics to assess insights of the most cited articles and the journals with the highest publication rates. In addition, we enter more deeply into the topics and discuss the main conclusions of each topic identified. Finally, we derive main policy insights addressed in the literature, assessing most recommended policy instruments for climate change mitigation and a sustainable economic recovery from COVID-19. A final section concludes.

2 Search and Selection of Studies

The data for this study were obtained from the peer-reviewed literature, using the Scopus database. On the 1st of April 2022, we searched for articles that had the words ‘covid’ or ‘coronavirus’ and ‘climate’ in the title. This generated 452 articles. Additionally, a snowball search strategy was undertaken by checking journal special issues and references cited in review articles, which resulted in an additional 36 articles, that is, 488 articles in total.

These publications were screened and assessed for eligibility according to PRISMA. Figure 1 summarises the sampling process. The first step – the screening process – was based on the structure and basic information of the studies. Here,

articles were analysed exclusively based on title, abstract and keywords. Articles that had no abstract (n = 99),[1] corrections (n = 6), duplicates (n = 5) and articles for which a full paper was not accessible (n = 5) were excluded. In total, 115 articles were excluded in this step. Next, we assessed the remaining 373 articles for eligibility based on the content of the studies – i.e. the issues investigated. This involved reading the abstract and, if insufficiently clear, reading the article texts as well. The exclusion criteria were as follows:

1. Review (n = 12). As we focus on primary studies of any type, whether theoretical, empirical, opinionated, etc. (Cf. Capstick et al. 2015).[2]
2. Other context (n = 131). These concern publications in which the word 'climate' is utilised in another context, unrelated to climate change. Examples are air quality in the workplace, climate conditions affecting crop growth and the potential influence of climate conditions on the outbreak of COVID-19.
3. Very superficial treatment of the relationship between climate change and COVID-19 (n = 18). This includes studies that have both keywords in the title, but at least one of the notions is addressed only very superficially so that the relationship between climate and COVID-19 is not the focus of the study (e.g. "effects of climate and environmental variance on the performance of a novel peatland-based integrated multi-trophic aquaculture (IMTA) system: implications and opportunities for advancing research and disruptive innovation post COVID-19 era").
4. The link between climate change and COVID-19 is not addressed at all (n = 8). While both notions are studied in the articles, they are discussed independently.

This procedure resulted in the exclusion of 169 studies, giving a final sample of 204 studies.

3 Results

3.1 General Study Characteristics

Following the selection process for the review, a combination of statistical and qualitative analyses was conducted to identify the main topics of research on the

1 Over 90 % of these studies are editorials, notes, letters, errata, conference proceedings and book chapters. As without abstract we cannot later do quantitative (topic modelling) analysis of the sample, we had to remove these papers.

2 This step is common for systemic literature reviews as it means focusing on original primary studies. This involves excluding comments and commentaries, which devoted a major part of their text on reviewing literature. Note that the introduction section mentions the reviews and summarises their main insights and findings.

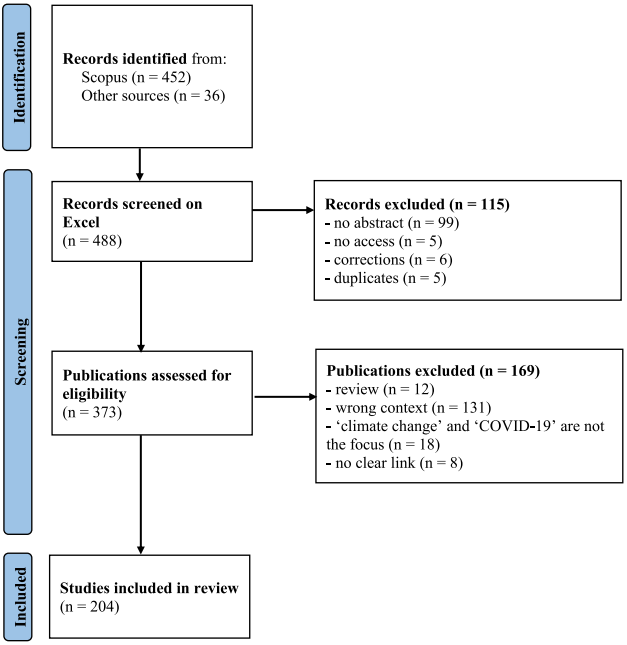

Figure 1: Systematic review process following PRISMA guidelines.

interface of COVID-19 and climate change. To this end, the data were grouped into different categories (see the Supplementary Information for a table with a full list of 204 reviewed studies and their categorization):

- Method,
- world area that the study application focuses on,
- main topic addressed,
- whether the study focused on policy or not and
- whether it involves analysis of economic processes or impacts.

Of the 204 articles selected, 62 were published in 2020, 118 in 2021 and 24 in the first three months of 2022. If the rate of publications were to be maintained for the entire year, 96 articles would be published by the end of 2022, leaving the year 2021 as having most publications.[3] This might be due to the urgency for new information and research concerning policy-making and economic recovery immediately after the pandemic. In fact, out of the 14 articles that mention the word 'recovery' in

3 Some journals publish more issues towards the end of the year, which suggests a higher estimate.

the title, the majority (n = 9) were published in 2021, and of the 13 articles that have the word 'policy' in their title, also the majority (n = 9) were published in 2021.

We identified four main methods: opinions and commentaries (n = 111), empirical surveys focusing on the analysis of primary (original) empirical data[4] (n = 41), other empirical methods, involving statistical analysis of secondary empirical data (n = 32) or applied models (n = 20). Concerning the method of data collection, the relevant distinction for our dataset is primary (empirical surveys) versus secondary data. Figure 2 shows the frequency of the approaches employed by the studies.

In terms of application, 109 studies are focused on particular countries or regions. A total of 31 studies are categorised as 'global', addressing issues such as global reduction in emissions due to COVID-19 (Gettelman, Chen and Bardeen 2021; Smith, Tarui and Yamagata 2021) or general lessons from the pandemic for policymakers (Perkins et al. 2021). The remaining 19 studies that analysed several specific countries were classified under 'other', meaning that they focused on more than one world areas (including continents). For instance, Samani et al. (2021) investigated the impact that changes in energy production during the pandemic had on greenhouse gas (GHG) emissions in Colombia, France, the Netherlands and Portugal. Similarly, Irfan et al. (2022) tried to identify the indirect environmental impacts of COVID-19 for the USA, China, Spain and Italy – considered to be the most affected economies. The last category is 'not applicable', covering 64 articles. None of these utilised original empirical data and were mostly commentaries/opinion articles (see Figure 3).

Figure 3 summarises the methods used in combination with each world area. It shows that empirical surveys are more common in Europe, North America and Oceania, and models in Asia as well as on a global scale.

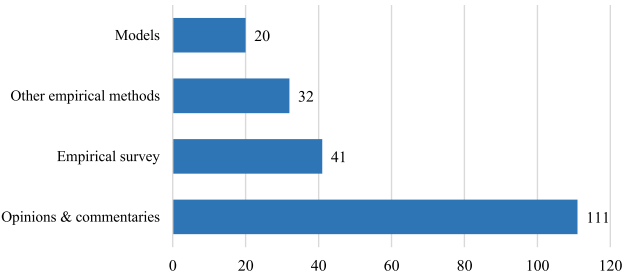

Figure 2: Methods used in the sample of studies on the nexus of COVID-19 and climate change.

4 The few studies undertaking an experiment in the sample were attributed to the category empirical survey as they analyse primary (original) empirical data.

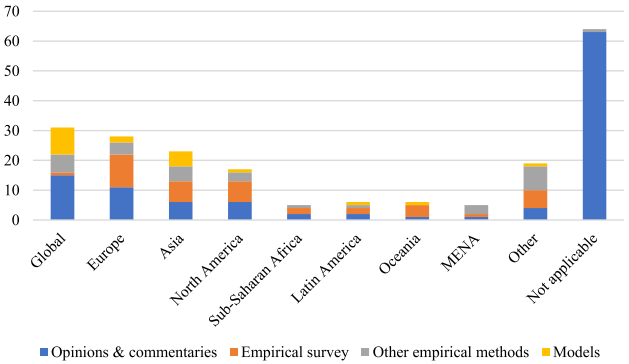

Figure 3: Methods employed in studies by world area. *Note:* MENA, Middle East and North Africa.

Regarding outlet of the study, there is no predominant journal on the relationship between climate change and COVID-19. Journals with the highest publication rates have published six papers each. These are *Environmental and Resource Economics* (with 146 citations accumulated by April 1, 2022), *Climate Policy* (30), *Sustainability* (32), *Global Sustainability* (10) and *IOP Conference Series: Earth and Environmental Science* (5). The remaining journals have published five or fewer articles. Table 1 shows the 10 most cited articles in the sample.[5] Note that none of the most cited articles were published in the five journals with most articles on the nexus of COVID-19 and climate change. As it is easier for articles that have been published earlier to get more citations, the table also indicates the citations per month. Finally, the journal *Science of the Total Environment*, which has five publications, appears as the most cited journal on the relationship between COVID-19 and climate change, accumulating 355 citations in total.

The most cited articles belong to the topic 'Impacts of COVID-19 on climate change and policy' (see Section 3.2), which focuses on the decrease in GHG emissions due to lockdown measures during the COVID-19 outbreak. For example, Baldasano (2020), who has the most citations, investigated air quality in Madrid and Barcelona during the period March–April 2020. His results show that, due to the drastic reduction in traffic, NO_2 concentrations decreased by 62 % in Madrid and by 50 % in Barcelona.

5 Although one might argue that the time period is fairly short for being cited, as the table shows, some studies received many cites – six of them even more than 100. In view of this, we think the information offered in the table is useful. If all studies would have been cited few times (say less than 10 times), such a table would not have been useful in distinguishing studies with much impact.

Table 1: Most cited articles on the nexus of COVID-19 and climate change.

	Title	Topic	Journal	Citations	Citations p/m	Journal impact factor	Author	Year	Attention for policy
1	"COVID-19 lockdown effects on air quality by NO_2 in the cities of Barcelona and Madrid (Spain)"	Impacts of COVID-19 on climate change and policy	*Science of the Total Environment*	182	10.7	10.754	Baldasano	2020	No
2	"Current and future global climate impacts resulting from COVID-19"	Impacts of COVID-19 on climate change and policy	*Nature Climate Change*	172	8.6	28.862	Forster et al.	2020	No
3	"Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?"	Impacts of COVID-19 on climate change and policy	*Oxford Review of Economic Policy*	170	7.7	6.326	Hepburn et al.	2020	Yes
4	"Sustainability and development after COVID-19"	Sustainable recovery after COVID-19	*World Development*	106	6.2	6.678	Barbier and Burgess	2020	Yes
5	"Food waste management during the COVID-19 outbreak: a holistic climate, economic and nutritional approach"	Impacts of COVID-19 on climate change and policy	*Science of the Total Environment*	101	5.9	10.754	Aldaco et al.	2020	No
6	"When pandemics impact economies and climate change: Exploring the impacts of COVID-19 on oil and electricity demand in China"	Impacts of COVID-19 on climate change and policy	*Energy Research and Social Science*	106	5.8	8.514	Norouzi et al.	2020	No
7	"Impact of the COVID-19 pandemic on environmental awareness, sustainable consumption and social responsibility: Evidence from generations in Brazil and Portugal"	Impacts of COVID-19 on climate change and policy	*Journal of Cleaner Production*	72	5.5	11.072	Severo et al.	2021	No

Table 1: (continued)

	Title	Topic	Journal	Citations	Citations p/m	Journal impact factor	Author	Year	Attention for policy
8	"The COVID-19 pandemic as an opportunity to weaken environmental protection in Brazil"	Impacts of COVID-19 on climate change and policy	*Biological Conservation*	52	4.0	7.499	Vale et al.	2021	Yes
9	"Lessons from COVID-19 can prepare global tourism for the economic transformation needed to combat climate change"	Sustainable recovery after COVID-19	*Tourism Geographies*	91	3.9	11.355	Prideaux et al.	2020	Yes
10	"COVID-19: Lessons for the climate change emergency"	Similarities and differences between COVID-19 and climate change	*Science of the Total Environment*	64	3.7	10.754	Manzanedo and Manning	2020	No

3.2 Topics Addressed

An important step when analysing abstracts was to organize the studies into main topics. Seven topics were identified, based on two steps. First, we classified the main topics of studies on a subjective basis. Going through titles, abstracts and keywords, we identified recurring subjects and consequently identified main topics. Some studies addressed more than one topic. For example, one article analysed the impacts of city tourism during COVID-19 on GHG emissions while also drawing lessons from the pandemic for climate change mitigation as well as challenges for city planning (Jiricka-Pürrer, Brandenburg and Pröbstl-Haider 2020).

Next, a computational-linguistic analysis was carried out using text from the titles, abstracts and keywords of all articles in the sample. This took the form of topic modelling, an approach that statistically classifies a set of words from documents and defines probability distributions for these to match the texts to underlying topics (Griffith and Steyvers 2004; Savin, Ott and Konop 2022b). This procedure resembles clustering of numerical data, but to calculate distances between words, we use information about the frequency of how often these co-occur in the same articles (Savin et al. 2020). This delivers a set of topics consisting of lists of words that with different probabilities appear in the articles. For example, words such as 'perception', 'threat' and 'survey' tend to appear together in a topic related to public concern about climate change and COVID-19. We followed the procedure employed earlier in Savin and van den Bergh (2021) and Savin and Teplyakov (2022). In particular, we first pre-processed the texts by:

- lemmatizing words, i.e. transforming them to their initial dictionary form;
- removing punctuation and non-letters;
- removing stop words (such as 'we', 'and');
- retrieving multi-word expressions (like 'climate_change' and 'fossil_fuel').

Subsequently, the textual documents were classified using a Structural Topic Modelling (STM) algorithm in the stm package of R software (Roberts, Stewart and Tingley 2019).

Nine topics were identified. For each topic, the five most frequent and exclusive words are provided below:[6]

1. Reduction, emission, aerosol, air, concentration
2. Sustainability, post, opportunity, environmental, coronavirus
3. Fossil_fuel, recovery, green, economy, sustainable
4. Participant, threat, concern, perception, knowledge
5. Energy, market, demand, renewable_energy, technology

6 Figure A1 in the Appendix provides more information by listing the 30 most frequent and exclusive words for each topic.

6. Risk, community, disaster, urban, resilience
7. Death, environment, variable, mortality, temperature
8. Food, ghg_emission, production, crop, food_security
9. Collective, problem, cooperation, response, politics

The STM algorithm also provided us with shares of topics estimated for each article in the sample. Many articles were dominated by one topic with a weight of 60 % or more for that topic. However, there were articles that did not fall entirely into one topic but represented a mix of two or three topics with rather similar weights. Additionally, there were some articles which, even though their theme related to the topic, a closer review of the article suggested it fitted better in another topic. Thus, 31 articles that had a weight of more than 60 % in one topic were later assigned to another topic. In fact, one of the main problems of using topic modelling is the lack of a quality metric as achieved by human judgement (Nikolenko, Koltcov and Koltsova 2017). To overcome this shortcoming, we combined topic modelling with qualitative analysis[7] to provide a thorough validation of the results.

A new topic was created as a result of this qualitative analysis, namely 'Similarities and differences between COVID-19 and climate change' – which included articles that had shares of 20 % and 30 % in multiple topics and hence could not be easily classified in the other topics. This topic has numerous articles that investigate the similarities and differences between COVID-19 and climate change and thus includes a wider variety of key words.

Combining the two approaches, qualitative analysis and topic modelling, resulted in the topics listed in Table 2. We will discuss them in detail in the next section. The table includes a summary of the main sub-issues addressed under each topic, ordered by frequency of appearance.

Figure 4 depicts which methods are employed in each topic, showing great variety and dominance of some methods in certain topics. While opinions and commentaries are more common in the topics 'Sustainable recovery after COVID-19', 'Lessons from COVID-19 for climate change action', 'Collective responses to crises' and 'Similarities and differences between COVID-19 and climate change', empirical surveys are more common in the topic 'Public concern about climate change and COVID-19', other empirical methods for topics 'Impacts of COVID-19 on climate change and policy' and 'Effects of COVID-19 and climate change on the economy, food security and poverty'. The method of modelling is especially common in the first topic, as earth system models are utilised to measure global GHG emissions.

7 Qualitative analysis was first conducted independently by the first and second authors. Subsequently they compared their results. In a few cases of disagreement, the third author was involved to help resolving the issue.

Table 2: Main topics identified on the relationship between climate change and COVID-19.

	Topic	Sub-issues	No. of studies (sample share)	Accumulated citations
T1	Impacts of COVID-19 on climate change and policy	Changes in CO_2 emissions, COVID-19 implications for progress on climate change, climate finance	40 (20 %)	1142
T2	Sustainable recovery after COVID-19	Climate action after COVID-19, sustainable economic recovery after COVID-19	40 (20 %)	473
T3	Public concern about climate change and COVID-19	Changes in perceptions of climate change due to COVID-19, public support of measures/ policies	32 (16 %)	91
T4	Lessons from COVID-19 for climate change action	Lessons for policy, lessons for urban and rural areas, lessons for individual/social behaviours	31 (15 %)	202
T5	Effects of COVID-19 and climate change on the economy, food security and poverty	Impacts of both crises on food security, poverty and the economy	26 (13 %)	121
T6	Collective responses to crises	Governance of COVID-19 and climate change	19 (9 %)	63
T7	Similarities and differences between COVID-19 and climate change	Shared pretences, interconnections and differences of climate change and COVID-19	16 (8 %)	107

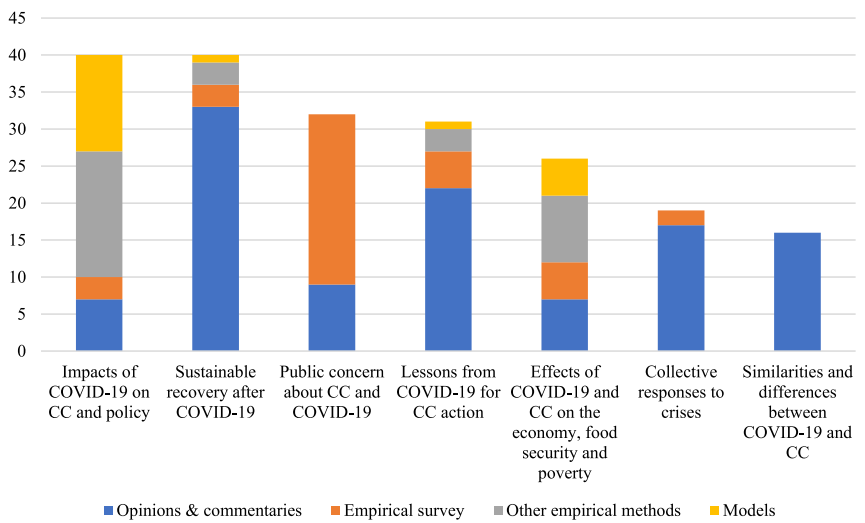

Figure 4: Methods employed in studies by topic. *Note:* "CC" denotes climate change.

We also looked at which topics are dominant in relation to particular regions. Out of five studies based on African data, three have focused on impacts of COVID-19 on climate change (T1) but none on sustainable recovery after COVID-19 (T2) or collective responses to crises (T7). T2 on sustainable recovery has been typically analysed for the global scale and Europe (9 studies each out of 40) and Asia (5 studies), while T7 on collective responses has been mostly analysed for the global scale (4 out of 19). This reflects that the equity perspective in developing and least developed countries has been largely neglected so far, suggesting more research is needed here.

4 Insights from the Seven Topics

In this section, we discuss the seven topics listed in Table 2 in more detail, to derive specific insights and recommendations.

4.1 Impacts of COVID-19 on Climate Change and Policy

Multiple articles within this topic discuss how the pandemic affected global as well as local air quality. Since earth systems models are common to estimate emission changes, 13 articles under this topic use models. The most cited articles also lie within this topic – for example, analysis of emissions data illustrates the positive impact of COVID-19 on air quality during the COVID-19 outbreak (Sarfraz, Mohsin and Naseem 2022; Tibrewal and Venkataraman 2022; Usman et al. 2021). A study by Elmousalami (2021) attributes the decrease in emissions to several policies in particular: the closure of national borders and travel restrictions, banning of public gatherings and closure of cultural and educational buildings, the mandatory lockdown in numerous nations, travellers' self-quarantine and isolation of individuals that contracted the virus.

Many studies attributed to this topic address the causal relationship from COVID-19 confinement policies via restricted mobility on air pollution. However, emissions reductions are only significant for the lockdown period, and a return to pre-pandemic emissions was expected (Luke et al. 2021). Forster et al. (2020) investigated global emission reductions from February and June 2020 due to the lockdown measures. By analysing mobility data in 114 countries and US states, they estimate that global NO_x emissions – declining up to 30 % in April – contributed to a short-term cooling of the atmosphere. On the other hand, a reduction in global SO_2 emissions weakens the aerosol cooling effect, causing short-term warming. This explains the observed temperature increases of 10 %–40 % over East China relative to 2019 (Yang et al. 2020).

Despite the short-term warming effect from decreasing aerosol emissions, a reduction of NO_x has a cooling effect that will probably offset a large fraction of this warming effect (Forster et al. 2020). It is thus necessary to aim towards policies that reduce pollution from all mobility sectors at a time. If current national policies are followed, the direct effect of pandemic-driven emission reductions will only lead to a cooling of approximately 0.01 °C by 2030. On the other hand, policies aiming at a green recovery can help avoid global warming of 0.3 °C by 2050 (ibid).

Irfan et al. (2022) find a significant relationship between contingency actions of the pandemic and positive environmental spillovers, including air quality improvements, clean beaches, and decline in environmental noise. However, they also report negative consequences such as increased waste levels and decreased recycling threaten land and water. The reduction in GHG emissions during the short time span of the pandemic is thus not a sustainable way to mitigate environmental deterioration. They suggest the design of action plans to encourage a sustainable economic recovery in a post-pandemic scenario.

Another aspect regarding the impact of COVID-19 on climate change concerns the implications that the pandemic has had on progress regarding climate change mitigation. Several studies in the sample examine this for Brazil. As is well known, the president of Brazil Bolsonaro has adopted an anti-environmental stance since taking office in 2019. Ferrante and Fearnside (2020) argue that the combination of the COVID-19 pandemic and weakening of Brazil's environmental agencies undermined environmental protection and indigenous rights. Vale et al. (2021) support this by identifying major legislative actions, environmental fines and deforestation since January 2019. They conclude that almost half of the legislative acts aimed at weakening environmental protection occurred during the pandemic, which may be explained by reduced public concern about and lower media attention to environment and climate in the period of health emergency (see Section 4.3). Furthermore, they find a 72 % reduction in the number of environmental fines during this time contributing to further deforestation of the Amazon.

4.2 Sustainable Recovery after COVID-19

Articles under this category address the uncertainties and opportunities for climate action as well as a sustainable recovery after the pandemic. Out of the 40 articles about this topic, only six are empirical studies and one includes a model – which explores the effect of persistence in energy demand changes through global COVID-19 shock-and-recovery scenarios (Kikstra et al. 2021). The other 33 papers are commentaries or opinions, sometimes involving some literature discussion.

The main issues discussed in these studies are climate change targets post-COVID-19, addressing both negative and positive outcomes. For instance, Gosens and Jotzo (2020) state that, although China has drafted the 14th five-year plan to reach carbon neutrality by 2060, there are no signs of clear environmental ambition. Indeed, Beijing's recovery program shows no support for renewable energy industries – while much investment flows to fossil fuel industries. On the other side, more positive approaches, such as sustainable innovative frameworks and funding opportunities, are suggested to be developed through Horizon Europe to boost sustainable urban areas and reach climate neutrality in 100 cities across Europe by 2030 (Maestosi, Andreucci and Civiero 2021). It is quite easy to be sceptical about this though.

The most cited article in the topic of sustainable recovery is by Barbier and Burgess (2020). They highlight the vulnerabilities of developing countries to COVID-19, partly due to the scarce international support towards the 17 Sustainable Development Goals (SDGs). They suggest three policies for developing countries to achieve sustainable development in a cost-effective and rapid manner: a fossil fuel subsidy swap to promote renewable energy investments and knowledge in rural areas; reallocating irrigation subsidies to improve water supply, sanitation and infrastructure; and a tropical carbon tax – i.e. a levy on fossil fuels that funds natural climate solutions. Countries like Colombia and Costa Rica have already implemented such a carbon tax.

4.3 Public Concern About Climate Change and COVID-19

Almost all articles about this topic are surveys of public opinion or analyses of public data.[8] An important subject discussed in this category is whether the COVID-19 pandemic has caused a decrease in environmental concern and/or action (Ecker et al. 2020; Loureiro and Alló 2021; Lyytimäki et al. 2020; Rauchfleisch, Siegen, and Vogler 2023; Spisak et al. 2022; Stoddart et al. 2021; Ulichney et al. 2021; Zhang, Hao, and Morse 2020). For example, according to the 'finite pool of worry' hypothesis, the pandemic reduced public concern about climate change, since people can be concerned only about a limited number of issues. The most cited article, by Ecker et al. (2020), portrays the discourse about the relationship between climate change and COVID-19 as going in two opposite directions: to bring attention back to climate change and learn from positive behaviours in response to COVID-19 (the authors call it a 'trial run') and to argue that governments need to focus for the moment on

8 Often these studies address the interconnection between concerns, attitudes and climate action (see, e.g., Ulichney et al. 2021), which requires us to discuss these issues together.

economic recovery of COVID-19 and leave climate action on the 'back seat'. They undertake two experiments in North America in which participants were given one of two opinionated articles with each point of view, finding no support for framing COVID-19 responses as a trial run for climate action but neither find strong evidence to reject the frame either.

Other studies show, using analysis of news media data, that the debate on climate change has decreased in attention due to the dominance of COVID-19 in recent news (Loureiro and Alló 2021; Lyytimäki et al. 2020; Rauchfleisch, Siegen, and Vogler 2023; Spisak et al. 2022). Other studies suggest, however, that the persistence of climate threats, gradual mainstreaming of climate concern and the debate around sustainable recovery after COVID-19 mean that climate change is likely to remain relevant to the public (Lyytimäki et al. 2020).

Another popular theme is whether there is a correlation between climate change support and personal views regarding COVID-19 – including political affiliation (Christou, Theodorou and Spyrou 2022; Elliott 2022; Geiger et al. 2021; Thaker and Cook 2021; Wong-Parodi and Berlin Rubin 2022). Studies show an association between the belief that infectious diseases increase due to climate change and pro-environmental attitudes as well as support for sustainable recovery policies (Kallbekken and Sælen 2021; Takshe et al. 2022; Thaker and Floyd 2021). Moreover, Thacker and Cook (2021) show that learning about the connections between climate change and health can help increase climate-policy support among right-wing individuals. This leads to a support for a climate-focus in COVID-19 recovery policy and positive individual behaviour towards climate change.

4.4 Lessons from COVID-19 for Climate Change Action

Articles in this category are quite diverse. They address lessons and opportunities that arise from the COVID-19 pandemic to deal with another crisis, namely climate change. Several studies examine regional lessons, focusing on adaptation strategies for climate change. For instance, Jiricka-Pürrer, Brandenburg and Pröbstl-Haider (2020) highlight that COVID-19 emphasised the need to reconsider free and green spaces in metropolitan areas to adapt to climate-related threats such as heatwaves. For Negev et al. (2021), who study the pandemic in Israel, Palestine and Jordan, better health surveillance and more resilient health care systems are important to prepare and be equipped for any threat, including climate change.

Individual behaviours during the pandemic have given rise to studies with a psychological dimension. These address the responses of individuals to rules and restrictions that were imposed to combat the pandemic as well as their association

with opinions and behaviours regarding climate change (Corvino 2021; Goebel et al. 2020; Hochachka 2020; Perkins et al. 2021). According to Corvino (2021), if we focus on the benefits and opportunities of a more sustainable world rather than on the risks of climate change, at least some of the individual behavioural successes from the pandemic could be applied to the climate crisis. In addition, Hochachka (2020) emphasises the usefulness of simple, concrete and relatable messaging as well as accessible climate knowledge to communicate complex issues. Section 5 provides more details about lessons from COVID-19 experiences for climate policy.

4.5 Effects of COVID-19 and Climate Change on the Economy, Food Security and Poverty

This topic brings together studies that share a focus on the effect that COVID-19 and climate change have on different aspects of our economy and society. Several articles study the impacts using a variety of indicators, such as the exchange rate (Langa, Massuangahne and Nhanala 2022), inflation (Wahidah and Antriyandarti 2021) or the link between GDP growth and energy consumption (Khurshid and Khan 2021). Dunz et al. (2021) study the relationship between banks' lending decisions and economic recovery policy in Mexico. They find that procyclical constraints in lending and credit markets amplify short-term shocks by limiting firms' recovery investments, reducing the effectiveness of government spending.

Other studies address the impact of COVID-19 and climate change on poverty and food security, especially in Asian countries (Rahayu 2021; Sifa, Sultana, and Bodrud-Doza 2021). Climate change, COVID-19 and poverty are interconnected in a way that increases the vulnerability of certain groups of the population. In line with Barbier and Burgess (2020), Sifa, Sultana and Bodrud-Boza (2021) express the need to implement pro-poor strategies addressing climate change resilience and sustainable economic recovery from COVID-19. Some of the objectives they promote are infrastructural improvements to safeguard vulnerable households, health and social security, employment opportunities and climate adaptive agricultural diversification as a climate-adaptation strategy. As the global economy is highly interdependent through supply chains, uncertainty and bottlenecks in production, transportation and income arising from the COVID-19 pandemic have disrupted agricultural activities, further aggravating challenges in food security (Rasul 2021). This motivates the authors to plea for sustainable strategies to combat and recover from both the pandemic and the climate crisis to build more resilient food systems.

4.6 Collective Responses to Crises

All articles under this topic – but two, which are empirical studies based on surveys – can be categorised as 'opinions and commentaries'. Many of these studies address collective action (or inaction) under COVID-19 in relation to similar action under climate change (Asker and Stefánsson 2021; Elander, Granberg and Montin 2021; Raymond, Kelly and Hennes 2021). They highlight that the collective responses have been inadequate in terms of international cooperation in both cases (Asker and Stefánsson 2021; Cole and Dodds 2021; Raymond, Kelly and Hennes 2021; Stuart, Petersen and Gunderson 2022). An original view is expressed by Schmidt (2021), who finds rather striking similarities between the two problems, regarding uncertainty, free-rider incentives and 'disincentives of politicians to adequately address the respective issue with early, farsighted and possibly harsh policy measures'. He argues that for such complex problems, it may be necessary to establish novel political decision procedures that actively involve experts and to lower the involvement of political parties driven by particular interest groups to overcome the barriers to urgently needed climate policies.

There are clearly different opinions about future action towards climate change. While some authors derive hope from government responses to COVID-19 for climate change governance (Raymond, Kelly and Hennes 2021; Van Lange and Rand 2022), others are more sceptical (Asker and Stefánsson 2021; Cole and Dodds 2021). The latter studies discuss that the hope of solving climate change like the pandemic is overly optimistic, arguing that the two collective action problems are very different, so that individual actions to solve problems posed by the pandemic provide little help for the problem posed by climate change. They also believe that, if anything, the actions taken in response to COVID-19 express the inability to cooperate towards climate change mitigation. This is because, for the pandemic, the economic costs that states accepted to limit harm for COVID-19 were 'suboptimal' for the 'global collective', but they might have been 'optimal' for each individual state. On the contrary, the economic costs that states might have to accept to limit harm from climate change are optimal for the global collective but might be suboptimal for individual states (in the short run).

4.7 Similarities and Differences Between COVID-19 and Climate Change

This topic includes studies that compare COVID-19 and climate change resulting in identification of interactions, similarities or differences. Every article belonging to this topic is an opinion or commentary article, and only one article has an area

focus (Sub-Saharan Africa). The two crises have been compared from several perspectives: the way they contribute to human fear (Jankó 2020), politics and responses to both crises (Lidskog, Elander and Standring 2020; van der Ven and Sun 2021), risk management (Pasini and Mazzocchi 2020; Ruiu, Ragnedda and Ruiu 2020), or in broader terms (Ebi et al. 2021; Grundmann 2021; Jately, Joshi and Jatley 2021).

In general, and in line with what is previously discussed regarding collective responses to both crises, it is agreed that the two issues share characteristics, such as the need for international cooperation, affecting vulnerable and marginalised communities worse, and interconnecting with food, water, health, energy and infrastructure systems (Ebi et al. 2021). Main differences include the time span of both crises – COVID-19 is short-term while climate change expresses short-term shocks as well as long-term trends. Additionally, these two challenges are perceived and communicated differently, treating the COVID-19 pandemic as a crisis but communicating climate change in terms of future risks (Ruiu, Ragnedda and Ruiu 2020).

5 Policy Lessons

In this section, we summarize studies that focus on the nexus of COVID-19 and climate policy. We will first identify the most cited authors and the topics most related to climate policy. Then, we will summarise lessons from COVID-19 for climate policy and sustainable actions after COVID-19.

There are 52 articles that focus on policy related to COVID-19 and climate change. Of these, 21 articles were published in 2020, 30 in 2021 and only one in (the first months of) 2022. Regarding methods, 34 articles are classified under opinions and commentaries, 13 use empirical methods and 5 use models. Of the journals that have published such articles (41 in total), only seven have published more than one article. *Climate Policy* is the journal with the highest number of publications, which is perhaps not surprising given the name and scope of the journal. Table 3 summarises the 10 most cited articles that give attention to the nexus of COVID-19 and climate policy.

As expected, the most cited articles related to climate policy lie within the topic of sustainable recovery after COVID-19. Indeed, 40 % of the articles that focus on policy belong to this topic (see Figure 5). The three largest topics in the literature concerning climate policy comprise sustainable recovery actions, collective responses to crises and policy lessons from the pandemic that are applicable to climate change. The studies do not show a clear distinction between mitigation and adaptation policy focus. Out of the 52 articles that focus on policy, eight studies stress the word 'mitigation' and six have the word 'adaptation' in the abstract, of which five studies have both words.

Table 3: Most cited articles on the nexus of COVID-19 and climate policy.

	Topic	Year	Journal	Countries	Citations	Citations p/m	Author
1	Impacts of COVID-19 on climate change and policy	2020	*Oxford Review of Economic Policy*	Other	170	7.7	Hepburn et al.
2	Sustainable recovery after COVID-19	2020	*World Development*	n.a	106	6.2	Barbier and Burgess
3	Impacts of COVID-19 on climate change and policy	2021	*Biological Conservation*	Latin America	52	4.0	Vale et al.
4	Sustainable recovery after COVID-19	2020	*Tourism Geographies*	Global	91	3.9	Prideaux et al.
5	Sustainable recovery after COVID-19	2020	*Environmental and Resource Economic*	Other	46	2.1	Barbier
6	Sustainable recovery after COVID-19	2020	*Sustainability: Science, Practice, and Policy*	n.a	36	1.6	Markard and Rosenbloom
7	COVID-19 lessons for climate change action	2020	*Journal of European Integration*	Europe	18	1.2	Dupont et al.
8	Sustainable recovery after COVID-19	2020	*Sustainability: Science, Practice, and Policy*	Global	24	1.1	Bodenheimer and Leidenberger
9	Collective responses to crises	2021	*Environmental Research*	Asia	16	1.0	Rahman et al.
10	Sustainable recovery after COVID-19	2020	*Environmental and Resource Economics*	Europe	19	0.9	Engström et al.

The COVID-19 pandemic has served as an opportunity to induce short-term policies in order to meet long-term objectives. Several studies connect the pandemic to the Sustainable Development Goals (SDGs) and Agenda 2030, drawing lessons from COVID-19 for policymakers in order to achieve the SDG 2030 Agenda (Armenia et al. 2022; Barbier and Burgess 2020; Doni and Johannsdottir 2021; Elmousalami 2021;

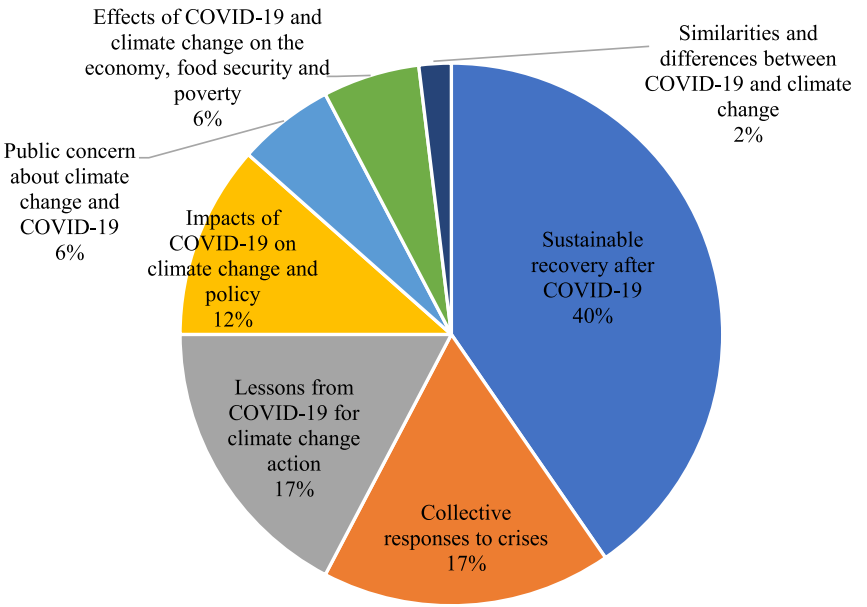

Figure 5: Share of main topics identified relating COVID-19 to climate policy.

Munasinghe 2020). The studies mostly focus on SDG 13, which refers to climate action, and measures to achieve the 13th goal. Similar to Elmousalami (2021), who suggests 'Sustainable Climate Change Policies (SCCPs) that depend on the COVID-19 policies', Table 4 summarises some recurrent policy instruments and targets drawn by the COVID-19 pandemic for climate change mitigation.

Lockdown measures during the COVID-19 pandemic forced people to stay at home, in turn reducing emissions from activities such as travelling to work or for leisure. Our impression is that the outcomes of (too few) studies and a short time period covered by them do not warrant definite conclusions about whether COVID-19 disrupted established behaviours and promoted permanent changes in favour of sustainable travel patterns. Some studies are positive: O'Garra and Fouquet (2022) undertook a survey in the United Kingdom showing that individuals are willing to reduce their travel consumption in the long term, which might lead to 20–26 % reductions in air travel and 24–30 % in car use. Another study by Patiño De Artaza, Lewis and Savin (2023) collected data for 27 EU countries plus the United Kingdom studying transport usage found more mixed evidence. In particular, the authors found different reaction in transport behaviour across countries: in Austria, Germany, Denmark, Sweden and the United Kingdom, a reduction in demand persisted for a while after restrictions were lifted; but in Greece, Portugal, Italy

Table 4: Sustainable climate policies and targets guided by COVID-19.

Policies	Targets
1. Investment in renewable energy (*n* = 9)	1. Smart green cities
2. Application of a carbon tax (*n* = 6)	2. 100 % renewable energy
3. Investment in low-carbon technologies (*n* = 5)	3. Reduction of GHG emissions
4. More efficient transport (*n* = 5)	4. Green growth
5. Communication strategies to promote individual and collective action (*n* = 3)	
6. Investment in education and training (*n* = 2)	
7. Retrofit buildings' energy efficiency (*n* = 2)	
8. Use of digital technology to reduce work/education hours outside the home (*n* = 2)	

Note: n denotes the number of studies proposing the policies. Note that some targets in Table 4 are not quantitative, but qualitative. Indeed, 'smart green cities' and 'green growth' aim for a qualitative transformation. As for reduction of GHG emissions, the numbers vary a lot depending on the ambition and development of the country as well as the time horizon within which the reduction is planned.

and Spain, transport rebounded after; in the remaining countries, there was little evidence for new sustainable transport behaviour persisting over time.

The most cited study is conducted by Hepburn et al. (2020). They surveyed 231 officials from central banks and finance ministries as well as other economic experts from G20 countries to assess the relative performance of 25 major fiscal recovery archetypes. The results show five policies with high potential on both economic and climate impact metrics: clean physical infrastructure, energy-efficiency retrofits of buildings and investments in education and training, natural capital and low-carbon technologies. According to the authors, these policies will not only develop more efficient and cleaner technologies but also address social problems such as unemployment caused by COVID-19 – notably through education and training. Additionally, energy-efficiency retrofits will lower social and health inequalities by shrinking real electricity costs and keeping houses warm during the winter periods.

Increasing digital work and education leads to a reduction in transportation and thus in CO_2 emissions (Bodenheimer and Leidenberger 2020). Moreover, by investing in more energy-efficient technologies, improvements in transport systems and infrastructure may lead to more intense use of public transportation and promotion of active mobility like cycling (Kakderi et al. 2021). Applying such policies now will lead to greener cities, cleaner and more efficient use of energy and ultimately achieve climate targets.

Although the theoretical and empirical support for carbon pricing as an effective and systemic instrument is impressive, it remains a controversial policy in some

circles. While it can introduce new revenue streams and contribute to a more sustainable recovery (Barbier 2020; Barbier and Burgess 2020; Mintz-Woo et al. 2021), subsidies for low-carbon actions receive a higher acceptance among general public than carbon taxes (Engler et al. 2021), even though they tend to lead to relatively high rebound (Murray et al. 2014). In general, although implementing a carbon tax is suggested by one study to potentially worsen the recession (which is highly uncertain in our view), there is high support for it if combined with other policies (Engström et al. 2020).

6 Conclusions

The main objective of this study was to identify the questions that recent research has raised regarding the relationship between COVID-19 and climate change. The unexpected COVID-19 pandemic laid bare the interconnection between economic, environmental and healthcare systems. Through an analysis of publications that include the keywords 'COVID-19' and 'climate' or 'coronavirus' in their title, 204 articles were collected and systematically reviewed. General study characteristics demonstrate that the most prominent article types are opinions and commentaries, followed by empirical surveys. In terms of geography, Europe, Asia and North America were the most studied areas.

Based on computational linguistics and qualitative analysis, seven main topics were identified in the literature surrounding the nexus of COVID-19 and climate change: (1) impacts of COVID-19 on climate change and policy; (2) sustainable recovery after COVID-19; (3) public concern about climate change and COVID-19; (4) lessons from COVID-19 for climate change action; (5) effects of COVID-19 and climate change on the economy, food security and poverty; (6) collective responses to crises and (7) similarities and differences between COVID-19 and climate change. The most cited topic is topic (1), which mainly discusses the change in emissions due to COVID-19.

Several of the reviewed studies discuss the lessons from the COVID-19 pandemic for climate policy. These suggest that one cannot be optimistic as solving the climate crisis is not like responding to a pandemic. While the two crises share as similarities the need for collective responses, international cooperation and involving experts in political decisions, there are also many differences. COVID-19 is short term and direct, while climate change is slower, complex in its mechanisms, and threatening not only humans but also ecological systems. Climate policy in times of COVID-19 suggests a need to focus on a sustainable recovery from the pandemic, implementing

measures that account for energy and transport efficiency, investments in low-carbon technologies and in education for new climate-induced industries, and regulation and pricing strategies to enforce individual climate action.

Regarding further research, as COVID-19 is now under control globally, it may be the time to start collecting temporal data to assess its long-term social, economic and environmental impacts as well as its influence on opinions about public policy in different fields (health, climate). Any results of these can serve as a robustness check of forecasts by studies covered in the review here.

For example, while several studies reviewed here found evidence that COVID-19 confinement measures reduced air pollution and global emissions via reduced mobility, it has not yet been studied whether such behavioural changes are persistent. Prior studies based on survey questionnaires show moderate optimism that people will work more remotely (Savin et al. 2022a), but evidence for impacts on climate action is scarce. In addition, further research is warranted on the question how COVID-19 has affected inequality, particularly in low- and middle-income countries.

Data and Code Availability

Data for this study are available at: https://github.com/IvanVSavin/CovidClimate.

Highlights

- We review 204 articles on the relationship between COVID-19 and climate change.
- They are classified into seven main topics using computation linguistics.
- Studies give most attention to the impacts of COVID-19 on emissions.
- Low-carbon technologies and carbon taxation are the most commonly suggested policies.

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Appendix

See Figure A1.

Figure A1: Word clouds of nine topics retrieved with structural topic modelling based on titles, abstracts and keywords of the 204 articles on the nexus between COVID-19 and climate change. *Note:* Font size reflects the probability (weight) of the respective word given the topic, while darker colour indicates a higher degree of exclusivity.

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