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A New Dark Age? Truth, Trust, and Environmental Science

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Abstract

This review examines the alleged crisis of trust in environmental science and its impact on public opinion, policy decisions in the context of democratic governance, and the interaction between science and society. In an interdisciplinary manner, the review focuses on the following themes: the trustworthiness of environmental science, empirical studies on levels of trust and trust formation; social media, environmental science, and disinformation; trust in environmental governance and democracy; and co-production of knowledge and the production of trust in knowledge. The review explores both the normative issue of trustworthiness and empirical studies on how to build trust. The review does not provide any simple answers to whether trust in science is generally in decline or whether we are returning to a less

enlightened era in public life with decreased appreciation of knowledge and truth. The findings are more nuanced, showing signs of both distrust and trust in environmental science.

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1. INTRODUCTION

Public trust in science is crucial to a well-functioning democracy and good governance. Policymakers and citizens rely on the environmental sciences for accurate information on critical issues such as anthropogenic climate change, loss of biodiversity, and pollution. Given the unavoidable gap in knowledge and information that separates experts and the public, trust—understood in its epistemic sense of willingness to believe in, and to act on, the accuracy or truth of information provided (see Section 2)—becomes a social precondition of fruitful communication between environmental scientists, citizens, and their representatives. It is particularly concerning then that many now speak of a crisis of trust in science and the possibility that public trust in science is eroding (1–4).

However, evidence from opinion polls and attitudinal surveys on trust does not always support such alarmist views. For example, Ipsos MORI's Veracity Index suggested that trust in professors and scientists had increased, whereas trust in politics seemed to be in sharp decline (5). Ipsos MORI's Global Trustworthiness Index also assessed the general trustworthiness of scientists across 23 countries as one in a long list of professions, including doctors, teachers, news readers, and politicians. According to this index, scientists are perceived to be the most trustworthy professionals on the list, followed by doctors and teachers (6). The public also has a generally positive attitude toward the idea of scientists being involved in public policy and political debates (7). Yet, although trust in scientists is consistently found to be high across a range of comparative and national surveys, there is a common misperception that environmental science—and climate science in particular—is less trusted than other scientific disciplines. Although there is limited data to enable comparison across disciplines, survey data collected by PERITIA in 2022 finds that there is little difference in expressed generalized trust levels in scientists working with the government and trust in climate scientists working with the government to provide advice and information on climate change (B. Duffy, K. Hewlett & R. Benson, unpublished data) (**Figure 1**).

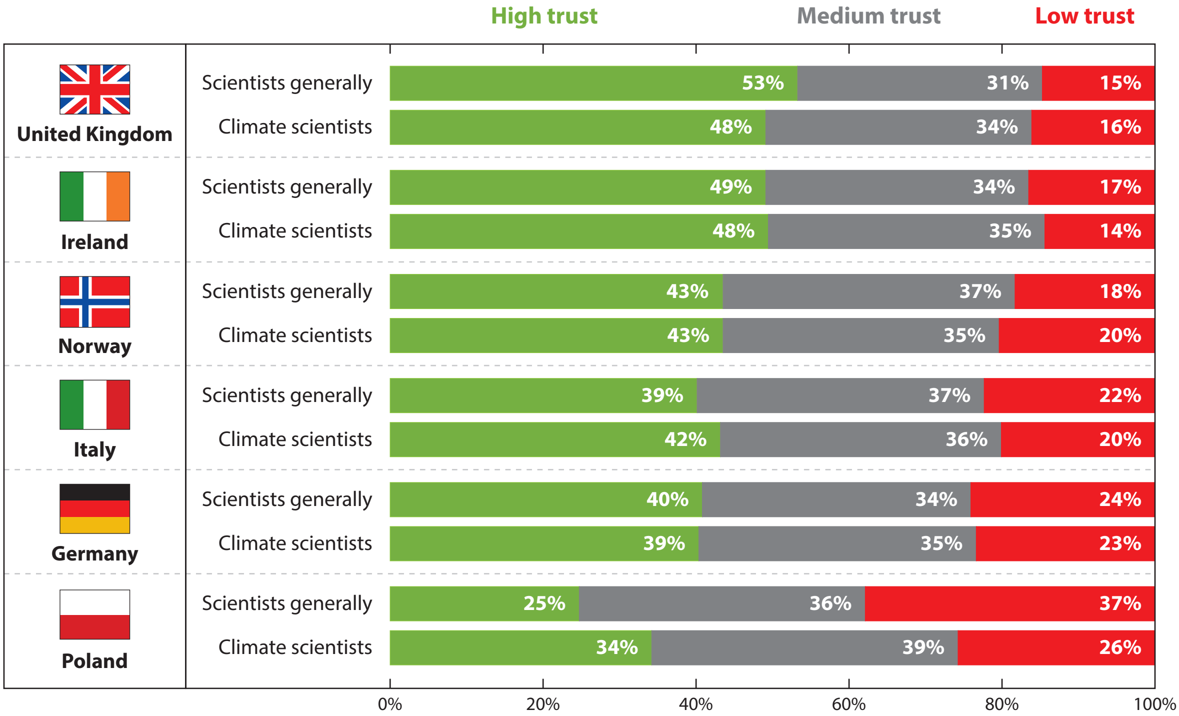

Figure 1

Trust in scientists and trust in climate scientists among European countries included in the forthcoming 2022 PERITIA survey (B. Duffy, K. Hewlett & R. Benson, unpublished data; see GESIS for updates: **https://www.gesis.org/en/services/finding-and-accessing-data/european-values-study/data-access**).

In fact, in comparative survey data, distrust in environmental scientists is far from a majority view. In 2021, 68% of survey respondents globally said that they would trust what scientists say about the environment, a great deal—a more than 10 percentage point increase from 2020 levels (8). However, the absence of long-term trend data makes it impossible to put this rise into historical context, but what is often interpreted as loss of trust in science is sometimes a reflection of quite different phenomena, such as legitimate questioning and critique of particular directions in technoscience (9). Although the hyperbole of new "crises" of trust may be ill-founded, the widespread incidence of scientific information being ignored or obscured through willful disinformation, the prevalence of conspiracy theories, doubt-mongering by commercial interests, and the rise of politicians in different parts of the world who appear hostile to established scientific expertise and knowledge deserve close attention.

Disinformation: misinformation, misleading information, or inaccurate information spread with the intention of deceiving or harming

In the case of environmental science, the problem of a lack of full trust in scientific advice has been exacerbated by widespread climate denial among public sectors and political leaders. As Oreskes & Conway (10) originally argued, much of the doubt and scepticism in environmental sciences—over issues such as climate change, acid rain, hazardous chemicals, and ozone depletion—is the result of a very deliberate strategy of conservative think tanks and corporations attempting to cast doubt on scientific consensus in the public sphere for the purpose of avoiding regulatory measures. Over the past few decades, there have been several controversies regarding the trustworthiness of climate scientists and the reports of the Intergovernmental Panel on Climate Change (IPCC), the foremost international scientific authority on climate change.

Conspiracy theories and disinformation spread far and wide and are amplified through online communication and social media (11, 12). Indeed, to decide whom to trust on environmental issues is often difficult in part because of a combination of characteristics that categorize environmental science as a post-normal or regulatory science (13, 14). Environmental controversies are typically characterized by uncertainties, ignorance, high stakes, and divergence of worldviews, such that informed people of goodwill can and do have different perspectives on the problems, potential solutions, and interpretations of the science (15).

Co-production: knowledge production embedded in wider political, social, cultural, and technical processes and collaborations between different actors

Epistemic trust: accepting and relying on the knowledge claims of others even when not in possession of complete evidence

The purpose of this review is to examine the alleged crisis of trust in environmental science and its impact on public opinion, policy decisions in the context of democratic governance, and the interaction between science and society. The topic under review raises a multitude of questions studied by a wide range of disciplines in the humanities and social sciences, resulting in numerous articles and books. We review significant contributions to the relevant literature, mainly from the past five years (2016–2021), but our analysis also, inevitably, touches on the historic dimension of the question of trust in science in general (e.g., 9, 10; see also Section 3). The main sections of this review focus on the following themes: the trustworthiness of environmental science, empirical studies on levels of trust and trust formation; social media, environmental science, and disinformation; trust in environmental governance and democracy; and co-production of knowledge and the production of trust in knowledge. Within the broader field of environmental science, we pay particular attention to climate science. Opinion surveys on trust often talk about scientists in general and do not look at the finer differences between the levels of trust in different areas of science or their institutional context. When examining the issue of trust and science, it is useful to distinguish between public trust in science and trust in the institutions that provide environmental knowledge assessments and mediate science-policy interactions (16). The review addresses both issues, as they are central to discussions of trust in climate science. It also links empirical discussions of trust to normative considerations of trustworthiness, i.e., to the question of when trust in climate science and in the institutions that connect science with policy is well placed.

2. THE TRUSTWORTHINESS OF ENVIRONMENTAL SCIENCE

It is often lamented that we are currently experiencing a crisis in public trust in science. However, trust can be misplaced. There are good reasons why expert claims should not automatically command trust or deference; for example, experts can and do get things wrong, they may be influenced by interests and biases, conscious or not (17, p. 277), they sometimes stretch their advice beyond their areas of expertise (18, p. 281), and they can get framings wrong, focusing on questions that are not of primary concern to others (9). Furthermore, environmental scientists need to make assumptions and judgments that may not always be transparent. Public distrust in experts is therefore only problematic when the experts are trustworthy (19). But what makes scientists trustworthy? This section reviews recent contributions from the philosophy of science and social epistemology about what makes public trust in science well-placed. At the end of this section, we focus on recent contributions to the issue of political ideologies and values in environmental science and how they can and should influence science's trustworthiness.

The variety of trust we are considering here is what philosophers call public epistemic trust (20). Epistemic trust entails accepting and relying on the knowledge claims of others even when we are not in possession of complete evidence. Thus, placing epistemic trust in science or any other knowledge provider is a reason to believe the information they produce and communicate (21). For instance, if the public has epistemic trust in the IPCC and other expert panels concerning environmental issues, they have reasons to believe what they say. For public trust in science to be well-placed, the public must have good reasons to believe that science provides truth and reliable knowledge (22) in the form of empirical claims backed by adequate evidence, laws, causal explanations, and predictions. Through extensive training, research experience, and critical engagement with their peers, scientists become "our designated experts for studying the world" (3, p. 59) and thereby worthy of our trust. Thus, environmental scientists have specialized knowledge in areas such as pollution, climate change, and natural resource management that makes them the authoritative experts in their respective fields.

To be trustworthy providers of knowledge, scientists not only should have a track record of reliable performance and requisite training, but they also must be responsible, honest, sincere, and committed to a set of widely endorsed public and democratic values (20, 23, 24). Trustworthiness is arguably also tied to the broader institutional and social contexts, in which scientists produce and disseminate their knowledge. Although the institutional aspects of trust in scientific expertise have not been a central focus in philosophy (for exceptions, see 1, 25), this has been more central in political science and science and technology studies (STS), which have focused on institutional independence and the separation of science and politics (see Section 6). The social aspects of scientific knowledge production and the way in which scientists collectively come to accept knowledge claims in an open and self-correcting manner are central to well-placed trust. Drawing on a body of thought emanating from social approaches to understanding science, Oreskes (3) argues that the main reason why we should trust science with providing us knowledge about the world is based on its social character (p. 56), such as science's institutionalized avenues for criticism, evaluation in conferences, peer review and hiring processes (p. 58).

The findings of environmental science—whether concerning the causes and effects of climate change, the toxicity of chemicals or the effects of air pollution on public health—are difficult to fully understand and evaluate by lay persons. This makes the public and policymakers dependent on the technical expertise of environmental scientists (26, p. 133). In the absence of detailed scientific information and the ability to evaluate the knowledge claims of experts directly, philosophers have underlined the importance of second-order judgments to identify the right experts, such as their track record, absence of conflicts of interest, and compliance with scientific consensus (3, 27).[1] This means that when deciding whom to trust in questions such as climate change, air pollution, or hazardous substances, the public should trust those experts and institutions that exhibit these traits.

When it comes to the trustworthiness of experts concerning climate change, their findings and dissemination have been challenged by well-established scientists from outside the climate sciences, often hired by conservative think tanks and fossil fuel corporations to use their scientific authority to challenge the findings of climate science (10). This points to the importance of viewing the trustworthiness of scientists not only as stemming from their general scientific credentials and affiliations but also from the *relevance* of their expertise to the issue at hand. Although criticism and skepticism are generally understood as central norms in the conduct of science, dissent in climate science, frequently coming from outside the discipline or research field, has often proven to be epistemically detrimental to scientific progress (28). Not to trust climate and other environmental scientists in their respective domains could amount to a lack of recognition of what has been referred to as the necessary "division of epistemic labor" in democratic societies (2, p. 21).

When lay people make judgments about which scientists they should trust, compliance with scientific consensus is a central criterion. Consensus can be interpreted as an indicator of trustworthiness because of science's openness to criticism (e.g., the practice of peer-review) and

[1]These second-order judgments are informed by direct and indirect assessments of trustworthiness based on social cues.

self-correction. The importance of consensus as an indicator of trustworthiness is underlined by the central role of group expert assessments in environmental policy, such as the IPCC, resulting in reports that aim to capture the current state of knowledge as the group of experts understands it (2; see Section 3 for empirical studies of consensus and trust formation). However, consensus has also been problematized as grounds for trust. Agreement among experts need not be an indication of truth, but rather group think and power, and it might set the bar too high for policy-relevant knowledge (29, p. 196). Moreover, focusing on a quantified consensus within climate science has proven to be insufficient for proper political application of science, which must also involve broader considerations of judgment, context, and attention to diversity (30). The notion that consensus is reliable only when there is almost unanimity among scientists might exacerbate the problems of doubt and distrust in climate science, according to Intemann: "It is precisely because there is a naïve perception that unanimity is required for consensus that instances of manufactured doubt are so effective" (29, p. 196). When it comes to public policy, it might be rational, at least in some cases, to adopt a policy even if there is a lack of agreement among scientists (29, p. 199).

The extent to which environmental scientists enable public understanding of the sciences is also central to trustworthiness. They must be able to communicate their knowledge in a way that is relevant and intelligible to their audiences, such as policymakers, citizens, and other stakeholders (31). In examining trust in climate change debates, Almassi (26) argues that trustworthiness not only involves conditions such as reliability, transparency, and the absence of ill-will, but also: "At its most trustworthy, expert scientific testimony is presented conscientiously: sincerely, . . . [and] with attention to fostering particular recipients' successful cognitive uptake" (p. 138). Almassi examines examples of climate science critics, such as Bjørn Lomborg and Patrick Michaels, who, in his view, have failed to perform their expert role conscientiously by exploiting the lack of knowledge in their audience (pp. 138–139). This underscores the idea that the trustworthiness of environmental scientists cannot be understood solely as a function of their scientific competency but also as an ability to communicate effectively and responsibly with different kinds of audiences.

Absence of conflict of interest is also often seen as a requirement for the trustworthiness of scientists. Conflicts of interest arise when there is a clash between the professional role of scientists in producing and communicating reliable knowledge and any vested interest that the scientists might have because of their funding sources, institutional or personal ties, or political agendas. Although researchers hired by the fossil fuel industry may well be trustworthy on several issues, they should not be viewed as authoritative on the issue of climate change due to their inherent conflicts of interest (3, p. 65). When scientists both have a conflict of interest and lack expertise in the relevant area of research, lay people should be particularly careful not to trust them. The combination of no publications of peer-reviewed articles in climate research and reliance on funding from the industry makes these putative experts "decidedly untrustworthy" (26, p. 141; quoted from 32). To meet some of the challenges raised by conflicts of interest, transparency and disclosure of interest are oft-mentioned antidotes.

The topic of trust in environmental sciences impinges on the notoriously controversial subject of how science relates to values and political ideologies and the normative question of whether environmental scientists should take political and ethical values or principles into consideration when disseminating their findings, in particular for practical uses. In the philosophical literature, values are dynamic ideals that can be "articulated and appealed to" (33, p. 196) to guide practices and determine goals, ultimately making these objectives "worthy of pursuit" (34, p. 11). This functional definition of values is echoed in Brown's (35) behavioral account, which understands values in our scientific activities as the "aims, objects, or ends that activity is directed towards" (pp. 101–102). Since much of environmental science is collaborative, we should expect a degree of value pluralism and so-called value perplexities (35) as a result of nontrivial differences in values among collaborators (36). These come from scientists' varying attitudes pertaining to values in science (37, 38), including their positions on the metaphysical, epistemological, and axiological dimensions of science (39).

Normative recommendations for how values should be incorporated into science and acknowledged are continuously being revised (40, 41). These recommendations, in large part, are a response to the value-free ideal of science, which remained the dominant conception of science until criticisms began to cast doubt on it starting in the second half of the twentieth century. The value-free ideal of science denies that non-epistemic motivations (e.g., personal, social, political values) should have a role in the evaluative phases of science. The ideal is grounded in the concern that non-epistemic motivations will harm science's integrity, open the way for conflicts of interest, and sooner or later undermine its predictive and descriptive accuracy.

The critics of the value-free ideal emphasize that in addition to playing a role in selecting methodologies, non-epistemic values are important when assessing the consequences of error and whether it is worse to claim something false to be true or fail to make a true claim (41, 42). There are inductive risks inherent to making scientific claims, given the gap between evidence and assertion. As there are always more tests that can be done, and since scientists can never be completely certain when asserting a claim, they always risk making false positive or false negative claims. By accepting or rejecting claims that can have foreseeable consequences for society, the critics of the value-free ideal claim that scientists have a moral as well as professional responsibility to consider non-epistemic values when setting evidential standards, especially in instances with high uncertainty and the possibility of significant social impact. However, the use of non-epistemic values can have consequences for levels of trust, if the public disagrees about which values are brought to bear and prioritized. For example, the decision to react to climate change is largely value-based, determining whether research resources will be put into preventative or mitigating solutions and how the evidence justifying these recommendations is assessed.

Climate scientists are only able to provide input on which climate targets to pursue if they are willing to stick their necks out and make more or less reasonable judgments beyond what they can be certain about (43). There is also the risk that suspending judgment—like when awaiting scientific consensus—can have significant ethical consequences and implications for public policy. However, in the face of uncertainty, particular outcomes might be more desirable based on a combination of reasonable value judgments and responsible moral considerations, in which case it might be advisable to adopt regulations even without consensus based on non-epistemic values. Given these uncertainties, transparency has been advocated as a means to encourage trust in science, for example, by being forthcoming about what defines permissible outcomes (34). Claims of uncertainty reflect and establish epistemological order, suggesting the need for particular research programs and policy approaches. According to Oppenheimer et al. (16), identifying, articulating, and characterizing uncertainty in qualitative and quantitative terms is a major focus of many environmental assessments (p. 220). Assessing uncertainty is a two-step process consisting of a review and critical judgment. The standards used to judge acceptable uncertainty are inherently value-laden and defined in relation to science, society, and policy.

In this section, we have seen how epistemic trustworthiness in science is tied to a wide set of epistemic, moral, and institutional factors. The difficult question is precisely which values should be used and when. Coming to socially acceptable decisions about values in environmental science will require models for public engagement with science that include possibilities for the public to contribute to science and to build a mutually informative relationship with science. Work on how dimensions of communication like transparency affect trust in environmental studies is ongoing (see 44, on sustainable fishing).

3. EMPIRICAL STUDIES ON LEVELS OF TRUST IN ENVIRONMENTAL SCIENCE AND ITS CAUSES

How is the trustworthiness of the work of environmental scientists actually perceived in practice? This section examines levels of trust and mistrust in environmental science and how these have changed over time; it also highlights a select group of factors that have been found to predict or foster trust or mistrust in environmental science. The picture that emerges reveals a gap between high trust in what environmental science says and much lower levels of action to achieve the targets that it sets.

In a recent study by the World Economic Forum, 68% of people globally said that they trust what scientists say about the environment either a great deal or a lot, with notable increases between 2019 and 2021 in Eastern Europe and Central Asia (27 percentage point increase), Western Europe (14 percentage point increase), and the Middle East and North Africa (12 percentage point increase) (8). However, despite seeing slight increases, levels of trust in environmental science remain comparatively lower in North America (58%) (8). This mirrors findings in national surveys conducted in the United States, where only a small majority have a mostly positive view of environmental research scientists: 57% (environmental health) and 60% (environmental researchers) (45).

Yet such questions that inquire directly and specifically about trust in the work of environmental scientists are rare. Although public attitudes and beliefs about environmental science have been captured in a range of quantitative and qualitative studies, much of the available data on public attitudes toward environmental science focuses specifically on climate change, with measures such as concern about climate change often being used as a proxy for public trust in the scientific evidence base. For example, a recent survey shows that climate change is a serious concern for a majority of the public in 20 countries around the world (46). Although there are substantial differences across nations, these figures stand out when compared to concerns about vaccines, genetically modified food, or artificial intelligence research.

However, recognition of climate change has historically fluctuated, as have the reasons for objecting to climate science. Public awareness of climate change first grew in many parts of the world from the 1980s to the early 1990s, remaining stable for almost a decade. It was not until the mid-to-late 2000s that declining concern and polarization of views began to set in, particularly in countries such as the United States and Australia, where the issue has been politicized (47, 48). However, the recognition of the existence of climate change has since recovered in most developed countries, including an uptick of attribution to anthropogenic factors from the late 2000s (47).

More recently, Hornsey & Fielding (49) find that outright denial about climate change is now only supported by a small minority (∼2–3%) of the population. Today, the focus of those who express doubts about the science is rarely placed on the existence of climate change but instead on its causes. For instance, even in the United States, where scepticism about climate change is unusually high, only 14% of the population denies the existence of climate change, while 30% attribute rising temperatures to natural rather than anthropogenic factors, putting them at odds with the scientific community, where anthropogenic causes are widely accepted (50).

One qualitative study conducted between 2017 and 2018 with self-identified climate sceptics in Idaho aimed to explore how doubts about climate science are rationalized. Researchers observed that sceptics did not display an outright denial of science but tended to focus on the inaccessibility of climate research to the general public, its methodological flaws, and the existence of coercive incentives, such as pressure to follow the consensus opinion in advancing one's career or being unduly influenced by funding sources. Nevertheless, this group of sceptics still exhibited qualified trust in scientists when it came to making policy decisions, so long as the policies were based on facts and not the opinion of vetted scientists (51).

Several factors predict levels of trust or mistrust toward environmental science. For example, trust in environmental science is highly correlated with general science education and curiosity. In the United States, Motta (52) finds that individuals who showed scientific interest, ability, and knowledge at a young age were consistently more likely to show greater trust in climate scientists as adults. Similarly, a variety of factors have also been associated with mistrust. For instance, in some countries, climate change scepticism or denialism has historically been correlated with conservative ideology—particularly in countries such as the United States, where environmental issues are drawn into polarized political contexts, resulting in attitudes and preferences for action becoming sorted by political identity (46, 53). Rejection of climate change evidence is also most pronounced among people with broad distrust of elite social institutions (54) and in countries with a high level of economic development and dependence on fossil resources (55), factors that further confound the role of political ideology.

Increasing support of environmental science and a strong understanding of the factors underlying trust and mistrust do not, however, solve the problem of translating concerns about environmental issues into action. Although several factors, such as trust in government and concern about climate change, predict how much individuals will support environmental policies (56), trust in environmental policies remains elusively lower than trust in the science underpinning or informing them, particularly when it comes to making personal investments or sacrifices (49, 57). For example, levels of trust in scientists are more strongly associated with a desire to see action on policies or technologies that address climate change (so-called public climate-friendly behaviors) than self-reported behaviors to reduce one's own carbon footprint or insure against environmental risk (58).

Various studies have found that solutions such as renewable energy installations or taxation of CO_2 emissions are often supported in principle but are met with a lukewarm reception or even active resistance in practice (59). In some cases, resistance may be well grounded—for example, when installations and associated infrastructures threaten habitats or important landscapes or are in other ways environmentally damaging. However, one aspect of the problem is translating climate beliefs into action. Proposing environmental solutions requires gaining the trust of the local communities involved, including by creating a meaningful and lasting connection with them (49, 60). Although most efforts in this direction have shown small and short-term effects, we report here three promising types of interventions: highlighting scientific consensus, strengthening citizens' voice, and adjusting communication to listeners' values (60, 61; see Section 2 on how consensus, effective and responsible communication, and values bear on the trustworthiness of science).

Strategies for communicating scientific consensus typically start from the premise that agreement among scientists on established facts, such as the anthropogenic origins of climate change, is often underestimated. The gateway belief model theory, for instance, suggests that presenting consensus data indirectly increases support for issues such as climate mitigation or the use of genetically modified organisms (GMOs) by reducing the perception of disagreement within the scientific community (62). Several studies have shown a causal connection between changes in perceived consensus and ensuing attitudes, even across different political views and levels of education (63, 64). Most importantly, effects of scientific consensus communication were measured to last for several months (65).

Community engagement is another promising approach to promoting trust. Selective or even absent communication is a known barrier in health campaigns (66) and also hinders environmental action (49, 67). Research suggests that activating community networks and promoting local discussions and initiatives, although not a panacea, foster public engagement. Deep canvassing door-to-door, for instance, is an approach originally used to reduce prejudice toward marginalized/out-groups by encouraging perspective taking and building a personal connection with members of such groups. Introducing people who have been directly affected by environmental disasters and successfully connecting with them in terms of values or identity could raise the salience of environmental risks and engender support for action (60). Word of mouth also drives community engagement: Discussion with like-minded groups has a considerably stronger impact than simple exposure to opinion messages from news sources (68).

Communication could also be framed to accommodate personal worldviews (61, 67, 69, 70). Indeed, even trustworthy communication risks falling on deaf ears if its tone clashes with the values of listeners. Identity representation strongly influences how individuals process information. In a recent experiment, participants who read a description accommodating their self-image identified with it even when forewarned of its arbitrariness (71). Identity-based messaging is also unlikely to backfire (72) in reducing the effectiveness of communication. There is, however, a lack of evidence on how long such framing effects last and how much they are affected by opposing framings (73).

These examples offer a snapshot of how empirical research can help to bridge the gap between concern and action, touching on the role of values in trustworthy science, as we discussed in Section 2. Engaging in meaningful conversations helps foster trust and motivates people to think deeply and lastingly about the implications of environmental conservation and pollution. Despite the enormous potential, however, this approach often requires considerable investment of time and resources. Thus, standard, one-size-fits-all procedures are often preferred (70). Current research on trust in environmental science also offers a narrow geographic perspective on specific countries and their particularities, predominantly focusing on evidence from anglophone and Western European countries, leaving little room for the study of other regions. For instance, as we saw, North America is exceptional in its lower levels of trust in climate science compared to the rest of the world (8), yet it seems to drive the global narrative about distrust and skepticism toward climate science.

There is also a lack of reliable long-term time series data on public attitudes toward environmental science. An overwhelming quantity of empirical evidence, particularly survey data, focuses on climate change, or environmental science in general terms, with little coverage of other environmental issues. Moreover, open access data sources rarely ask about trust in scientists—or rarer still, particular disciplines. Questions that capture attitudes toward environmental policies or concern about environmental issues such as climate change are therefore often operationalized in more indirect ways. It thus remains difficult to understand how perceptions of the trustworthiness of scientists, in particular, have changed and what role they may play in engaging with the public. The development of evidence-based science communication depends on greater institutional trust in investing in more empirically informed campaigns on the one hand, and on an expansion of the methodology and scope of research itself on the other. In summary, empirical evidence helps reveal the factors that explain mistrust of environmental science and how it is now evolving, but there is limited data to allow us to look back in time. Such research, furthermore, suggests that although levels of trust in science are high, the manifestation of mistrust in public behavior and preferences for action lie more in the implementation of environmental science in policy and points to some changes that can help reconnect with the public, such as greater public involvement.

4. SOCIAL MEDIA, ENVIRONMENTAL SCIENCE, AND DISINFORMATION

This section reviews literature on the role of social media in relation to science (dis)information about environmental issues, primarily from the field of communication science and media studies.

It suggests that social media have varied or even contradictory roles when it comes to shaping discussions around specific climate change–related phenomena, depending on local events, political contexts, and the situated emergence of climate issues. These complex roles include the spread of disinformation, which has been defined as misinformation (or misleading/inaccurate information) that is spread with the intention to deceive or harm (74–76). On social media in particular, the distinction between disinformation and misinformation becomes blurred as content circulates beyond its source context and intentions become even more difficult to determine (74); thus, we focus on both varieties of inaccurate information.

Climate science is an area of environmental science that attracts disinformation because, despite a large consensus among scientists, the public discourse around it remains contested. It is also an area that understandably receives a particularly high degree of scholarly attention. Although social media have been discussed in relation to science dissemination regarding a wider range of environmental issues such as water quality, biodiversity, and energy production (see, for instance, 77), topics such as climate change, GMOs, and vaccines are more frequently targeted for online disinformation and are therefore more frequent subjects of study compared to less controversial or more local issues in science. Although the phenomenon of climate change denialism precedes the emergence of social media, climate science has become one of the key issues around which not only misinformation but also concerted disinformation campaigns on social media circulate (11, 78). And although it has become more urgent to understand how social media platforms influence the spread of certain kinds of science disinformation, it is also important to understand social media's role in relation to a wider media landscape.

For instance, the phenomenon of fake news dovetails with social media's role in spreading science disinformation and also extends beyond the communicative space of social media platforms. Fake news has been defined as fabricated information that mimics news media content in form but not in how and why it is produced (79). Social media platforms have been shown to be key conduits for fake news sites (79), illustrating that particular social media content categories raise specific kinds of concerns regarding how they operate and affect users/audiences. Research has further shown that professional journalism's problem of creating false equivalences between scientifically authoritative information with contrarian viewpoints is exacerbated by the rise of new media (80). It is not only social media platforms but blogs and other websites that encourage lay participation in the production and circulation of information about climate issues, allowing more nonexperts to gain access to larger audiences. Such newer modes of communication and dissemination pose challenges to identifying trustworthy information by creating an information deluge that is "likely to overwhelm the traditional safeguards of professional editorial oversight" (80, p. 11). As recent scholarship points out, there is a significant gap in our understanding of how misleading information about climate change spreads online (74). Although the mechanisms by which disinformation spreads on social media platforms are important, it is also relevant for further investigation of what social media's influence on science communication implies for processes outside platforms. What might these changes mean for institutionalized science journalism? The question is particularly significant when both traditional and new media "seek to cover whatever can attract 'eyeballs'" (81, p. 42). Under these conditions, the disruptive effects of social media platforms on traditional standards for establishing what information can be trusted makes not only social media but also the wider media landscape more vulnerable to climate science disinformation.

However, social media platforms have not only been a vector for misleading information of various kinds about climate science, they have also afforded possibilities for climate activists, environmentalists, and publicly engaged scientists to spread up-to-date information about climate change in various contexts (82). Social media's role in shaping climate science communication has ranged from facilitating the effective sharing of public-facing content on climate scientists' professional blogs, to fostering alternative scientific networks, to affording both bi-partisan engagement and polarization through Twitter (83). Indeed, there are indications of a positive correlation between social media use and trust in science (84), as research on specific platforms has suggested that science communication on social media can achieve positive knowledge transfer outcomes (85). Furthermore, scholarship on the direct effects of social media usage on public knowledge about and opinion on climate change points to multiple impacts, including greater knowledge levels, the strengthening of already existing opinions, and disengagement due to alarmist tones rather than any single key effect (82). Acknowledging this multiplicity, some scholars have turned to an issue-based approach for investigating climate discussions on social media, following the observation that peaks in social media engagement take place around extreme weather events or policy interventions experienced locally by specific publics (82, 86).

The political contexts within which climate-related social media discussions take shape, with or without the involvement of climate experts, are an important factor for understanding the attempts to undermine scientific knowledge about climate. Research on climate science denialism suggests that lay audiences' pre-existing ideological leanings can more effectively explain tendencies toward denialism, skepticism, and conspiracy thinking than the audiences' discerning and critical engagement with scientific claims (87). Studies have also looked at the influence of national political contexts as a long-running factor in how social media is used to spread both local and international conspiracy narratives (88). The role of social media platforms is evidently not so much constitutive of conspiracy thinking or beliefs as it is a possible facilitator of the rapid spread of conspiracy ideas such as claims about so-called climate hoaxes (89). In addition to concerns about the spread of disinformation by various malevolent actors, we should also consider the influence of the overarching commercial interests that dominate participatory communication formats. Media scholars have long critiqued the celebration of online participation that masks the underlying profit motives of platforms (90, 91) or their techno-commercial logics and architecture (92). Such parameters in the political economy of platforms contribute to the commodification of information on social media (93), undermining epistemic authority and scientific trustworthiness, and to substituting the formal qualities of information in platform economies—e.g., virality and shareability—for its truth.

Simultaneously, calls for environmental scientists to be more active in public debates have increased in urgency, especially with the rise of what has been identified as politically motivated efforts to undermine science (94–96). This sets up a situation where climate science and lay audiences have much to gain from more in-depth communication, but the platforms they most readily use for such engagement are not neutral spaces, nor are traditional gatekeepers of science communication, such as science journalists, in the same position as they previously were. Indeed, "a considerable share of science communication by scholars, universities and research institutes, is performed via social media" (97, p. 7). As discussed, social media platforms have specific potential for science communication practice while platforms simultaneously present general problems of governance and oversight that pose new challenges for establishing the trustworthiness of information in a changing media landscape. The varied influence of social media on engagement with climate issues signals the need for a sophisticated range of regulatory and other responses to address phenomena such as science disinformation, denialism, and conspiratorial thinking. There is a growing tendency among scholars across the fields of science communication, psychology, and political economy to point out that the communication of a greater quantity of accurate science information about climate is an insufficient response to the kinds of politically motivated attacks on scientific knowledge characterized by post-truth politics (94, 96, 98). Recommendations for applied responses to contemporary science communication in social media contexts tend to focus on two broadly overlapping initiatives. One focuses on promoting discerning or "media literate" consumption of information or "inoculation" against disinformation (99), and the other on regulating tech corporations by proposing greater government oversight over platform companies by requiring content moderation in the form of (fact-checked) content flagging or making the sources of information funding more transparent to the users (100). Further investigations of effective science communication strategies that integrate attention for the social aspects of online communication are important, as there is some evidence to suggest that this influences public knowledge, opinion, and behavior positively (101). Such research can help address gaps in current knowledge about how social media, in particular, contribute to the creation of trusted knowledge communities.

5. TRUST IN ENVIRONMENTAL GOVERNANCE AND DEMOCRACY

It is a well-known insight from a broad set of social science research streams that trust in science depends also on trust in the political and administrative institutions that mediate between science and policy, the factors that shape and determine trust in such institutions, and their policies and decisions. Spurred by the contemporary rise of populism and the critique of environmental elites and technocracy, recent contributions within the fields of democratic theory, public policy, and administration have focused on the mediation between environmental science and policy. Discussions have tended to cluster around a set of broader overarching concepts. More specifically, this section focuses on how contributions increasingly highlight (*a*) administrative traditions, (*b*) accountability, (*c*) reputation, (*d*) deliberative democracy, and (*e*) the quality of government as determinants of trust in environmental policymaking and governance. Although this review concentrates on the topic of trust in environmental policy and science, it is important to note that the literature we survey frequently uses "trust" interchangeably with terms such as credibility and legitimacy.

An administrative tradition refers to "a historically based set of values, structures and relationships with other institutions that defines the nature of appropriate public administration" (102, p. 781). Studies have highlighted how different features of such traditions of appropriateness in public bureaucracy contribute to determining the shape, effectiveness, and legitimacy of environmental policy (see the review in 103). One lesson is that bureaucracies where civil servants see themselves primarily as strict interpreters of the law may hamper innovation in environmental governance compared to those where civil servants see themselves more as managers who translate policy into practice. However, legalistic conceptions may facilitate a more systematic and persistent implementation and thus contribute to cultivating the long-term credibility of environmental policy (103, pp. 888–889). Findings regarding the role of autonomous bureaucratic agencies, such as the European Environment Agency in the European Union or the Environmental Protection Agency in the United States, are mixed. On the one hand, independent environmental agencies may constitute a bulwark against undue pressure from social and market actors, including interest groups and industry. On the other hand, links and bonds to such actors may be central to both providing relevant knowledge and information and ensuring the legitimacy of environmental measures among stakeholders and in wider publics. Similarly, studies of uniform, top-down approaches versus pluralistic and experimentalist approaches to the making and implementation of environmental policy point in somewhat different directions. In some cases, in the area of climate policy, strict uniform enforcement may be needed for effective governmental action, but scope for diversity and flexibility toward local approaches may be more conducive to public support of environmental governance and innovation over time (102, pp. 780–784). Finally, different administrative traditions regarding the use of external scientific advice make a difference. The bureaucracy itself may possess considerable scientific competence, but environmental governance that draws on independent advisory bodies, such as panels or commissions of experts, tends to be regarded as particularly competent and trustworthy (103, pp. 889–890; 104, 105).

Accountability is a present-day symbol of good and responsible environmental governance. Actors—for example, politicians or civil servants—are held accountable when they are obliged to explain and justify their conduct to a forum, such as a bureaucratic body or a parliamentary committee, and this forum has authority to ask the actors for information and justifications and, when needed, to sanction actors' behavior (106). Generally, the institutionalization of effective accountability mechanisms is conceived of as a precondition for legitimate public policy and governance and the trustworthiness of expert bodies (107). Across policy areas, studies have also found a positive relationship between public accountability and levels of trust in government; moreover, conversely, they have identified that public and social trust facilitate the cultivation of robust accountability regimes (108). Similar patterns have been identified within environmental governance specifically, and the lack of workable accountability mechanisms and effective fora of control in parliaments and civil society have been recognized as significant obstacles to the development of better and more legitimate environmental policy (109, 110). Still, the institutionalization of accountability mechanisms is also known to give rise to new problems, which may decrease both effectiveness and trust. These include, for example, problems of "many hands" and "many eyes" and "forum drift," when a forum does not fulfil its obligations and fails to hold actors to account (106). Mechanistic "box-ticking" interpretations of accountability have also been criticized (111), and in the case of expert advisory bodies in environmental governance, tensions have been identified between (mechanistic) accountability and autonomy as well as between transparency and provision of space for deliberation (e.g., see 104, pp. 162–163).

Organizational reputation has become an important new perspective in the study of bureaucracy over the past decade. The successful cultivation of a strong reputation has been established as a decisive element of regulatory power and as key to a proper understanding of how public administration works (112). Public organizations, including agencies within environmental governance and risk regulation, increasingly engage in reputation management activities (113, 114). When it comes to environmental regulators, an important finding is how the performance of public organizations may be of primary significance for private actors, whereas procedural and moral aspects also weigh heavily in the eyes of stakeholders. Accordingly, to ensure "a positive organizational image" and necessary authority, the performance management turn among public agencies in this policy area may need to be supplemented by "an enhanced organizational attention to procedural and moral aspects" (114, p. 415). Another finding is how agencies involved in environmental and risk regulation try to shape levels of public trust by responding strategically to different "reputational threats," emphasizing variably in their role either as "guardians of the prevailing social values" or as reliable and professional expert bodies (113, p. 70).

Democratization of environmental science and policymaking is often emphasized as a key determinant of trust, and scholarly contributions have highlighted the need for participatory procedures, stakeholder inclusion, transparency, and local knowledge in climate and environmental governance (115). However, a particular branch of democratic theory, investigating and discussing the role of deliberative democracy, has recently argued that based on a range of studies from the domain of environmental policy and attitudes, democratic "deliberation"—inclusive processes of argumentation and not only inclusion and participation as such—matters for public support and trust in political institutions and procedures (116, 117). An important finding is how citizens who take part in cross-cutting discussions acquire stronger pro-environmental attitudes and are more trusting toward environmental public policy and green advocacy, irrespective of factors such as party affiliation and sociodemographic background (118). Another lesson is how deliberative approaches must be implemented across institutions and on a "system level"—"democratizing science," disregarding the deliberative features of the institutional environment, will not do (119–121). Simultaneously, deliberative mechanisms must be genuinely anchored in citizens' initiatives and will formation, so that public engagement is not reduced to top-down consultation and institutional management (104, 122).

Finally, the quality of government refers to the extent to which a government is free of corruption, civil servants are recruited in a meritocratic way, and public bodies and services treat citizens impartially. Large-*N* studies have found that the quality of governance by this definition is even more important for levels of social trust than democracy, a welfare state or rule of law (123). Studies have found similar patterns in the domain of environmental policy and governance. Povitkina (124) finds, for example, that the benefits of democracy for trust and climate change mitigation are limited in the presence of widespread corruption that lessens the capacity of democratic governments to reach climate targets and reduce CO_2 emissions, and increases both the likelihood and citizens' perception of failed policies and flawed outcomes. If corruption is high, democracies do not seem to do better than authoritarian regimes. Similarly, Kulin & Johansson Sevä (125) show that people who think that it is the government's responsibility to protect the environment are more likely to support increasing government spending on the environment in countries where government institutions are fair, effective, and noncorrupt (126). Recent findings from survey experiments indicate, moreover, that people find it more acceptable to delegate decision-making power to those they perceive as impartial experts in the area of environmental policy than in any other policy area.

6. CO-PRODUCTION OF KNOWLEDGE AND THE PRODUCTION OF TRUST IN ENVIRONMENTAL SCIENCE

Like the field of democratic theory, science and technology studies (STS) has been through a deliberative turn, adopting ideas about more participatory modes of knowledge production and governance (127, 128). The focus of STS, however, has been on how knowledge production is embedded in wider political, social, cultural, and technical processes, captured in the idiom of co-production (129). This provides a helpful conceptual framework for a discussion of "relationships between the ordering of *nature* through science and technology and the ordering of *society* through power and culture" (130, p. 14; emphasis in original). This idiom has particularly influenced the study of how environmental science and governance are shaped and reshaped by each other, exemplifying ways in which the natural and social orders are co-produced, but it has also been adopted by neighboring academic fields, such as public administration and sustainability science (131). Moreover, co-production has in itself shaped the practices of science as it has become the "gold standard" of participatory knowledge production (132), observed inter alia in the increasing emphasis on public engagement with science in science policy documents (133, 134).

This section introduces the role of trust in descriptive versus normative approaches to co-production (135) and shows how trust is interchangeably portrayed as a precondition for and an outcome of co-production. Lastly, we discuss critical contributions that question the promises of co-production in the context of the alleged "crisis of expertise" (136).

6.1. Trust in Descriptive Approaches to Co-Production

Building on the research of authors like Jasanoff (129) and Latour (137), descriptive approaches to co-production analyze how social orders and scientific representations of the natural world are mutually constitutive and how science and society are shaped and reshaped by each other through repeated interactions in contexts such as climate governance (135). In this context, trust in science is conditioned by the warrants of credibility within the prevailing social order, which signals the authority and trustworthiness of individuals and institutions (129). Warrants are accordingly not established a priori but are shaped through more or less intended processes of co-production, such as when experts present science in ways that meet the expected configurations between science and policy through strategies of "stage management" (104, 138–140).

Dominant warrants within the so-called normal or canonical view of science-society relations include (*a*) separation of the spheres of science and policy and (*b*) formalization of the methods for producing and summarizing knowledge for policy—signaling science as an objective and value-free enterprise (141) (see Section 2 on the philosophical discussions of the value-free ideal). Empirical studies of the construction of science–policy boundaries in environmental governance have, however, shown that by insisting on the separation of science and politics, science risks becoming vulnerable and disconnected from political realities and experiences of a changing environment (142–144). Any political influence is interpreted as compromising the credibility of science, leading to "flip-flopping" of science from being "pure" to becoming political (144, 145). The construction of apolitical and universal representations of the environment, such as global means in temperature scenarios (142) or integrated assessment modeling scenarios (146, 147), may also disguise the complexities of knowledge production and trigger contestation and distrust rather than meaningful understanding and acceptance among actors in pluralist settings. Uncertainty is an inherent feature of science, and transparency about the multiple dimensions of uncertainty in communication with the public has therefore been recommended as a strategy to nurture public trust in environmental science (148). Although the empirical research on the relationship between communicated uncertainty in science and trust has been described as limited (149), loss of trust is mainly found to be caused by the lack of consensus among scientists or within a body of research (150). Establishing and communicating consensus has therefore been a strategy within, e.g., the IPCC to build credibility (140). Conversely, the promotion of "alternative" experts has been used strategically to cast doubt on the credibility of climate science (10).

6.2. Trust in "Normative" Approaches to Co-Production

The deliberative turn in STS reflects the ambition to enhance the legitimacy of science by opening the practices of knowledge production to public participation (127, 128). Spurred by growing concerns about public distrust in science in general, and science–policy controversies and polarization around environmental issues in particular (151), co-production has been promoted as a means of nurturing public trust in science. By engaging with different ways of knowing nature and society, co-production is expected to (*a*) promote the procedural legitimacy of science through dialogue and inclusion of epistemically and socially diverse perspectives (127, 152) and (*b*) make knowledge more socially robust and responsive to societal needs by expanding its epistemic and social embeddedness (153). Hence, participatory practices have been expected to foster public trust in science based on both the legitimacy of the process of co-production and the robustness of its outcomes.

Although the rhetoric of co-production has been characterized by a conceptual vagueness regarding its definition, motivation, and implementation (131, 134, 154), the promise of public engagement with science has spurred a number of policy initiatives, including open science (155) and Responsible Science and Innovation (133, 156). Co-production has made progress as a strategy to foster interaction across science–societal boundaries in climate change arenas (132, 135), perhaps most visible in sustainability science, where co-production is framed as a normative commitment linked to the realization of sustainability transitions (131).

Although sharing a constructivist approach to the co-production of science and society with STS, co-production in the case of sustainability science is primarily a means to produce more usable knowledge. Furthermore, trust is mainly discussed as a feature of microrelations between researchers and users of science—both the general public and policymakers—and as a precondition for successful processes of co-production (157). Such relational trust may reduce information and processing costs in co-production, and building and managing trust between researchers and users of science has thereby evolved into a strategy, with empirical studies emphasizing transparency, independence toward stakeholders, the use of intermediaries and time and mutual respect as critical to the formation of trust in co-production (158, 159). Lacey et al. (158) argue, however, that too much trust at the science–policy interface may cause cognitive lock-in, favoritism, tolerance of less than optimal outcomes, and capture—referring to situations where users are "captured" by science or vice-versa—leading to the exclusion of differing views.

6.3. The Dark Side of Co-Production and the Crisis of Expertise

While demands for public engagement in science and co-production activities have been steadily increasing, its promises and merits have met growing scrutiny. Conceptually, the legitimacy of public participation is questioned due to a lack of clear standards for performing and evaluating deliberative encounters between the public and science (160). Unequal power relations among different publics or users of science and expertise and the inclination to downplay political, social, and economic differences may obstruct trustworthy and transformative practices of co-production (161). Co-production is moreover time consuming and costly, which may further influence the inclusiveness of the planned activities (132, 154).

Others (162, 163) point to how public participation has become a bureaucratic exercise introduced from above and with experts seeing the public as less knowing. Underlying this notion is the prevailing dominance of a linear model of the relationship between science and society. The empirical evidence of increased public trust in science due to public engagement is accordingly interpreted as mixed (164); there may be rhetorical support for public participation, yet it is also found that the public and stakeholders sustain a view of trustworthy science as being neutral and independent from political and societal interests (134, 164, 165). The rise of a post-truth era has accentuated this paradox and has accelerated attacks on environmental science as well as other contentious issues, such as vaccines; simultaneously, what should be seen as publicly accessible facts have fallen prey to appeals to emotions and personal belief. However, the era of post-truth is also accompanied by strengthened calls on objectivity and facts in search for truths that are disentangled from values (136, 166). This seemingly contradictory development has led Eyal (136) to argue that inclusion and more participatory procedures are not sufficient for restoring public trust in science and expertise. Rather, "the ability to bring reasoned debate to an end" (136, p. 145) and to draw a line between what scientists can answer and where public deliberation should begin is an essential precondition to the production of trust in science.

7. CONCLUSION

Our exploratory review does not provide a clear conclusion as to whether trust in science is generally in decline or whether we are returning to a less enlightened era in public life with decreased appreciation of knowledge and truth. The public's perceptions of science and science policy are more complex and nuanced. One important insight is that trustworthiness cannot be understood solely as a function of the scientists' expertise and ability. Not only must policymakers and citizens have good reasons to believe that science provides reliable information and advice, but scientists must also be responsible, honest, sincere, and committed to a set of widely endorsed public and democratic values. Empirical evidence shows how distrust in environmental science is linked to distrust in the institutions that implement this science in policies. One way to reconnect with the various societies affected by such policies is to involve them more actively as well as to make the connection between scientific findings and practical solutions clearer. We have also seen how social media have attracted disinformation and fake news about climate change. Yet, social media have also afforded possibilities for scientists and citizens to disseminate and share up-to-date information about climate change. A general insight from democratic theory and public policy and administration is that the more detailed organizational and cultural features of the institutions that mediate environmental science and policymaking matter for citizens' trust. There is thus a reason to move from general grievances of decreasing popular trust in environmental science to a more persistent focus on questions of institutional design in environmental governance. In this endeavor, it is important to consider the central role of bureaucratic institutions, how they work and what they look like, and the extent to which democratic procedures have deliberative qualities. On the basis of analyses of science and society as mutually constitutive, science and technology scholars have called for more participatory modes of knowledge production. Public engagement with science is expected to foster public trust in science, as it includes epistemically and socially diverse perspectives of knowledge production and generates more robust outcomes. The rise of the post-truth era has, however, exposed the need to redraw the boundary between science and the public, with a more settled role for arrangements for co-production and continued reflexivity about how credibility is established in the view of the public.

SUMMARY POINTS

1. The trustworthiness of science involves not only competence and reliability but also the broader institutional and social context, in which scientists produce and disseminate their findings.
2. Coming to socially acceptable decisions about values in environmental science will require models for public engagement with science that include possibilities for various publics to contribute to science and to build a mutually informative relationship with science.
3. Recognition of climate change has historically fluctuated, as have the reasons for objecting to climate science.
4. Empirical studies suggest that, although levels of trust in science are high, mistrust is manifested in the behaviors, choices, and preferences of publics regarding the implementation of science-based environmental policies.
5. Social media have attracted disinformation and fake news about climate change but also afforded possibilities for scientists and citizens to disseminate and share information.
6. Studies in democratic theory and public policy and administration suggest that organizational and cultural features of the institutions that mediate environmental science and policymaking matter for citizens' trust.
7. The rise of the post-truth era has exposed the need to rethink the relationship between science and publics, with calls for a more defined role for the co-production of science and continued participatory reflections on how credibility from the citizens', and not just the scientists', viewpoint is established.

FUTURE ISSUES

1. The discussion in the philosophy of science has mainly revolved around whether it is acceptable for scientists to make value judgments when communicating their findings

to policymakers and citizens. An important future issue concerns what kinds of ethical, political, and social value judgments environmental scientists should make.

2. More research is needed on the normative implications of building trust through greater accountability and better reputation.
3. We need more inquiries across the different research strands about how to handle possible goal conflicts—for example, between ensuring government quality through bureaucratic autonomy and meritocratic procedures and the need to democratize environmental policymaking.
4. To connect insights from different disciplines in the humanities and social sciences, the relationship and potential overlap between concepts such as trustworthiness, credibility, and legitimacy should be explored.
5. Current research on trust in environmental science offers a narrow geographic perspective on specific countries and their particularities, predominantly focusing on evidence from anglophone and Western European countries. More studies of other regions are needed.

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