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Contextualizing the Covid-19 pandemic for a carbon-constrained world: Insights for sustainability transitions, energy justice, and research methodology

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ABSTRACT

The global Covid-19 pandemic has rapidly overwhelmed our societies, shocked the global economy and overburdened struggling health care systems and other social institutions around the world. While such impacts of Covid-19 are becoming clearer, the implications of the disease for energy and climate policy are more prosaic. This Special Section seeks to offer more clarity on the emerging connections between Covid-19 and energy supply and demand, energy governance, future low-carbon transitions, social justice, and even the practice of research methodology. It features articles that ask, and answer: What are the known and anticipated impacts of Covid-19 on energy demand and climate change? How has the disease shaped institutional responses and varying energy policy frameworks, especially in Africa? How will the disease impact ongoing social practices, innovations and sustainability transitions, including not only renewable energy but also mobility? How might the disease, and social responses to it, exacerbate underlying patterns of energy poverty, energy vulnerability, and energy injustice? Lastly, what challenges and insights does the pandemic offer for the *practice* of research, and for future research methodology? We find that without careful guidance and consideration, the brave new age wrought by Covid-19 could very well collapse in on itself with bloated stimulus packages that counter sustainability goals, misaligned incentives that exacerbate climate change, the entrenchment of unsustainable practices, and acute and troubling consequences for vulnerable groups.

1. Introduction

The global Covid-19, or coronavirus disease, pandemic has overwhelmed our societies, shocked the global economy, thrown energy markets into disarray and overburdened struggling health care systems and other social institutions around the world. Unlike earlier modern disease outbreaks such as severe acute respiratory syndrome (SARS), swine flu (H1N1), or Ebola, the Covid-19 virus is very easily transmitted by person-to-person contact. Further, it has no known preexisting immunities, it is spread by people that do not appear to be sick, and the ratio between infections and fatalities is very high, particularly for older people and people with preexisting medical conditions. In medical terminology, society is undergoing a global pandemic with an immunologically naïve population. When addressing a group of sustainable development and medical professionals in April 2020, Columbia University Professor Jeffrey Sachs estimated that the virus that causes Covid-19 (i.e. SARS-CoV-2) could infect *half* the world's population within the next few years [1].

Although the global response to Covid-19 may not be fully commensurate to the severity of the challenge, it has nevertheless disrupted longstanding notions of human resilience, disease preparedness, and even global health governance [2]. National and subnational responses to the disease have often been far-reaching and at times transformative, including not only mandatory lockdowns, quarantines and restrictions on travel but key interventions such as evacuations, the distribution of hygiene and sanitation kits, and the suspension of all public visitors. Some countries have utilized mass surveillance (as well as tracking and contact tracing apps) to monitor symptoms within their populations, funded community participation in the development and distribution of personal protective equipment, or participated in the design of intersectoral and transnational cooperation and aid packages.

More than $11 trillion in fiscal support measures had been

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announced by governments globally as of June 2020 to mitigate the economic impact from the pandemic, particularly impacts from the lockdown measures implemented to prevent spread of the disease [3]. These relief packages amount to nearly 15% or more of GDP in Germany, Japan and the United States, with the United States alone signing a massive $2 trillion Covid-19 emergency bill and stimulus package in March 2020 [4]. The European Union set up a €37 billion Coronavirus Response Investment Initiative to provide liquidity to small businesses and the health care sector [5]. The United Kingdom also has invested heavily, launching a furlough program where the *government* paid the wages of 9.1 million affected workers (one quarter of the workforce) at a cost of more than £20 billion with an additional £38 billion in loans to businesses [6]. Initial assessments of the economic consequences of the pandemic are sobering, with estimations of a global GDP contraction of 4.9% in 2020 [3], global trade shrinking by 32% [7] and as many as 300 million people losing their jobs [8].

Although the impacts of Covid-19 on health systems and national economies are heavily covered in the media, and oft debated in the public, the implications of the disease for energy and climate policy are more prosaic. This Special Section of *Energy Research & Social Science* seeks to offer more clarity on the emerging connections between Covid-19 and topics such as energy supply and demand, energy governance, future low-carbon transitions, social justice, and even the practice of research methodology. It features articles that ask, and answer: What are the known and anticipated impacts of Covid-19 on energy demand and climate change? How has the disease shaped institutional responses and energy policy frameworks, especially in places such as Africa where Covid-19 is negatively affecting ongoing efforts to achieve access to modern energy? How will the disease impact ongoing patterns of innovation, social practices and future transitions, including not only adoption of renewable energy but also the electrification of mobility and mobility-as-a-service? How might the disease, and social responses to it, exacerbate underlying patterns of energy poverty, energy vulnerability, and energy injustice? Lastly, what challenges and insights does the pandemic offer for the *practice* of research, and for research methodology?

2. The energy and climate impacts of the virus

Although ostensibly never intended as measures to reduce energy consumption, air pollution, or climate change directly, responses to the virus have had substantial connections with energy demand and greenhouse gas emissions. The most prominent drivers of these have been mandatory lockdowns or quarantines for households (people are only permitted to leave for essential reasons) and the related severe restrictions on travel. In late April 2020, more than *half* of the entire global population (54%) was under some form of a coronavirus lockdown, with their movement actively restricted and controlled by their respective governments. The share of energy use that was exposed to containment measures reached 50% [9]. As the top panel of Fig. 1 indicates, the largest lockdowns were in India, China, and the United States. One article calculated that more people were in lockdown due to Covid-19 than were alive during World War II [10]. As the other panels of Fig. 1 indicate, more than 100 countires had travel restrictions in place due to coronavirus in late March 2020 and the number of commerical flights has plummeted dramatically. Abu-Rayash and Dincer (this volume [11]) add that *road transport* is also down significanty given the large number people forced to stay at home. They further show that in Canada not only did civil aviation activities drop by 71% compared to business-as-usual in late 2019, but also military aviatation activities were down by a significant 27% in 2020. They also projected that for 2021, greenhouse gas emissions for the Canadian transport sector will be nearly 25% lower than than in 2019.

Covid-19 has not only affected travel and the energy involved in providing it, but also global energy supply chains and the viability of energy firms. Writing in this volume [12], Hosseini argues that the most affected renewable energy sector has been solar energy and remarks that indeed, "the COVID-19 pandemic has struck the renewable energy manufacturing facilities, supply chains, and companies and slowed down the transition to the sustainable energy world". The causes behind such shifts are manifold: governments have understandably redistributed public funding to combat the disease in a way that leaves less available for renewable energy incentives and tax credits. Various renewable energy technology suppliers have placed staff on furlough and also adopted austerity measures and reduced operating capacity. Projected installations are down significantly over earlier forecasts; one investment bank in the United States predicted residential-solar installations to fall by 48% year-over-year in the second quarter of 2020 and by 17% in the fourth quarter of 2020. This reinforces the projections provided by IRENA that total new solar PV capacity additions in 2020 will be roughly on par 2019, but this is as much as 20% below earlier expectations stated by several industry organizations [13].

The off-grid renewable energy sector could face even more dire circumstances, with the World Bank noting that the pandemic has seriously disrupted electrifications efforts, meaning that SDG 7 (that encompasses universal energy access by 2030) is now unlikely to be met [14]. It is in this context that Mark McCarthy Akrofi and colleagues (this volume [15]) caution that the pandemic could "reverse the enormous progress that off-grid energy companies have made to bring power to some 470 million people in the last decade." Solar PV alone is responsible for employing about 4% of the entire African workforce but solar firms and enterprises are already being forced to cut jobs, lay off staff, and confront declining liquidity. Due to a strong dependence on imported solar PV technology from China, where manufacturing has declined due to the pandemic, dramatic reductions on future installed solar capacity are also projected for countries such as India [16].

Covid-19 is affecting global fossil fuel markets as well. Hosseini (this volume [12]) adds that the coronavirus has disrupted global oil markets far more than any geopolitical event has (such as an embargo from OPEC), weakening the ability of oil suppliers to control markets and driving down natural gas spot prices into the $2/MMBTU (million British Thermal Units) range. Although geopolitical tensions between Saudi Arabia and Russia played an early role in the 2020 oil price collapse [17], demand destruction due to Covid-19 has indeed been the driving force. Jefferson (this volume) [18] writes "In the run-up to the collapse of crude oil prices in early 2020 it was primarily a division between Russia and Saudi Arabia within OPEC which appeared to be the main force at work, but then the COVID-19 pandemic took over, followed by US oil prices turning negative in April 2020, as May contracts expired and traders had to offload stocks with ongoing storage becoming extremely limited." He further states that despite the stimulus and recovery packages being offered by many nations, "there will be many oil sectors incurring losses, from US shale oil and Canadian tar sands producers, to many standard crude oil exporters incurring problems with production equipment access and costs, or experiencing lack of competitiveness in key markets." Recent data from the International Energy Agency confirms this point, noting severe reductions in global demand for oil and natural gas (see Fig. 2).

Although not representative of all countries and regions, the Special Section does feature some deep and nuanced assessments of the particular impacts the pandemic is having on national energy supply or demand. Nima Norouzi and colleagues (this volume) [19] intimately trace the impacts of the virus where it first emerged in Wuhan, China, looking at how it impacted not only national energy demand, but also precipitated steep declines (and future uncertainty) in patterns of electricity consumption and oil consumption, industrial productivity and energy markets. They specifically propose a methodology for analyzing such patterns during periods in which historical data becomes inaccurate because of a crisis event such as Covid-19. Azzam Abu-Rayash and colleagues (this volume) [20] closely analyze the impacts of the pandemic on electricity demand in Ontario, Canada, where they calculate declines in electricity consumption during April of about

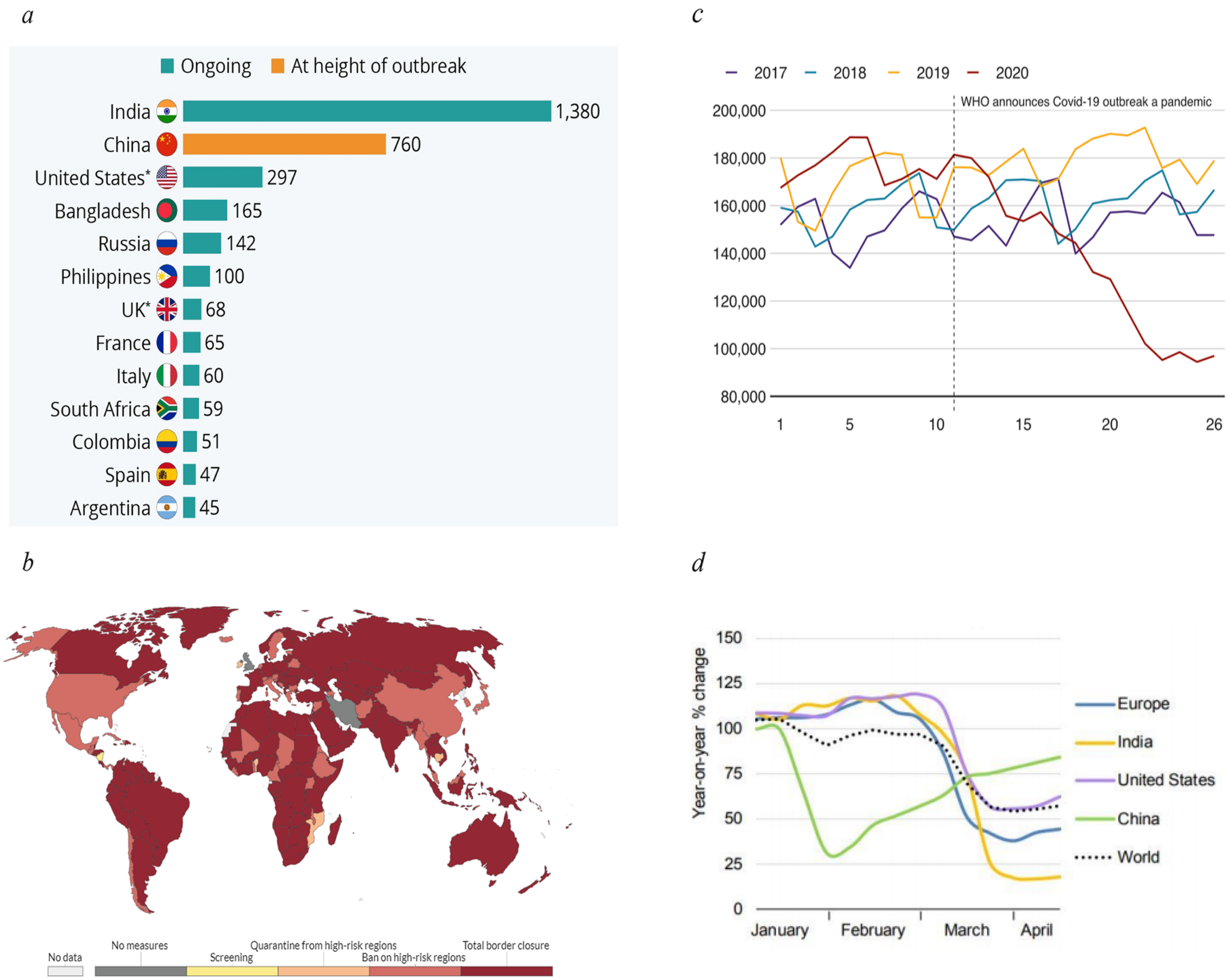

Fig. 1. Effects of the Covid-19 pandemic on household freedoms and global travel patterns. A. Size of lockdowns by national population (millions of people). B. Countries with travel restrictions or bans on international movement in April 2020. C. Number of daily commercial flights in March 2020. D. Road transport activity in early 2020. Source: Authors compilation of data from the BBC, Business Insider, Statistica and the International Air Transport Association.

14% or 1,267 GW and note distinct changes in demand patterns due to quarantine and travel restrictions. This corresponds with some positive externalities as well, including greenhouse gas emission reductions of 40,000 tons of CO2 equivalent attributed to Covid-19 with a monetary value of $131,844 for the month of April 2020.

Fig. 3 shows a similar trend in Europe, with significant (and positive) reductions in air pollution noted across France, Italy, and Spain, largely from the curtailment of road transport. Abouzar Estebsari and colleagues (this volume [21]) offer a well-reasoned explanation for why related reductions in electricity demand occurred, having analyzed patterns of electricity demand in Spain, Italy, Belgium and the United Kingdom (countries with more severe Covid-19 movement restrictions) as well as the Netherlands and Sweden (countries with less restrictive measures). They found that during the second week of April 2020 only in Sweden demand remained more or less the same (actually rising slightly) relative to a reference week in 2019. Significant reductions were experienced in Spain (25%), Italy (17.7%), Belgium (15.6%), the UK (14.2%) and even the Netherlands (11.6%) due to Covid-19.

The ramifications of Covid-19 extend well beyond the avoided energy consumption and emissions associated with travel and household lockdowns; they are also drastically shaping the strength (or erosion) of some energy institutions and policy frameworks. For instance, the pandemic is having a particularly pronounced effect on institutions and policy frameworks in Africa, even though it is not (at the time of this writing) a major center of infections or death. Mulualem Gebreslassie (this volume) [22] writes that the closure of energy intensive businesses and industries in Africa has meant a positive shift in that states can now provide scarce energy services to homes or national health care systems. As they conclude, the pandemic "may even convince the African continent to rethink and clear the way for investing more in clean and reliable energy resources and make business processes easy for those who are interested to enter the renewable energy sector." Mark McCarthy Akrofi and colleagues (this volume [15]) add that African states are already rushing to intervene and stimulate recovery but do not specifically address how stimulus packages will influence the clean energy transition. Further research therefore needs to examine how government stimulus can strengthen the renewable energy sector via various aid packages, economic incentives, and monetary and fiscal incentives—efforts Müller et al. note are all broadly consistent with many national policy frameworks across the continent [23].

3. Implications for social practices and sustainability transitions

As already stated, the pandemic has significantly disrupted lives, businesses, and economies. Furthermore, it could culminate in lasting effects on social norms and practices. To contextualize this claim,

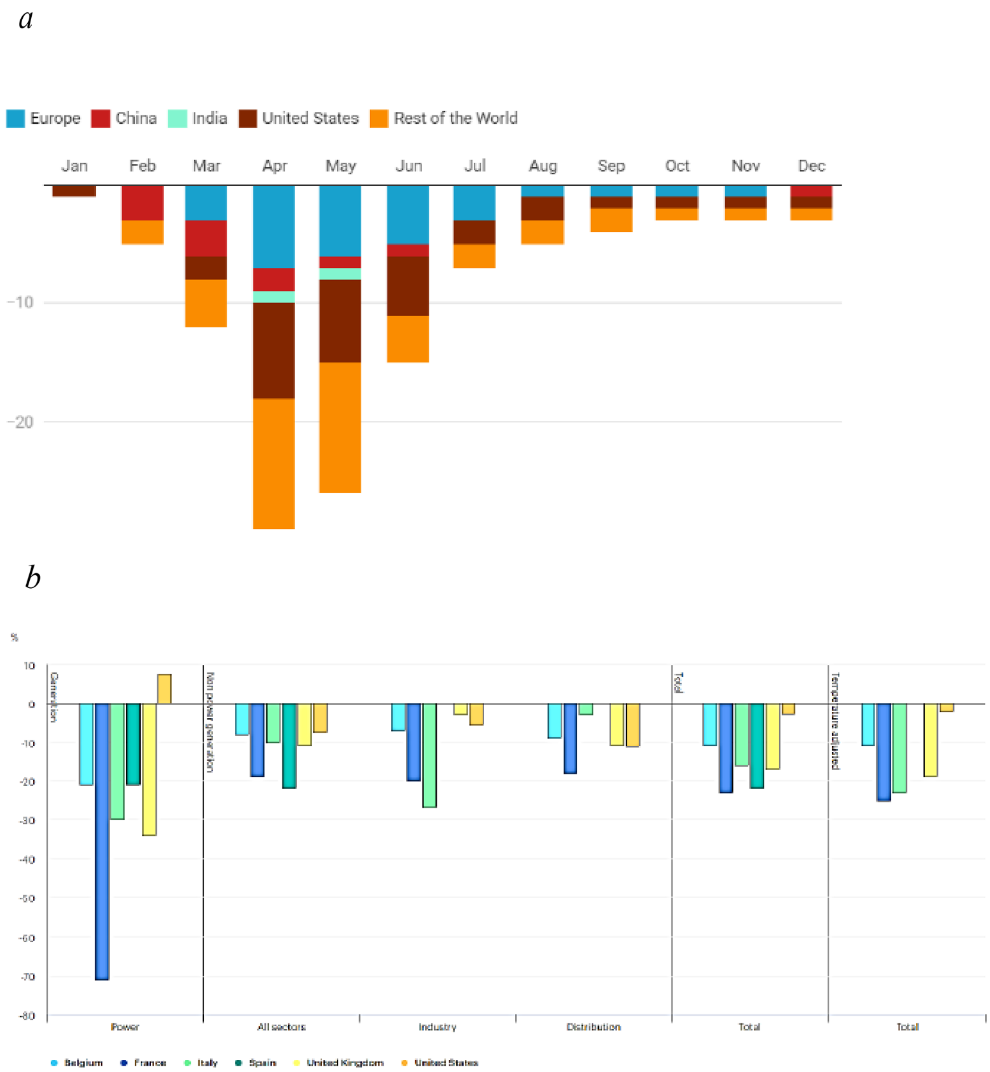

Fig. 2. Impacts of Covid-19 on global oil and gas supply and demand. a. Projected reductions in global oil demand in 2020 compared to 2019 (million barrels per day). B. Effects of Covid-lockdowns on sectoral natural gas consumption (from the first day of 2020 to 15th April 2020). Source: Authors complication of data from the International Energy Agency.

consider that the global response to Covid-19 has necessitated unprecedented levels of coordination and information sharing with the intent of ultimately curtailing outbreaks and minimizing harm [24]. This has occurred at multiple levels of society at once across many different types of institutions—making it what the Nobel Laureate Elinor Ostrom would have called "organizational multiplicity" and a "polycentric" phenomenon [25,26].

Fig. 4 displays the variety of messages received about Covid-19 merely by the lead author, including those from the mass media (Covid-19 dominated headlines in the UK for weeks), companies and travel providers, national government, grocery stores, universities, restaurants, social groups and charities, and even churches. This phenomenon parallels what scholar Eve Kosofsky Sedgwick terms the "Christmas Effect" [27] to describe the way that major parts of Western society come together and speak "with one voice" for the Christmas holiday. For it is annually during the Christmas season that churches build nativity scenes and hold a greater number of masses; state and federal governments establish school and national holidays; the media run major advertising campaigns; and social events and domestic activities align. Whenever society combines institutional inertia in this manner, it can exert profound and lasting influence over patterns of behavior, transcending individual firms and people. Although certainly not festive, the "Coronavirus effect" may be just as effective as the "Christmas effect."

Such messages and strategies of communication underscore an immense amount of coordination across diverse and heterogeneous actors and organizations. The resulting messages were *persistent*, coming repeatedly and daily. They were *prominent*, in many times coming from sources people trust. They were *multifaceted*, coming from many sectors beyond health care including not only those in Fig. 4, but also the Mayor of London Sadiq Khan, banks, libraries, political groups, airlines, friends, and family. One of the authors even had his "smart printer" send an automated email about ink delivery during the pandemic, as well as six emails from his dentist about dental hygiene during the pandemic. And the messages were *personal*, often prescribing very specific actions or recommendations (about washing, essential travel, social distancing, self-quarantining, and mask wearing) connected to personal health and calling for immediate changes in behavior and practice.

Given the coronavirus' ability to achieve this "Christmas effect," hundreds of millions of people immediately adopted the new behavior of "social distancing," with Fig. 5 showing its adoption in India, the United States, the United Kingdom and Singapore. When making the predictions mentioned in the Introduction, Jeffrey Sachs even remarked that "we should expect to change our behaviors not just during this pandemic but perhaps forever."

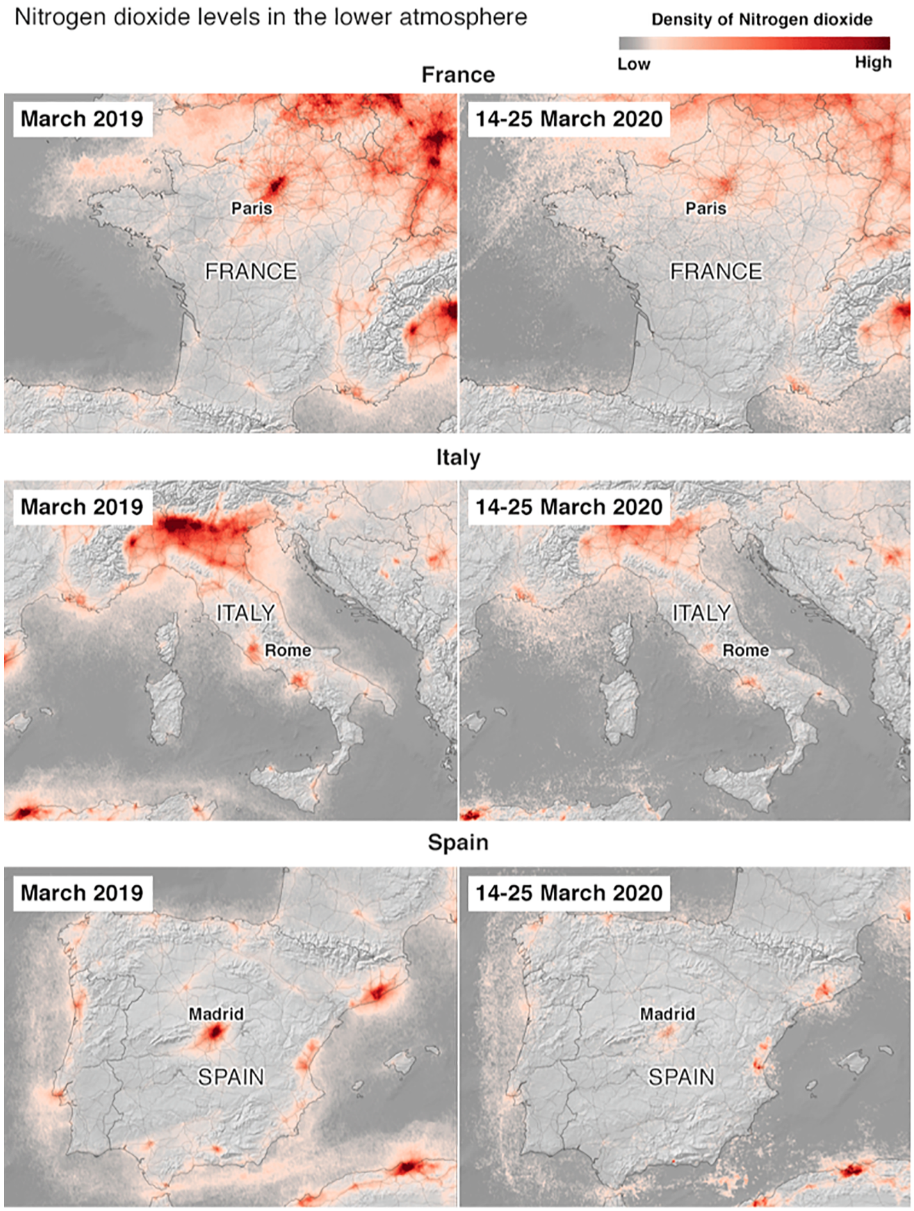

Fig. 3. Reductions in air pollution across Europe in March 2020 due to Covid-19. Source: European Space Agency/Copernicus Satellite, March 27, 2020.

Indeed, Wisdom Kanda and colleagues (this volume [28]) argue that in the context of sustainability transitions, the pandemic is causing "disruptive" change not only by potentially accelerating transformations in incumbent socio-technical systems, but also by also affecting emergent innovations and niches. In the mobility sector, they discuss how in Finland and Sweden the virus has weakened the push for mobility-as-a-service efforts (given they involve sharing rides, not ideal in an environment of social distancing) but had less impact on the push for electric vehicles (given they permit individualized, private transport). They therefore suggest that the impacts of COVID-19 on mobility practices and transitions are important research streams moving forward.

Caroline Kuzemko and colleagues (this volume [29]) take an even broader and more holistic view of the ways the pandemic can place pressure on sustainability transitions in the near-term and the long-term. They argue that Covid-19 can alter the scope and pace of *energy systems change* with declining electricity demand and prices, the disruption of supply chains, and possible rebounds associated with recovery and stimulus packages. It could also shift *financial investment flows* away from incumbent industries and carbon intensive fuels. The pandemic is changing *multi-scalar policy and politics* by calling into question longstanding conventions about globalization and interconnectivity, as well as freedom of movement and geopolitical tensions between groups such as the United States and China or the United States and the World Health Organization. The pandemic is lastly transforming *social and political practices*, especially those related to telework/working from home as well a preferred modes of travel given the near-term focus on social distancing. Here they warn that the lasting imprint of the pandemic is uncertain, with the potential that it entrenches unsustainable practices (such as driving a car) perhaps as great as its ability to introduce more sustainable practices (such as walking). They raise the critical question of whether there will be an acceleration of pre-pandemic drivers for sustainability across the dimensions they consider or whether momentum for sustainability will be lost as pandemic recovery plans are rolled out.

Kester et al. recently refer to this as the "dialectic" nature of future sustainability transitions, given they can reinforce dominant practices as much as they can reform existing ones [30]. Even electric mobility, an innovation Kanda and colleagues noted may ultimately be less affected by the pandemic, has unclear and highly differentiated impacts

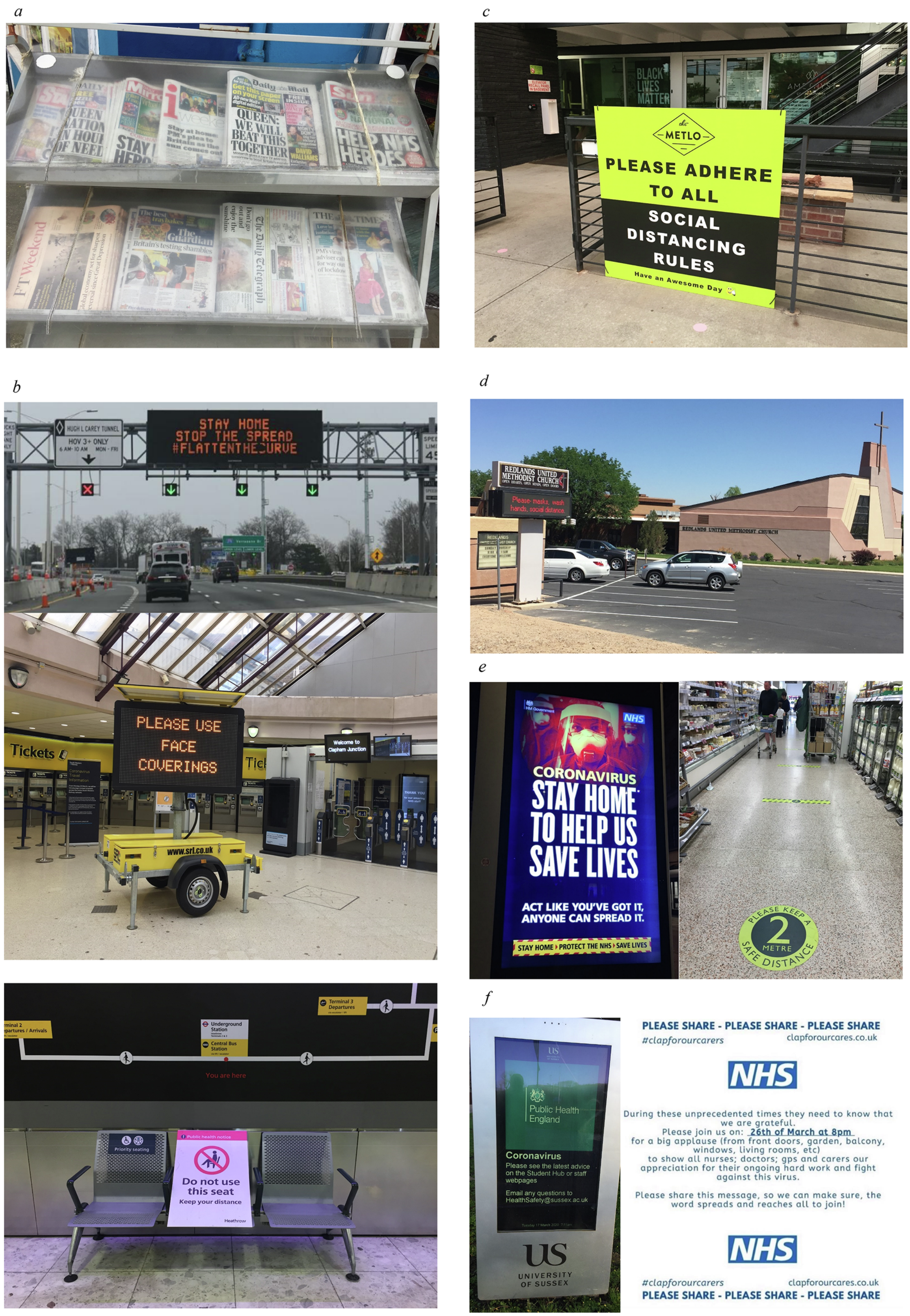

Fig. 4. The polycentric and multi-institutional nature of Covid-19 information and messages. A. Mass media (newspapers). B. Companies and travel providers. C. Restaurants. D. Churches and places of worship. E. National government and grocery stores. F. Higher education and universities, social groups and charities. Source: Compiled by the authors.

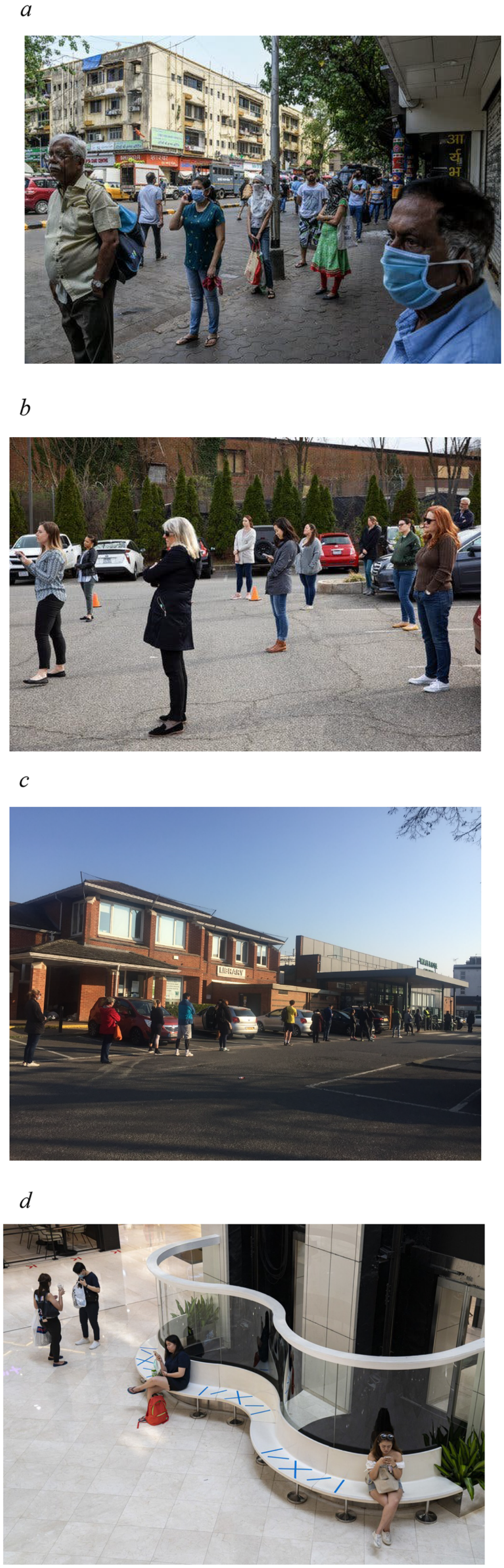

Fig. 5. The adoption of social distancing around the world, April 2020. A. India. B. United States. C. United Kingdom. D. Singapore. Source: Compiled by the authors.

on sustainability as noted in Table 1. This means the adoption of electric vehicles is neither good nor bad in sustainability terms, it instead *depends* on how such innovations are governed and managed across areas such as vehicle use, daily life, social identity and system-wide environmental effects.

4. Connections with energy justice and vulnerability

The Covid-19 pandemic has equally compelling linkages with energy crises, energy poverty, energy vulnerability and energy injustice. Kathleen Brosemer and colleagues (this volume [31]) write that the pandemic will only “illuminate and compound existing crises in energy sovereignty.” It is worsening already terrible inequalities in health care access among the Navajo Nation in the United States, where hospitals were overburdened before Covid-19 outbreaks with caring for indigenous peoples harmed from coal mining and extraction as well as increases in kidney disease and cancer that resulted from many years of living next to abandoned uranium mines. The pandemic is compounding environmental injustices as Covid-19 most affects those with preexisting medical conditions, and yet decades of poor environmental and air quality leave minority groups at heightened risk of having those conditions. It is undermining the ability of energy firms to guarantee the provision of energy access and modern energy services in times of austerity and uncertainty. It is lastly serving as a mechanism for powerful incumbent interests to usurp various regulatory processes that back their own narrow interests at the expense of the public good. One particular example is Enbridge “taking advantage of divided public attention and a fraught financial situation during the Covid-19 crisis to push forward permit applications” for a major change in the routes of one of their pipelines. Such attempts at regulatory manipulation are not limited to North America; Kalyani writes how vested interests in India were using the pandemic as an excuse to increase employment in the coal and gas sectors, even though these sectors operate contrary to India’s stated climate policies [16].

Paolo Mastropietro and colleagues (this volume [32]) add that “the Covid-19 pandemic and the consequent lockdown exacerbated energy poverty and insecurity worldwide.” However, they also note that the collective response from policymakers has been to attempt to safeguard vulnerable citizens by an array of protection measures including:

- Disconnection bans;
- Energy bill deferral and payment extension plans;
- Enhancement of energy assistance programs;
- Energy bill reductions or cancellations;
- Support measures for commercial and small industrial activities;
- Creation of funds and other support measures to suppliers.

After reviewing the global prevalence of these measures, they conclude that two are “best” at minimizing vulnerability: direct energy assistance programs and bans on disconnections, the latter being the most widespread measure introduced by governments during the pandemic.

Matthew Henry and colleagues (this volume [33]) take an equally useful global analytical lens, reinforcing the recent call for a “Just Transition.” This debate about a “Just Transition” is ongoing across many countries and provinces, with at least 14 national commissions, policies, or task forces in place across Canada, China, Czech Republic, Germany, Ghana, Indonesia, New Zealand, Scotland, South Africa, Spain, the United States and Vietnam. As Table 2 indicates, a “Just Transition” is backed by powerful coalitions and groups around the world.

As Henry and colleagues note, a Just Transition intends to ensure that as global society decarbonizes, it does not leave anyone behind. Efforts must be made to offer income support for workers during the full duration of transition, to tailor local economic development tools for affected communities, and to offer realistic training or retraining

Table 1
The differentiated impacts of electric mobility and electric vehicles on sustainability.

	Elements	Strengthens sustainability	Weakens sustainability
Vehicle use	Vehicle uptake	EVs substitute for conventional cars and motorcycle.	EVs increase car-based mobility by drawing people away from active and public modes of transport.
	Intermodality	EVs used more in intermodal (active and public transport) systems and in combination with measures to discourage car use.	EVs encourage excessive driving and are bought as second or third (luxury) cars.
	Ridesharing	EVs increase the use of car sharing/ride sharing schemes.	EVs increase the preference for private, single-occupancy driving practices.
Daily life	Suburbanization	EVs are a wakeup call to address private vehicle use if alternatives are available – public transport, shared services etc.	EVs, through their cheaper variable costs, enable longer distances, thus supporting urban sprawl. They also compete with public transport and shared services.
	Routines and lifestyles	EVs allow for more family time as commutes are part of office hours.	EVs allow office hours to be extended to include commuting time.
Social identity	Expression of gender	EVs and EV marketing break with gender distinctions through alternative design, comfort and ease of operations.	EVs and EV marketing reinforce stereotypical car images of masculinity (large, sporty, pickup trucks) or femininity (small, quiet, early generation EVs).
	Expression of stereotypes	EVs and EV marketing point to new stereotypes around responsible and sustainable car use.	EVs and EV marketing reinforce stereotypical car discourses of joy and notions of freedom.
	Expression of class/ wealth	EVs break with class distinctions, as low variable costs enable more mobility for all.	EVs reinforce class/wealth distinctions as high capital costs imply that only rich can afford them and their benefits.
System-wide effects	Environmental stewardship	EVs, through their broad deployment, signal a need for more efficient low-carbon propellants, alternative modes of transport, less mobility and spur pro-environmental behavior in other sectors	EVs have lower emissions, which lead to rebound effects: more miles travelled, heavier vehicles, more private vehicles. This is especially relevant if the ecosystem around EVs fails to materialize, e.g. no battery recycling, only dump charging, non-renewable electricity, etc.
	Oil independence	EVs minimize and signal lower oil/gas consumption, which reduces dependency among households and non-oil producers on oil companies and oil producing countries.	EVs cause a reduction in demand for oil, which reduces the oil price and makes fueling conventional vehicles cheaper. Lower oil prices also reduce oil sector investments and thereby limit production to a smaller group of oil producing countries (those with low variable costs) and counterintuitively increasing oil dependence on a smaller group of countries.
	Employment an competitiveness	EVs are designed and promoted by sustainably oriented firms with a focus on innovation and entrepreneurship.	EVs are co-opted and marginalized by transnational conglomerates with little desire for social change.

Source: Authors modification from Kester et al [30].

programs that lead to decent work. They worry, however, that both the Covid-19 pandemic and the global fall in oil prices could complicate ongoing attempts to realize a Just Transition—especially since the pandemic has resulted in the loss of more than 500,000 clean energy jobs and halted momentum in the push for solar energy and wind energy. They conclude however that the COVID-19 crisis represents "a unique opportunity to adopt Just Transition principles into community and economic recovery efforts."

5. Insights for research practice and methodology

The insights offered by this Special Section are not just topical or thematic. They also relate to the very art and craft of undertaking research, with some interesting insights for research design and research methodology.

Both Jefferson (this volume [18]) and Kanda and colleagues (this volume [28]) note how scholars, especially those designing energy programs (such as the Global Energy Assessment) or utilizing

Table 2
Selected organisations and movements supporting a "Just Transition" in 2019.

BlueGreen Alliance (US)	Labor Network for Sustainability (US)
Beyond Coal campaign (US)	NAACP (US)
Climate Justice Alliance (US)	National Union of Mineworkers of South Africa (South Africa)
Deutscher Gewerkschaftsbund (German Trade Union Confederation) (Germany)	Sierra Club (US)
European Trade Union Confederation (EU)	Sunrise Movement (US)
IndustriALL Global Union (global)	The Trade Unions for Energy Democracy initiative (Global)
Indigenous Environmental Network (US)	Trade Union Confederation of the Americas (TUCA) (Americas)
International Labor Organization (global)	Transitions Town Movement (UK)
International Trade Union Confederation (Just Transitions Center) (global)	Women's Environment and Development Organization (Global)
ITUC-affiliated Just Transition Centre (Global)	350.org (Global)
Just Transition Alliance (US)	
Just Transition Fund (US)	
Kentuckians for the Commonwealth (US)	

Source: Compiled by the authors, with special thanks to Noel Healy and the Chapter 4 team of the IPCC's forthcoming Sixth Assessment Report.

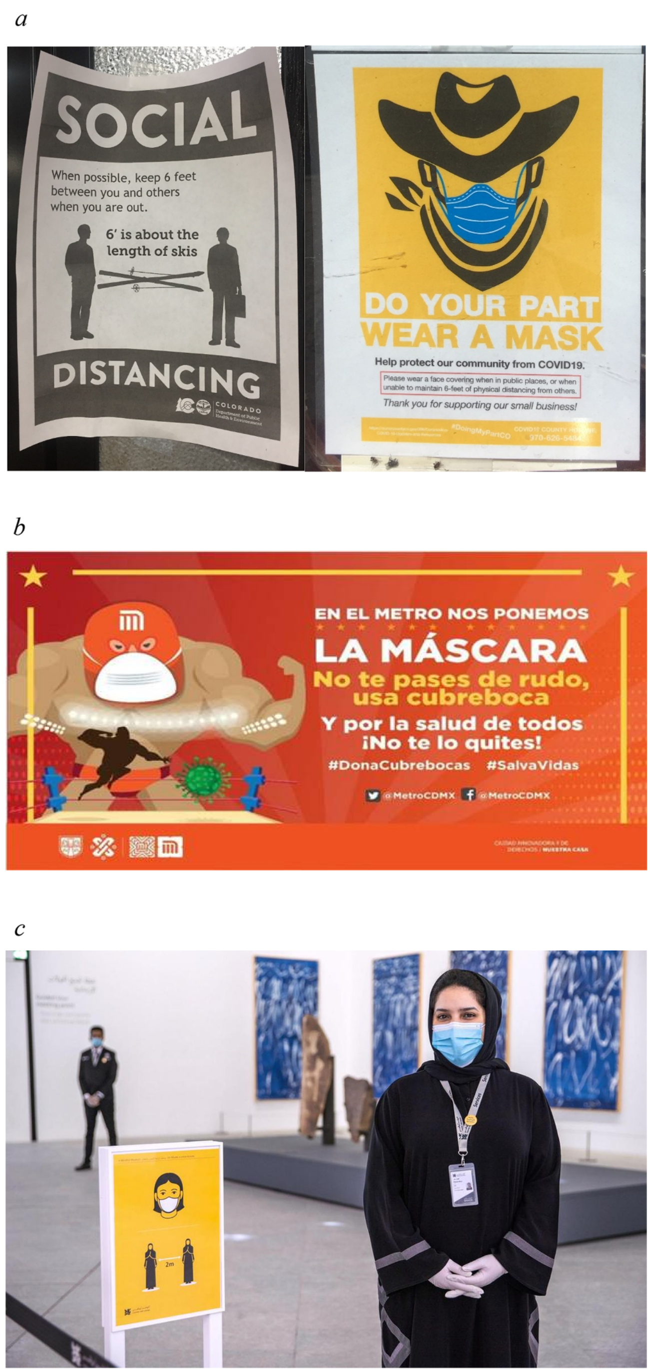

Fig. 6. Cultural variation in messaging and information campaigns about the Covid-19 pandemic. A. A social distancing sign in Denver (showing skis) and Ouray (a cowboy hat), Colorado, United States. B. Advertisement from Mexico's Ministry of Health stating: "In Mexico we wear facemasks. Do not be a 'rule breaker' and wear a mouth-covering mask. For everyone else's health: do not take it off!". C. In the United Arab Emirates, the Louvre Abu Dhabi welcomes guests to the museum in late 2020 after 100 days of closure due to the Covid-19 pandemic. Source: Compiled by the authors.

conceptual frameworks (such as the multi-level perspective) need to better account for epidemics and pandemics as landscape shocks.

The persistence, prominence, multifaceted and personal nature of effective messaging about the virus (discussed in Section 3) also remind us about the importance of recognizing culture [34,35] whenever researchers engage in communication or outreach. Fig. 6 even shows the adapting to local culture of messages about social distancing and wearing masks. For instance, images about the virus in the Western state of Colorado (in the United States) feature skis and cowboys—symbols well embedded in local culture. *Lucha Libre* in Mexico has played a relevant role in its culture since the late 1950s, mainly due to its masked wrestlers, who have incorporated their own family traditions, beliefs and fears into the design of their masks [36]. The Louvre Abu Dhabi similarly adapted their messages about the pandemic to feature culturally appropriate attire for women, e.g. abayas on images of women performing social distancing.

Michael Fell and colleagues (this volume [37]) suggest that the pandemic represents not only an existential threat to society, but also a threat to the practice of research, given that it calls into question the internal and external validity of our findings in the academy. This includes both the validly of research done *before* the pandemic (given that society may never be the same after) and the future robustness of any research conducted *during* the pandemic (a situation of extreme anxiety and stress far removed from "normal" life, potentially making findings less stable over time). They argue that Covid-19 changes the context for research as it creates an environment that may be unprecedented and highly unusual compared to future years. They note the pandemic is reconfiguring demographics in rapid and unforeseen ways, with advanced morbidity and mortality and differentiated effects across age, gender, or ethnicity. They argue (much as we have in Section 3) that the pandemic is altering behaviors and daily routines; changing perceived personal and cognitive constraints and feelings; putting pressure on exiting social norms and identities; and materially changing homes and workplaces. Taken together, these features of Covid-19 may demand that we rethink in meaningful ways the design of future studies, how we determine demographically representative samples, how we collect data, how we interpret findings, and how we translate those findings into recommendations. Such considerations are timely and relevant given the explosion of Covid-19 publications that have appeared since the start of the pandemic. Nearly 7,000 papers on the pandemic were published between February and May 2020 alone, and 3,000 of these were released through the preprint servers BioRxiv, MedRxiv and arXiv [38].

Chen and colleagues (this volume [39]) further these themes in their work on acceptance of and willingness to pay (WTP) for home energy management systems (HEMS) during the Covid-19 pandemic in New York, USA. They note that the pandemic is having a distinct effect on survey participants with social-psychological variables, such as attitude toward HEMS and social norms, arising as important factors for explaining technology adoption intention. They also affirm some of the points raised by Fell et al. about the unique situation survey respondents have found themselves in. Many reported feeling "anxious" and others suggested that they felt they had a high chance of getting infected by coronavirus themselves—a salient message considering that the survey was conducted in New York, one of the global epicenters of the disease. The authors indicate that they hope that their survey results offer a "foundation for researchers to conduct larger-scale energy studies by considering the opportunities to build transdisciplinary collaborations through integrated methods and matching datasets." This might include future work on cultural differences in social distancing, how energy burdens are framed and distributed, what constitutes healthy built-home environments, and other social-psychological factors including perceived fairness or social networking.

Marius Schwarz and colleagues (this volume [40]) offer additional insights regarding the impacts of the pandemic on research methodology that are perhaps obvious but nonetheless highlight important and perhaps persistent trends. They argue that Covid-19 is opening up new ways of doing research, of being an academic, of collecting data and attending conferences. They argue "The pace with which researchers adopted digital formats for conferences, lectures, and meetings showed that currently available tools can substitute many of the physical interactions at work. It also showed that academics are willing to use digital tools for scientific exchange." The pandemic has showcased that academics and those in higher education can quickly and

Table 3
The dialectic or dualistic impacts the Covid-19 pandemic can have on energy and climate sustainability and research.

	Positive intersections with sustainability	Negative intersections with sustainability
Energy and climate impacts of the virus	- Sharp reductions in travel related energy consumption and carbon emissions - Immediate reductions in electricity consumption - Depression of fossil fuel markets (particularly coal, oil and gas) - Immediate reductions in global air pollution - Redistribution of scarce energy resources in African nations to homes or national health care system - Acceleration of African stimulus packages for low-carbon transitions	- Disruption of clean energy jobs - Disruption of clean energy supply chains - Risk of real and substantial rebounds in consumption accelerated by stimulus and recovery packages - Disruption of off-grid energy markets and eroded progress on energy access programs
Implications for social practices and sustainability transitions	- Potentially bolstered trends in the electrification of private transport - Shifted financial and investment flows away from carbon intensive assets - Transformed social and professional practices in ways that are less energy intensive (e.g., working from home, walking, cycling)	- Undercutting of demand-side innovations such as ride-sharing or mobility-as-a-service - Dis-incentivizing mass-transit and public transport due to social distancing norms - Calling into question the increasing interconnectivity and globalization of socio-technical systems - Accelerating a geopolitical divide between the United States and other actors (e.g. China, World Health Organization)
Connections with energy justice an vulnerability	- Implementation of a variety of emergency protective measures including bans on disconnection and targeted assistance packages - Increased attention to the principles of a "Just Transition" and the need for stimulus packages to be low-carbon and equitable	- Overburdening of health care systems already dealing with the health impacts of fossil fuels - Compounding existing environmental injustices related to preexisting conditions and air quality - Undermining the provision of universal energy services and energy as a human right - Facilitating the exploitation of various energy policy or permitting processes
Insights for research practice and methodology	- Augmenting the ability to devise conceptual frameworks and heuristics that better incorporate pandemics as landscape shocks - Heightening academic appreciation for culturally appropriate communication - Increasing the familiarity of academics with digital modes of interaction	- Threatening external validity and the stability of research findings over time - Rapidly changing the demographics of sample populations and surveying techniques - Exposing academics to digital surveillance or cyber security issues through online formats

Source: Authors.

creatively change how they deliver lectures and are accessible to students; how they give guest seminars and discuss findings; even how they may interview for jobs, do research interviews, and host online workshops. They hope that "going digital" in many of these formats and contexts will continue, given the generally positive nature of the energy or carbon savings involved [41]. They further suggest that such digital modes of interaction could come to substitute for physical modes in how academics work in groups, hold team meetings, and socially network.

6. Conclusion

Situated at the nexus of the Covid-19 pandemic, energy systems, and climate change, this Special Section has revealed the complex, and often shifting, contours of how the disease is shaping global patterns of energy consumption, policymaking, and governance. It is altering the desirability of some emerging innovations and sustainability transitions, and heightening concerns over energy vulnerabilities and injustices. It is even challenging in fundamental ways how future energy and climate researchers go about their work. As Table 3 reveals, these intersections can be weighty and protean, but they are also perilous and precarious. For every noted positive intersection with some aspect of stainability or doing research, or benefit, we see an almost equally salient negative intersection, or risk. Take one of these examples: lowering demand for, and prices of, fossil fuels. Is this a blessing—-foretelling that fossil fuels are becoming unviable—or a curse—cementing fossil fuels as cheap and abundant sources of energy to be utilized for many years to come? Potently, it is the aspect of energy justice and vulnerability that particularly has more negative intersections (risks) than positive ones (benefits).

Covid-19, as various authors presented in this Special Section, represents a strategic opportunity to work in parallel on designing and implementing economic and social recovery programs and advancing the global climate agenda towards a just transition. What is also evident from the Special Section is the multi-scalar and multifaceted nature of social responses to the pandemic, which have created a "Christmas effect" or "Coronavirus effect" of:

- Instructing people how to immediately alter and change their routines and practices in response to a crisis (e.g., social distancing, wearing masks, quarantining, and handwashing);
- Bolstering the strength and resilience of infrastructure and institutions (e.g., of hospitals and medical research institutions);
- Building capacity to monitor and manage emergency measures (e.g., trace infections, test people);
- Properly financing social responses in ways commensurate to a grand challenge (e.g., donations to National Health Services or the World Health Organization);
- Restoring economic activity gradually and via approaches that are backed by science (e.g., mandatory lockdowns and partial reopening, deployment of government rescue and stimulus funds);
- Harnessing innovation and rapidly developing critical new technologies (e.g., new therapeutics and vaccines);
- Utilizing a variety of trusted institutions and individuals to convey information and messages (e.g., the CDC, major news outlets, doctors and medical professionals);
- While undertaking these steps, protecting the vulnerable (e.g., those with preexisting conditions, the unemployed and/or the indigent).

Although the impacts from the pandemic have so far been far from equitable or welcomed by the majority of people, this list of actions does offer a possible recipe for how future energy and climate planning could proceed as well, if policymakers and planners see the opportunity to transform social practices and institutions as much as the pandemic has. This could help achieve a "Christmas" or "Coronavirus" effect for energy and climate policy that encompasses:

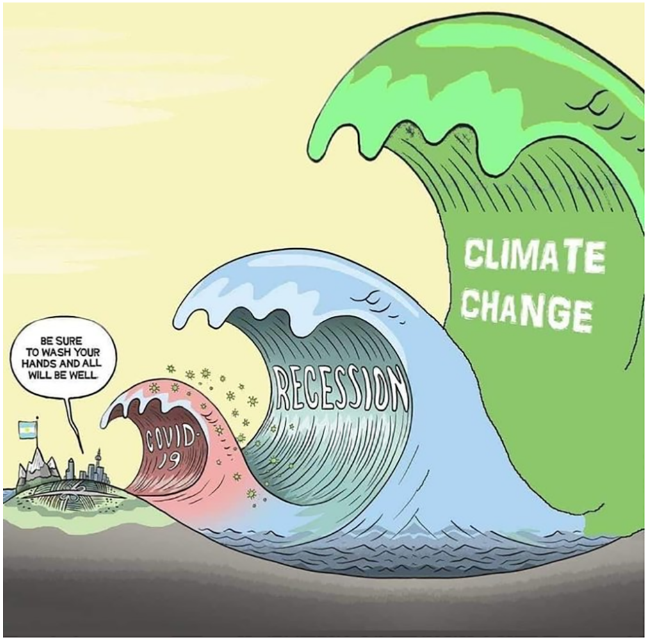

Fig. 7. The Covid-19 pandemic, global recession, and climate change.

- Instructing people how to immediately reduce their carbon footprints (e.g. using energy efficient technologies in their homes, eating less meat, avoiding air travel [42]);
- Bolstering infrastructure, institutions and industrial strategy (e.g.. incentives for clean energy manufacturing and deployment including wind turbines, solar panels, electric vehicles [43]);
- Building capacity to mitigate, monitor and manage emergency measures (e.g., tracking plans for universal energy access and SDG7, deployment of micro grids, bans on disconnection [44]);
- Properly financing social responses in ways commensurate to the challenge (e.g., substantially increase funding for national and multinational climate and development organizations or green investment banks, investment for deployment of low-carbon technologies and infrastructure [45,46]);
- Restoring economic activity gradually and via approaches that are backed by science (e.g., development pathways synchronized to the NDCs of the Paris Accord or the findings of the IPCC, investment of economic stimulus funds in low-carbon technologies, Green New Deals [47–49]);
- Harnessing innovation and the development of new technologies (e.g., the next generation of transport fuels, energy storage, smart grids or hydrogen fuel cells) [50–52];
- Utilizing trusted institutions and individuals to convey persistent and repeated information, messages and narratives in ways that resonate with audiences (e.g., major news outlets, the IPCC, governments, major corporations, churches, restaurants and celebrities sent persistently through various media channels) [53–56];
- While undertaking these steps, protecting the vulnerable (e.g., households in energy or mobility poverty, marginalized groups or indigenous peoples) [57–60].

If such actions were taken in concert, progress on energy and climate would likely outpace all previous targets and milestones, rather than remaining chronically underfunded, underperforming and continually lagging behind expectations.

Both of these core findings—that Covid-19 matches its promise of change with precariousness about the direction it goes, and that Covid-19 responses offer a possible template for future energy and climate action—remind us that we remain at a critical but fragile crossroads. As much as we see great progress in efforts toward ameliorating the Covid-19 crisis, we also see the same types of hindrances that have plagued progressive energy policy and climate action. Specifically, lack of attention to warnings about a potential crisis, delayed responses to building evidence of crisis onset, nationalism at the expense of the global good, politics overshadowing social welfare, marginalized populations (e.g., people of low socio-economic status, or people in low and middle income countries) experiencing adverse consequences at higher rates, conspiracy theories and fatigue of mitigation measures. As Fig. 7 both comically and tragically seeks to depict, climate change is akin to a perpetual pandemic, but one that multiplies threats in steeper and more severe ways than Covid-19 or its economic consequences. Markard and Rosenbloom have the right of it when they write that unlike the pandemic, "climate change, in particular, threatens the very basis for continued human prosperity and requires an equal, if not greater, societal mobilization" [61].

Hence, the opportunities emerging from the pandemic for energy systems and climate policy can be secured or squandered. Without careful guidance, governance and consideration, the brave new age wrought by Covid-19 could very well collapse in on itself with bloated stimulus packages, misaligned incentives, the embedding of unsustainable practices, and acute and troubling consequences for vulnerable groups.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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