Rethinking Science Literacy in the Face of Anthropogenic Climate Change: The Power of Productive Skepticism

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To my late father, Zbigniew.

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Introduction

Climate denialism is rampant within the United States. Widespread resistance to the findings of climate scientists and denial of the phenomenon of climate change are deeply troubling issues that threaten to undermine measures that human civilization needs to implement in order to adapt to a rapidly changing climate regime.[1] The leading scientific body on climate change, the Intergovernmental Panel on Climate Change, or IPCC, has published six comprehensive reports on the state of the scientific understanding of climate change since it was established in 1988 by the World Meteorological Program and United Nations Environmental Programme.[2] In the IPCC's latest assessment, published in 2021, they state that, "climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes."[3] They add that, "Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia."[4] These foreboding assessments of the current state of the Earth's climate stand in stark contrast to perspectives of climate deniers and so-called "skeptics" who believe that anthropogenic climate change is either not occurring, not influenced by humanity, or is not as urgent of an issue as the global community of climate scientists have indicated in their research and public advocacy.

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[1] See Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime*, trans. Catherine Porter (Malden, MA: Polity Press, 2017), 3. Latour explains that the use of the term "New Climatic Regime" describes how "the physical framework that the Moderns had taken for granted, the ground on which their history had always been played out, has become unstable" (Latour, 3). He emphasizes that the use of regime is meant to indicate human governance over the Earth's climate, wherein CO_2 emissions present a distinctly different type of pollution of the atmosphere that is not easily mitigated.

[2] IPCC, "Intergovernmental Panel on Climate Change," History of the IPCC, 2022, https://www.ipcc.ch/about/history/.

[3] IPCC, "Summary for Policymakers: Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," *Intergovernmental Panel on Climate Change (IPCC),* (August 2021): 10.

[4] Ibid, 20.

Climate deniers occupy some of the highest levels of the government and industry, where their views are broadcast to wider audiences who integrate their theories into the public perception of climate change, the central driver of which identified by the IPCC is anthropogenic global warming.[5] Senator Ted Cruz of Texas openly stated in 2015, "According to the satellite data, there has been no significant global warming for the past 18 years. Those are the data. The global warming alarmists don't like these data - they are inconvenient to their narrative. But facts and evidence matter."[6] Fellow Senator James Inhofe of Oklahoma has repeatedly cast doubt on the factual basis of anthropogenic climate change, stating that

> It's…important to question whether global warming, assuming it's occurring or going to occur, is even a problem for human existence. Thus far no one has seriously demonstrated any scientific proof that increased global temperatures would lead to the catastrophes predicted by alarmists. In fact, it appears that just the opposite is true: that increases in global temperatures may have a beneficial effect on how we live our lives.[7]

Both statements by these members of Congress who wield some of the greatest political power in the United States promote the idea that climate change science is overtly skewed by alarmist narratives which seek to upend an American way of life that is defined by and attributed to the unfettered use of fossil fuels. Given these strong statements made against prevailing scientific consensus around climate change, I am concerned with how non-scientists within the American populace interpret scientific information about climate change and engage with climate science.

The term "science literacy" is often utilized to describe the extent of the knowledge or awareness about science possessed by an individual who is not explicitly involved in

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[5] IPCC, "Technical Summary: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," *Intergovernmental Panel on Climate Change (IPCC)*, (August 2021): 14. The IPCC defines global warming as "the change of global surface temperature relative to a baseline depending upon the application. Specific global warming levels, such as 1.5°C, 2°C, 3°C or 4°C, are defined as changes in global surface temperature relative to the years 1850–1900 as the baseline (the earliest period of reliable observations with sufficient geographic coverage)."

[6] "Sen. Cruz Confronts The Dogma of Climate Change Alarmism," Press Release, December 8, 2015.

[7] James Inhofe, "The Facts and Science of Climate Change," 2005, 2.

professional scientific research. The National Academy of the Sciences (NAS) explains that science literacy is well encapsulated by three critical aspects:

> (1) the understanding of scientific practices (e.g., formulation and testing of hypotheses, probability/risk, causation versus correlation); (2) content knowledge (e.g., knowledge of basic facts, concepts, and vocabulary); and (3) understanding of science as a social process (e.g., the criteria for the assignment of expertise, the role of peer review, the accumulation of accepted findings, the existence of venues for discussion and critique, and the nature of funding and conflicts of interest).[8]

The general public's understanding of anthropogenic climate change is not limited only because of deficits in the second aspect, that of content knowledge, which is often identified in political debates as being the most important area of science education that addresses a basic overview of the scientific explanation for climate change. In general, when climate change science, and other scientific phenomena with significant social and economic implications, such as human health, i.e. vaccine science, is discussed, the broader definition of science literacy put forward by NAS is not used to describe what it means to be "scientifically literate." Senator Cruz and Inhofe's claims showcase a limited understanding of what constitutes science literacy by their use of broad statements about what scientific "evidence and facts" or "proof" mean without ever directly addressing the processes used by scientists to establish scientific knowledge and how research is vetted and scrutinized by different scientific communities in order to evaluate the epistemic strength of claims made by researchers. The IPCC's findings demonstrate the immediate urgency of climate change, driven by anthropogenic global warming, and the threat that it poses to human civilization, but American society is still embroiled with questions of how and why people should trust the scientific determinations made about the phenomenon.

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[8] National Academies of Sciences, *Science Literacy: Concepts, Contexts, and Consequences*, (Washington, DC: National Academies Press, 2016), S-2.

In this project, I analyze how the propagation of doubt and skepticism around the scientific explanations of the causes, projected impacts, and even the very existence of anthropogenic climate change has taken shape within the United States. The focus of this project is on how efforts to improve science literacy via expanding content knowledge within the general public of the United States are necessary but not sufficient in communicating and articulating the urgency of climate change to individuals who embrace denialist or skeptical rebuttals to the scientific arguments which illustrate that climate change is in fact occurring and that is driven by human activities.

In scientific investigations, researchers are devoted to the task of gathering empirical data which subsequently rejects or fails to reject the null, or negatively constructed, hypothesis which they have put forward in pursuit of answering a singular, narrow question that barely scratches the surface, so to speak, of the full scope of a given topic like climate change. If a researcher is evaluating an issue such as underreported methane emissions from a given geographical area in order to improve the collective understanding of the magnitude of greenhouse gas emissions (GHGes) and how quickly GHGes are being produced, there are several barriers that prevent a nonscientist from understanding the technical components of the analysis, reasoning, and methodology that the researchers in this case are employing. It is a daunting task for individuals who do not regularly engage with scientific literature to accurately distill scientific information that is built upon vast structures of understanding within the physical sciences, such as geology, chemistry and atmospheric science, areas that are distinctly out of intellectual reach for people who do not belong to a scientific community or have not received any scientific training. Thus, in order for this information to be made accessible to and maintain its explanatory power within the general public, it has to be translated or reframed into terms that are easily understood.

The implications of the findings of scientific literature need to be communicated in a manner that actively engages the public in the conversation around this topic to the extent that said findings gain currency in decision making processes. Science communicators also need to be mindful of how scientific knowledge production is represented in public discourse. In order to effectively engage with a phenomenon like climate change, we must acknowledge that the findings of an individual researcher who studies different elements of this global issue, such as paleoclimatology or oceanology, do not represent the totality or definitive source of truth about this phenomenon. Instead, the American public must understand that scientific knowledge about anthropogenic climate change embodies the cumulative efforts of individuals across space and time who have sought to deepen our collective understanding of this issue, where no single voice in the Earth science community claiming to know the absolute truth about climate change takes precedence or is privileged over another.

This basic overview of the scientific process gives rise to the question: What does it mean for someone to be skeptical of climate science? In order to address this question in its entirety, it is necessary to provide a working definition of what skepticism is and how to identify different forms of skepticism.

Philosophical skepticism hinges on the idea that we do not know, with certainty, things that we generally claim to know to be trivially true, i.e. the sun rising in the morning or the existence of the external world.[9] This type of skepticism is not consistent with the claims of

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[9] Sven Ove Hansson, "Science and Pseudo-Science," In *The Stanford Encyclopedia of Philosophy*, (Stanford University: Stanford, 2021) https://plato.stanford.edu/archives/fall2021/entries/pseudo-science/.

climate "skeptics" who challenge the scientific claims about the causes or implications of anthropogenic climate change. A philosophical skepticism that argues against the proposed phenomena of climate change would not be appropriate to begin with, given that climate change in itself is not as visceral of an experience, at least in terms of understanding its mechanistic explanation, as seeing the sun rise every morning. Our ability to know that the sun will rise is ultimately given up to maintaining the belief that it will.

So-called "climate skeptics" are not necessarily arguing in favor of obtaining more evidence to substantiate the claims that anthropogenic climate change is indeed happening. Thus, a better-suited term to describe the position of individuals who argue that anthropogenic climate change is not occurring is "climate denialism." Denial of the phenomenon of anthropogenic climate change presupposes the rejection of the empirically supported propositions made by the vast majority of climate scientists and does not acknowledge the epistemic dimensions of the scientific consensus around this issue. Climate deniers emphasize that the scientific evidence and reasoning that strongly suggests that anthropogenic climate change exists and is exigent is not consistent with the reality of climatic conditions on Earth presently or in the future. Thus, common usages of "climate skepticism" is not consistent with a more accurate definition of skepticism.

A climate denier is poised to reject, on epistemic grounds, climate science in its entirety, as opposed to addressing specific qualms that they may have with how the empirical evidence gathered is applied to the theories within climate science. This is fundamentally a denial of the validity or relevance of the empirical evidence and the methods that are employed within climate science to establish a comprehensive, physical understanding of anthropogenic climate change.

More generally, overt science denialism occupies its own realm of belief systems where adherents to said beliefs tend to deny scientific claims made about environmental issues, such as acid rain, ozone depletion, and the link between atmospheric CO_2 concentrations and climate change solely on the basis of alternative theories that are substantiated by little to no empirical evidence.[10] Scholars Haydn Washington and John Cook illustrate that science denialism is ultimately at odds with the goals of science. While they acknowledge that the scientific process is flawed and does not guarantee absolute truth, they write,

> …at least science *tries* to be objective, tries to seek the truth, and has a philosophy of challenging its biases and beliefs, not adhering to blind faith or blind denial. Denial does not do this, it is about refusal to believe the truth. Sometimes science may be slow to accept something that challenges the prejudices of key luminaries in that field, but eventually it moves past denial to accept the new evidence. Those in denial do not.[11]

Science denialism does not necessarily stem from the idea that we cannot know the truth about certain phenomena, but rather that people who deny science would rather put forward their own theories based on their personal understanding of how the physical world works, rather than deferring to the systems of scientific understanding which structure and provide a durable basis for the claims made within the scientific community.

In contrast, a climate "skeptic" is someone who questions the arguments put forward within the framework of climate science with the goal of wanting to make the claims of climate scientists more robust. An examination of skepticism as an epistemic position from the

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[10] Washington and Cook discuss the social dimensions of science denialism extensively in their book *Climate Change Denial: Heads in the Sand*, (New York: Routledge, 2011), particularly in the chapter, "Denial and the Nature of Science." They explicate the commonly shared beliefs of individuals who deny the existence or validity of different scientific phenomena and describe the arguments employed by science denialists to rebuke scientific claims. A central claim of their argument about climate denialism is that "It is…important to realize that today's denial about climate change follows on from a long trend in denial about the environmental crisis (Washington and Cook, 72)."
See Naomi Oreskes and Erik Conway. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. (New York: Bloomsbury Press, 2010). Naomi Oreskes and Erik Conway identify the central actors involved in campaigns to challenge the validity of scientific research that assesses the environmental, atmospheric, and ecological impact of anthropogenic activities.

[11] Washington and Cook, *Climate Change Denial*, 10.

perspective of ancient philosophy is apt if we consider how scientists, or any individual for that matter, actually use evidence from observations and experience to make claims about complex physical phenomena. Challenging the epistemic strength of the claims made by climate scientists involves understanding on what rational basis these claims are made.[12]

The ancient school of thought known as *academic skepticism* advised an investigator to challenge claims by examining the existing beliefs of the claimant. This skeptical outlook was adopted to improve not only an individual understanding of a given phenomenon but also to address the gaps in collective knowledge about said phenomenon. Arcesilaus (316/5–241/0 BCE) articulated that an investigation of a question should be guided by the dialectical method, in which one questions someone with a dogmatic stance on a given issue in order to determine the beliefs of the dogmatist who purports to know the truth, but cannot unequivocally prove that their beliefs are consistent with reality.[13] The notion of specifying a criterion of truth is relevant to distinguishing between skepticism and denialism in that to maintain a skeptical position does not entail an automatic refusal to accept a claim.

The evolution of *academic* skepticism leads to Cicero's view of skepticism, which pushes the idea of a criterion of truth further by proposing that there are "notions of what is probable (*probabile*) or likely to be true (*veri simile*)" where the aim of an investigation of a particular claim is to identify a position on an issue which "is [the] most rationally defensible."[14] Additionally, Cicero also proposes that "it is better for us to adopt a view that is likely to be true,

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[12] Katja Vogt, "Ancient Skepticism," *The Stanford Encyclopedia of Philosophy*, (Stanford: Stanford University, 2021), 3.1.
[13] Vogt, "Ancient Skepticism," 3.1
[14] Ibid, 3.3.

rather than remain unconvinced by either side."[15] Cicero's view of skepticism explicitly shows that skepticism should be in service to producing knowledge about a given matter. Thus, the production of knowledge is informed by a notion of what is *likely*, but not absolutely certain, to be true given certain observations. I propose that a modern understanding of *academic* skepticism could be referred to as *productive* skepticism, in that it promotes a progression of thought towards a truer understanding of a given phenomenon.

In contrast to *academic* skepticism, Pyrrohnian skepticism holds that it is unproductive to think that one can form beliefs based on external impressions or observations. This school derives from the philosophy of Pyrrho (365/60–275/70 BC), who held that things we perceive "are indifferentiable and unmeasurable and undecidable, because we fail in differentiating, measuring, and determining how they are."[16] These flaws in our ability to trust what we perceive subsequently suggests "that our perceptions and beliefs are neither true nor false. They are not truth-evaluable, presumably because there are no facts which could be correctly captured."[17] This is not to say that there is no truth, but rather that a notion of truth is untenable for humans, given the limitations of our senses in capturing the reality of the physical world. Thus, I argue that someone who holds a Pyrrhonian outlook is practicing what I define as *entrenched* skepticism, in that this philosophy is rooted in rigid guiding principles which actively encourages one to maintain a state of nonbelief in all of their investigations.

While I propose that modern instantiations of *academic* skepticism are "productive" in the sense that this epistemic method favors presenting a clearer picture of a given phenomenon,

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[15] Ibid.
[16] Ibid, 4.1.
[17] Vogt, 4.1.

both *productive* and *entrenched* skepticism offer stimulating and efficacious counterpoints to dogmatic interlocutors who maintain a defensive position on and unyielding commitment to positive claims.

Using the distinctions between productive and entrenched skepticism, we can characterize each in the context of our discussion around scientific literacy, specifically with regard to the perception of climate change in the American public. A productive skepticism endorses the idea that an epistemic position, when challenged using a dialectical method of questioning, is not without flaws and is almost always backed by some system of beliefs. Examining these beliefs entails reaching ever greater levels of acuity in a line of questioning about how certain beliefs have been shaped and formed over time. However, what I refer to as productive skepticism does not mean that the investigator is committed against the formation of any beliefs, as one would be if they practiced entrenched skepticism.

In the context of the contemporary debates and discussions around anthropogenic climate change, I propose that a commitment to productive skepticism does not necessarily mean that someone who seeks to address points of contention around this global climatic phenomenon, such as how human activities are contributing to increases in the atmospheric GHGs concentrations and how global warming is attributed to these increases, is opposed to accepting any of the conclusions put forward by climate scientists. Thus, practicing a productive type of skepticism helps to address knowledge gaps and works towards the goal of developing a more comprehensive understanding of climate change whilst acknowledging that disagreement over scientific conclusions is largely rooted in how one views the implications of scientific evidence, and subsequent reasoning, that is presented. In the context of a broad social response to the scientific explanations and warnings about anthropogenic climate change, an entrenched skeptic holds that the evidence and reasoning presented by leading scientific bodies does not sufficiently show that anthropogenic climate change is as urgent of an issue as scientific bodies like the IPCC have indicated.

If someone's entrenched skepticism calcifies to become steadfast denialism, then previous attempts at science communication to improve science literacy which are focused on providing the mechanistic or technical explanations of anthropogenic climate change would be counterproductive to the goal of getting climate change deniers to recognize the significance and far-reaching implications of anthropogenic climate change. Instead, science communicators should work towards cultivating a science literacy amongst non-scientists in the general public which addresses misunderstandings about the process of science and illustrates the importance of how science is a social process, both aspects identified in NAS's definition of science literacy.

Additionally, explaining complex scientific ideas requires distilling information down into accessible and easily reproduced frameworks, because otherwise the pursuit of science communication is not an effective means of communicating vital scientific knowledge to the public. Generally what we have to recognize is that even though an individual might not have the technical ability to understand how something works, like vaccines or satellites that take Earth surface temperature data, that does not necessarily prevent them from trusting and utilizing said items in their everyday lives. Ergo, I want to emphasize the significance of our individual belief systems and their role in influencing our willingness to trust experts in different fields who are utilizing scientific principles that non-scientists may never come to fully understand.

In order to show that while improving scientific literacy is necessary, but not sufficient, in creating an informed populace and rooting out denialism, I will examine historical examples of when science and technology posed a threat to human existence, and thus ultimately ignited a public debate over the consequences of using scientific knowledge untethered to an articulated ethics. The development of nuclear weapons in the U.S therefore serves a useful lens through which we can examine our contemporary moment when our struggle to fully recognize the predicted consequences of anthropogenic climate change is reaching a fever pitch. While most of the history of the United States' development of nuclear weapons and technology is characterized by the secrecy that surrounded these programs, the information that is available now about nuclear weapons development, and the thoughts and opinions of the scientists who participated in programs like the Manhattan Project, speaks towards how this revolution in human understanding of atomic energy fundamentally changed the manner in which humanity in general viewed the intersection between science and technology. I will show how the Manhattan Project began a new era of public concern over how science was used either for weapons development or in everyday life.

In my first chapter of this project, I make the argument that simply expanding the content knowledge of the American public on science is not sufficient in addressing and communicating the urgency of anthropogenic climate change and the threat that it poses to human society in the contemporary moment. I illustrate this by analogizing the Manhattan Project, the catalyst of the development of nuclear weapons and a massive advancement in technology that posed an acute existential threat to humanity, and the subsequent proliferation of more destructive nuclear warheads to the phenomenon of climate change. Through this analogy, I argue that scientific issues of significant social import catalyze and demand the need for public awareness. Explicit in the goal of raising public awareness about these issues is improving scientific literacy. Using the NAS definition of scientific literacy, I find that the motivations behind science denialism or entrenched skepticism that propagate around contentious scientific issues, such as nuclear weapons and anthropogenic climate change, are largely attributed to a lack of attention paid to aspects one and three of the NAS definition.

In the second chapter, I analyze the meaning and objectives of scientific investigation in the context of anthropogenic climate change in conjunction with the prevailing arguments put forward by entrenched skeptics and climate change deniers. By problematizing the widely shared feeling amongst entrenched skeptics and climate change deniers that personal affiliations and beliefs unequivocally undermine scientific integrity, I illuminate the social character of scientific knowledge using philosopher of science Helen Longino's analysis of the values and principles held within scientific communities. This will show how using a primarily technical explanation of scientific concepts to advocate for the urgency of climate change is limited by the fact that a person who is not engaged with a scientific community may expect unreasonably high standards of proof for justifying scientific claims or may not understand how to evaluate the epistemic strength of scientific conclusions. Scientific research and the scientific process are not accurately represented by mass media outlets, which often report on individual studies or focus on specific scientific institutions without acknowledging that science is inherently a community-driven process with a shared values system that regulates and scrutinizes the veracity of knowledge claims made within scientific literature.

In conclusion, I will discuss how having an operational understanding of anthropogenic climate change and the research which is done to evaluate this issue is not easily communicated to an array of people within American society with widely different educational backgrounds. I emphasize the need for a more holistic approach towards science literacy which communicates the significance of scientific practices and that science is a social process. I propose that through a reevaluation of the relationship between technology and the scientific principles that inform features of our everyday lives has the potential to demonstrate how humanity has developed strong explanatory frameworks to be able to interact with and, in some sense, create our own physical world. In order to reconcile humanity's operable and extensive understanding of the physical sciences with the deleterious consequences of the technologies that have been developed using this knowledge, we must acknowledge the inherent power that humans possess to fundamentally alter the natural world.

Chapter 1: A Testament to Human Power

This chapter will argue that efforts to expand the American public's content knowledge of science are not sufficient in communicating the urgency of anthropogenic climate change. To help illustrate this, I consider the historical moment of post-World War II America in which science literacy was broadly promoted by educators and academics who believed that the advent of nuclear weapons and the development of nuclear technology "marked a dramatic change in the interrelationship between scientists and public affairs."[18] The conversation around modern initiatives for science literacy for non-scientists following World War II were stimulated by the emergence of nuclear weapons and when humanity entered a rapidly changing era of technology used in warfare and civilian life. The United States played a significant role in initiating this transition by virtue of the massive military-industrial Manhattan Project, which centered on applying the revelations made in quantum mechanics in the 1930s.[19] The Manhattan Project and the subsequent development of more destructive nuclear warheads in the Cold War period offers a unique parallel to the contemporary moment in which human civilization faces the existential threat of anthropogenic climate change.

Both phenomena, which operate on vastly different timescales, point towards the intersection of science and technology in public life. I propose that educating the American public about the scientific concepts which structure nuclear science and anthropogenic climate change is necessary to address the consequential nature of both of these issues, but is not

[18] Norriss Hetherington, "The History of Science and the Teaching of Science Literacy," In *Journal of Thought*, (Caddo Gap Press: 1982), http://www.jstor.org/stable/42588968, 57.
[19] Richard Rhodes, *The Making of the Atomic Bomb*. (New York: Simon & Schuster, 2012), 695-703.

sufficient in convincing people of the overwhelming need to approach either issue with the type of care and thoughtfulness that both, essentially ecological issues demand. In order to illustrate to those who doubt the severe implications of either phenomenon, whether they are entrenched skeptics or science denialists, I argue that it is necessary for the social process of and methodologies employed in scientific research to be explained in science communication to the American public in order to build trust between scientific communities and non-scientists.

The power of analyzing the threat of nuclear weapons and climate change stems from the fact that the massive societal implications of both phenomena demand a public response. The epistemic aspect of understanding the sheer power of nuclear weapons and the threat they pose to human civilization is on par with the destructiveness and destabilizing nature of anthropogenic climate change, as the IPCC's latest assessments make abundantly clear. One might argue that the two examples are disanalogous in ways that would invalidate their being compared at all, particularly because nuclear weapons are designed with the goal of destruction in mind, while climate change is a mere consequence of combusting fossil fuels and increasing the concentration of carbon in the atmosphere.

This counterargument, however, overlooks how climate change and nuclear weapons represent areas where scientific discovery and progress are defined by a distinct ethical component. This is particularly evident if we consider the opinions and perspectives of scientists engaged in these areas of research which have immense consequences for human society. One of the primary architects of the first atomic weapon, J. Robert Oppenheimer, was aware that he would be regarded by some as a gifted theoretician who had helped to realize what was considered to be impossible: the weaponization of atomic energy. He was also aware that he would likely be regarded by others as "the man who led the work of bringing to mankind for the first time in its history the means of its own destruction."[20] Oppenheimer was introspective about the existential questions that were raised by humanity's harnessing of the destructive power of nuclear weapons. Oppenheimer knew the destructive nature of these weapons and had the foresight to know that the creation of nuclear weapons that were several orders of magnitude more destructive were feasible and imminent. At the beginning of the Eisenhower administration, Oppenheimer explicitly called for the US government to openly discuss the consequences of nuclear war with its citizens, much to the chagrin of those within the government who felt this was akin to sharing nuclear secrets with the USSR.[21] He suggested that the arms race between the US and the USSR can "be likened to two scorpions in a bottle, each capable of killing the other, but only at the risk of his own life."[22] One could argue that the proverbial "bottle" is Earth, wherein the threat of nuclear weapons is overtly existential. In fact, many of the scientists involved in the Manhattan Project stepped away from weapons research, an implicit acknowledgement by some scientists of the dangers of perpetuating destruction through scientific innovation.[23]

The analysis of anthropogenic climate change represents a very different aspect of the scientific enterprise than that of nuclear weapons proliferation, in that it is more focused on explicitly characterizing the relationship between humanity and the Earth's systems. The IPCC AR6 assessment illustrates the need for human society to recognize the worst predicted outcomes of anthropogenic global warming. The shared feature between both scientific issues is the

[20] Rhodes, *The Making of the Atomic Bomb*, 852.
[21] Kai Bird and Martin Sherwin, "The Beast in the Jungle," In *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer*, (New York: Random House, Inc., 2005), 465-6.
[22] Ibid, 464.
[23] Oreskes and Conway, *Merchants of Doubt,* 37.

understanding that innovation via the application of scientific knowledge is not achieved without consequences for both humanity and the Earth. Within the US, fossil fuels are undoubtedly ingrained within its national culture and heralded as responsible for ushering in modern civilization, given that the economic prosperity and technological innovations that people experienced in the US following World War II are largely attributed to the expansion of the use of fossil fuels across industries.[24] Thus, it is not surprising that scientific analyses about the effect of fossil fuel consumption on the atmosphere led to a formal understanding of anthropogenic global warming driven by GHGes coincided with this era. Presently, there are numerous scientific bodies based in the United States which have joined in the agreement about the IPCC's assessments about the causes and observed trends of anthropogenic global warming, such as the National Academy of Sciences, the American Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science.[25] Additionally, these scientific bodies support the conclusion that anthropogenic global warming significantly increases the risk of global climate change that will affect, as stated by NAS, "a broad range of human and natural systems."[26] The official recognition of anthropogenic global warming and the larger phenomenon of climate change are in essence distinctly human issues which require

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[24] Naomi Oreskes, *Naomi Oreskes' Research*, Harvard Speaks on Climate Science, 2022. https://climatechange.environment.harvard.edu/naomi-oreskes: 2:34-5:29.

[25] Naomi Oreskes. "The Scientific Consensus on Climate Change: How Do We Know We're Not Wrong?" In *Climate Change: What It Means for Us, Our Children, and Our Grandchildren*, edited by Joseph DiMento and Pamela Doughman, 2nd ed., (Cambridge, MA: The MIT Press, 2014), 108-9.

See John Cook et al, "Consensus on consensus: a synthesis of consensus estimates on human-caused global warming," *Environmental Research Letters*, (IOP Publishing, April 2016). Cook et al (2016) found that out of 11,944 studies published between 1991 and 2011 that mention "global climate change" or "global warming," 97.1% of the 4,014 abstracts that stated a position on anthropogenic climate change were found to be in agreement with or explicitly endorsing the assertion that climate change is human induced and driven by carbon emissions from the burning of fossil fuels.

See Krista Myers, "Consensus Revisited: Quantifying Scientific Agreement on Climate Change and Climate Expertise among Earth Scientists 10 Years Later." *Environmental Research Letters* 16 (October 20, 2021). Myers finds that after surveying climate scientists and other climate experts, consensus on the existence of the phenomenon of anthropogenic global warming (AGW) has grown since Cook et al (2016), and that the level of consensus is positively associated with the level of expertise that a given climate researcher has within their respective field.

[26] Oreskes, "Scientific Consensus", 110.

international scientific and diplomatic collaboration to address, as it presents a collective threat to human civilization. Similarly, the existence of nuclear weapons has always presented a collective threat to not only people from dominant nation states, like the US and the USSR, but to the entirety of humanity.

The prospect of full-scale nuclear war has posed a uniquely existential and immediate threat to both human civilization and all living species on Earth ever since their extensive proliferation. Even though there is no definitive corollary moment when anthropogenic climate change was brought to bear, like there was in regards to nuclear weapons, the overall threat that climate change as a global phenomenon poses is ecological in nature. This sentiment is well encapsulated by author and anti-nuclear advocate Jonathan Schell, who wrote,

> The two perils [climate change and nuclear weapons] have a great deal in common. Both are the fruit of swollen human power— in the one case, the destructive power of war; in the other, the productive power of fossil-fuel energy. Both put stakes on the table of a magnitude never present before in human decision making. Both threaten life on a planetary scale. Both require a fully global response. Anyone concerned by the one should be concerned with the other. It would be a shame to save the Earth from slowly warming only to burn it up in an instant in a nuclear war.[27]

While Schell clearly believes that the projected effects of anthropogenic climate change are going to happen on a planetary scale and will be destructive in their own right, this assertion is predicated on the acceptance of the predictions of climate scientists who have illustrated the worst predicted outcomes of future increases in fossil fuel emissions. In their AR6, the IPCC state that

> The magnitude of feedbacks between climate change and the carbon cycle becomes larger but also more uncertain in high CO2 emissions scenarios (very high confidence). However, climate model projections show that the uncertainties in atmospheric CO2 concentrations by 2100 are dominated by the differences between emissions scenarios (high confidence). Additional ecosystem responses to warming not yet fully included in climate models, such as CO2 and CH4 fluxes from wetlands, permafrost thaw and wildfires, would further increase concentrations of these gasses in the atmosphere (high confidence).[28]

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[27] Jonathan Schell, *The Seventh Decade - The New Shape of Nuclear Danger,* (New York: Metropolitan Books, 2007), 7.
[28] IPCC, "Summary for Policymakers," 20.

This assessment of current and projected GHGes showcases the perpetually destructive character of anthropogenic global warming, in that the various feedbacks that accompany this phenomenon are likely to amplify global warming, i.e. increased GHGes from permafrost, wetlands and wildfires. Entrenched skeptics and denialists would assert that such predictions are not accurate and thus do not justify taking either actions to reduce GHGes or not reducing GHGes as soon as feasibly possible. This is especially alarming when we consider the scale and severity of the consequences, outlined by the IPCC, that further global warming is expected to have for the global climate. In this sense, the analogy that I have drawn in order to compare and contrast the development of nuclear weapons and anthropogenic global warming is only valuable if one believes that the ensuing climate change presents a threat to human civilization on a global scale comparable to nuclear weapons. This is not possible if one does not accept the findings of or predictions made by climate scientists. Similarly, this is not possible if people do not understand the scale of the damage that would be caused by nuclear weapons use.

The analogy between anthropogenic climate change and nuclear weapons is further strengthened by the fact that addressing either issue requires the public and political leaders to defer to scientific authorities in order to make informed decisions about how we should collectively proceed given the information that we possess. However, whether we will take into account the guidance and advice that communities of scientists have to offer about the ethical and epistemic dimensions of these issues is dependent on our willingness to trust not only the evidence, but effectiveness of the methodology and reasoning that they employ in their assessments. The American public's general understanding of scientific concepts definitely plays a role in how well the general public understands and can distill scientific information. However, content knowledge of science is not a panacea to widespread distrust of scientific authorities. In order for someone to trust a scientific body, or any institution for that matter, their value system must incorporate and acknowledge the ability of scientific reasoning to make valid epistemic claims and regard the scientific process as an effective approach towards ascertaining a truer understanding of a given phenomenon.

Trusting scientists, from disciplines ranging from ecology, nuclear physics, and atmospheric science, to make reasonable predictions about what the outcome of a full scale nuclear war was paramount to communicating the seriousness and existential nature of what a nuclear war would be. Towards the end of the Cold War era, at the beginning of the Reagan Administration in the early 1980s, the debate over whether or not to implement the so-called Strategic Defense Initiative, a plan proposed by Reagan's scientific advisors to develop an anti-ballistic missile defense system in space, sought to end the nuclear stalemate between the US and the USSR, which had taken shape following the development of intercontinental ballistic missiles (ICBMs).[29] ICBMs outfitted with thermonuclear, or hydrogen bomb, warheads posed a fundamentally new risk in the era of nuclear weapons in that they were orders of magnitude more destructive than the atomic bomb dropped on Hiroshima in addition to being essentially impossible, given the existing technology, to defend against, thus leaving both the US and the USSR in a position where neither power had a distinct strategic advantage over the other.[30] This

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[29] Orekes and Conway, *Merchants of Doubt*, 42-3.
See William Burr and David Rosenberg, "Nuclear Competition in an Era of Stalemate, 1963–1975," In *The Cambridge History of the Cold War*, edited by Melvyn P. Leffler, (Cambridge: Cambridge University Press, 2010), 88-111.
[30] Burr and Rosenberg, "Nuclear Competition", 91-6.
See Stuart Casey-Maslen, "The Development of Nuclear Weapons", in *Nuclear Weapons: Law, Policy, and Practice* (New York: Cambridge University Press, 2021), 26.
https://doi.org/10.1017/9781009039864.002.

realization led many prominent scientists from several American research institutions to organize around the idea that a full-scale use of nuclear weapons could not be deterred by any technology that existed at the time and would have an irreversible effect on the planet.[31]

The Union of Concerned Scientists, which was formed in 1969 at the Massachusetts Institute of Technology by scientists who worked at Los Alamos and Lawrence Livermore National Laboratories on nuclear weapons systems, sought to use their expertise to inform the American public that an anti-ballistic missile defense system was not feasible and only served to further escalate geopolitical tensions over the potential use of nuclear weapons.[32] Additionally, scientists from other disciplines, such as biologist Paul Erlich, astronomer and popularizer of science Carl Sagan, and scientists from the NASA-Ames research center, sought to characterize the global ecological and atmospheric impact of various potential scenarios involving the exchange of nuclear weapons through the use of computer modeling.[33] Sagan and his colleagues published their findings in 1983, in an article titled "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," which unequivocally asserted that such an exchange would mostly likely lower land surface temperatures dramatically, posing an acute risk to agriculture. These findings were corroborated later by modeling performed by other researchers, indicating that what Sagan et al had established was representative of the effects of an actual nuclear war.[34] However, there were members of the scientific community such as Robert Jastrow, a NASA scientist and founder of the Goddard Institute for Space Studies, who rebuked these assessments

[31] Oreskes and Conway, 42-4.
[32] Oreskes and Conway, 54-5.
[33] Ibid, 50
[34] Ibid, 50-2.

and criticized these efforts as intent on undermining the national security of the United States whilst simultaneously critiquing the validity and veracity of these claims.[35]

Jastrow critiqued the scientific research *itself* and described the scientific process that the NASA-Ames researchers had used to produce their study of the potential atmospheric impact of nuclear weapons as lacking rigor, thus undermining the reasoning that supported the scientific claims rather than critiquing specific aspects of the presented findings and accusing the researchers of being ideologically motivated. The nature of such a critique engenders the issue of how research which evaluates scientific issues of extreme social-ethical import should be communicated to the public. Those who levy the criticism that researchers who evaluate a scientific issue in which significant social, political, or economic fissures exist are prone to not honor their commitment to objectivity ultimately fail to recognize that science is done within a social community of people who share similar values. Assessing the integrity of research is an explicitly defined value within scientific communities. Objectivity itself is not an absolute epistemic principle that is blatantly violated by the presence of social concerns which motivate scientific research. Rather, when one considers that there are mutually discussed principles which structure scientific investigation across all disciplines, we begin to recognize that a commitment to objectivity does not preclude a researcher from having personal values. The notion that scientists' having personal values that motivate research can compromise the scientific process as a whole suggests that objectivity cannot exist in tandem with ethical values. A commitment to objectivity in itself is part and parcel of an ethics of responsibility to collectively establish criteria of truth.

[35] Ibid, 58-9.

Philosopher of science and microbiologist Ludwik Fleck articulates that a fundamental aspect of scientific reasoning is the collective manner in which all scientists gather information and attempt to challenge their hypotheses. Fleck proposes that the notion of an independent researcher, unencumbered by social affiliations and committed to a lofty, and essentially intangible idea of objectivity, is inconsistent with the realities of the scientific process.[36] Fleck explains this sentiment, writing,

> A truly isolated investigator is impossible (…). An isolated investigator without bias and tradition, without forces of mental society acting upon him, and without the effect of the evolution of that society, would be blind and thoughtless. Thinking is a collective activity (…). Its product is a certain picture, which is visible only to anybody who takes part in this social activity, or a thought which is also clear to the members of the collective only. What we do think and how we do see depends on the thought-collective to which we belong.[37]

By introducing the concept of a "thought-collective," Fleck offers a strong challenge to the claim that scientists, given the nature of their profession, are untethered to the community of non-experts who do not actively participate in the scientific process. To Fleck, knowledge production within scientific communities is defined by the "diverse interactions" of a given group of people who all specialize in a specific field.[38] Thus, the common belief that is espoused by non-scientists within the American populace that science is in it of itself objective fails to fully interrogate the idea of objectivity as it is applied in a scientific context. This leaves physical scientists who investigate socio-politically contentious issues in a position where they have to defend their motivations for their research against people who may have an inflexible perception of the scientific process as being defined by standards of truth that are defined outside the "thought collectives" of scientific communities.

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[36] Wojciech Sady, "Ludwik Fleck," *Stanford Encyclopedia of Philosophy* (Stanford: Stanford University, 2012).
[37] Ludwik Fleck, "Scientific Observation and Perception in General," Edited by Robert Cohen and Thomas Schnelle 87 (1935): 77.
[38] Naomi Oreskes, *Why Trust Science?* (Princeton: Princeton University Press, 2019), 32.

The relationship between scientists and the public becomes even more fraught when one considers that issues like anthropogenic climate change and the threat of nuclear war have enormous societal consequences which must be reconciled. A primary issue with how research about these issues is communicated and how it is perceived by entrenched skeptics and denialists is that the research on both of these issues is ultimately speculative, where claims about these potential scenarios will possess a specific degree of uncertainty. This is a result of a cumulative understanding of more established concepts that structure the physical systems being studied. This is to say that atmospheric scientists at the time were using conceptual frameworks which had varying degrees of explanatory power. Convincing people that predictions about both issues are epistemically valid rests upon the understanding of how these conceptual frameworks operate in addition to an understanding of the social dimension of the scientific process.

It is important to note that the 1983 paper by Sagan and his colleagues was not the only analysis of potential global atmospheric effects of the use of nuclear weapons. Other researchers in atmospheric science sought to build upon the model created by Sagan et al, such as scientists from the National Center for Atmospheric Research (NCAR).[39] While the NCAR scientists found different results in their analysis compared to Sagan et al, their model still corroborated the basic conclusions stated by Sagan et al. The scientists who sought to challenge specific aspects of the model created by Sagan et al were practicing a productive skepticism, wherein they took it upon themselves to do more analysis to improve general scientific understanding of this phenomenon. In opposition to what was essentially a collective agreement about atmospheric effects of a "nuclear winter," Jastrow was unwavering in his resolve that Sagan's advocacy for

[39] Oreskes and Conway, 51-2.

disarmament disqualified the results, which illustrates how entrenched skepticism and denialism persists despite scientific consensus. Jastrow believed that the conversation around “nuclear winter” was influenced by environmentalist perspectives which called for disarmament, stymying the potential for technological innovation, that of SDI, which would give the United States an edge over Soviet strategic weapons.[40] In this sense, Jastrow’s entrenched skepticism of the atmospheric models was motivated by the idea that science could be used to strengthen the US’s nuclear posture, rather than use scientific concepts to communicate candidly to the American public about the threats of a thermonuclear exchange.

Understanding how scientists throughout history and across cultures have worked collaboratively to develop concrete frameworks of scientific phenomena, whether it is thermodynamics, quantum mechanics, cell biology, or any other discipline within the sciences, is paramount to recognizing how the application of these fields has led to productive changes within our technological abilities but also exacerbated humanity’s fraught relationship with our local and global ecosystems. Overall, to maintain doubt over the question of anthropogenic climate change, or deny that humans that have the capacity to alter the Earth on a global scale, is to neglect looking at what many would consider to be the scientific achievements of humanity as evidence that our technological capabilities have rapidly outpaced our ability to rectify the consequences and implications of acquiring and subsequently utilizing scientific knowledge.

Prominent scientists involved in the development of nuclear weapons and academics from around the world voiced their concerns about the expansion of the nuclear weapons capabilities of the US and USSR directly following World War II and the manufacture of the

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[40] Ibid, 56-7.

hydrogen bomb in 1952.[41] Theoretician Albert Einstein, whose theory of special relativity, $E=MC^2$, made an irrevocable mark on our understanding of the physical world, and analytical philosopher Betrand Russell issued a manifesto on July 11th, 1955 to call on the nuclear powers at the time, namely the US and the USSR, to recognize the threat that the newly developed thermonuclear weapons posed.[42] They stated,

> In view of the fact that in any future world war nuclear weapons will certainly be employed, and that such weapons threaten the continued existence of mankind, we urge the Governments of the world to realize, and to acknowledge publicly, that their purpose cannot be furthered by a world war, and we urge them, consequently, to find peaceful means for the settlement of all matters of dispute between them.[43]

The Einstein-Russell manifesto illustrates that the destructive power of these weapons and their capacity to threaten the continued existence of humanity was widely known amongst members of the scientific community, long before the modeling developed by atmospheric scientists in the early 1980s in the context of the proposal of SDI by the Reagan administration. Einstein and Russell acknowledge that the potential effects of a full-scale thermonuclear war were not necessarily *known* at the time, but they defend their speculations about the disastrous consequences of such a conflict by stating that,

> Many warnings have been uttered by eminent men of science and by authorities in military strategy. None of them will say that the worst results [of a war with H-bombs] are certain. What they do say is that these results are possible, and no one can be sure that they will not be realized. We have not yet found that the views of the experts on this question depend in any degree upon their politics or prejudices. They depend only, so far as our researches have revealed, upon the extent of the particular expert's knowledge.[44]

Many prominent scientists in the 1950s had understood long before atmospheric scientists in the 1980s had modeled what a "nuclear winter" would mean for the Earth, Einstein and Russell had

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[41] Stuart Casey-Maslen, "The Development of Nuclear Weapons", in *Nuclear Weapons: Law, Policy, and Practice* (New York: Cambridge University Press, 2021), 26-7. https://doi.org/10.1017/9781009039864.002.
[42] Albert Einstein and Betrand Russell, "The Russell-Einstein Manifesto" (Manifesto, London, July 9, 1955).
[43] Ibid, 2.
[44] Einstein and Russell, "Manifesto," 1.

effectively stated that regardless of any measure of “certainty”, that an exchange of thermonuclear weapons would undoubtedly threaten the existence of humanity. This historical account, in conjunction with the previous discussion of the scientific push to meaningfully characterize the phenomenon of a “nuclear winter” in the 1980s, offers an additional rebuke to entrenched skeptics who might challenge efforts to predict the inherently unknowable outcomes of a thermonuclear war. The reasoning supporting the scientific assessments made in the Einstein-Russell manifesto fundamentally cannot be dismissed as speculation because the scientists who authored this statement knew that the destructive power of nuclear weapons had been clearly demonstrated.

If we return to Oppenheimer, his description of the Trinity Test, the first detonation of an nuclear-fission atomic bomb, serves as an incredibly powerful description of the ethical weight that was placed onto the shoulders of the physists, chemists, and engineers that had used their scientific expertise to manufacture a device with such terrible power. Reflecting upon his thoughts of that day, Oppenheimer said,

> When it went off, in the New Mexico dawn, that first atomic bomb, we thought of Alfred Nobel, and his hope, his vain hope, that dynamite would put an end to wars. We thought of the legend of Prometheus, of that deep sense of guilt in man’s new powers, that reflects his recognition of evil, and his long knowledge of it. We knew that it was a new world, but even more we knew that novelty itself was a very old thing in human life, that all our ways are rooted in it.[45]

Oppenheimer proposes that the creation of this technology was a truly novel development in human history, which raises the question: how does humanity respond and adapt to the reality that our experience was categorically altered by a singular moment? Oppenheimer explicitly identifies with researchers before him, such as Alfred Nobel, and the notion that whenever humans have thought that we have reached a point where our power over the physical world, via

[45] Rhodes, *Making of the Atomic Bomb,* 1,001.

the formulation of discrete scientific phenomena, has met its limit, we find ourselves terribly astonished and in an even more fraught relationship to the Earth when we achieve something what we thought was theoretically impossible.

Nuclear and climate scientists have an ethical responsibility to communicate their findings and knowledge with the public. However, the nature of these threats to human civilization cannot be illustrated in the same way. The physicists involved in the Manhattan Project knew full well what the creation of such a weapon would mean for humanity and that deploying such a weapon would usher in a new era of military conflict. It is also clear that the advent of nuclear weapons presented scientists with an ethical quandary in which depriving the public of information about nuclear technology would put people at a greater risk. Similarly, climate scientists have recognized that the only way in which our society can work towards a better future is if public awareness of climate change is heightened. This entails communicating the scientific concepts that structure the phenomenon of anthropogenic climate change. Without an understanding of the scientific principles that dictate climate science, or if one outright rejects the scientific basis of climate change, collectively as a society the American public cannot move towards viable solutions.

Improving scientific literacy is a critical component of addressing both climate change and the proliferation of nuclear weapons. While the management of these issues appears to be a matter of policy making and diplomacy, underlying both issues is the fact that the political will to address either problem will only be generated if people adopt a disposition that yields to and embraces scientific reasoning in lieu of other epistemologies. Entrenched skepticism and science denialism engenders resistance to accepting the climate assessments of scientific bodies like the

IPCC because these epistemic positions cast doubt on the ability of the scientific process to make accurate predictions about future climate scenarios. We have also observed how entrenched skeptics challenged the efforts by Sagan et al to produce a substantive analysis of the existential threat of nuclear weapons on similar grounds. The scientific perspectives offered on nuclear weapons, by figures such as Oppenheimer and Einstein, illustrated that this technology presented an undeniable threat to the existence of the human species and our way of life, even without the findings of Sagan et al. Overall, what these two seemingly different issues show is the ability of entrenched skepticism and science denialism to challenge the scientific process, even though there has been broad agreement on the part of nuclear scientists who knew of the scale of the threat nuclear weapons posed since their inception, and on the part of climate scientists who have definitely shown that based on the principles of hard science, such as physics, geology, and chemistry, that there is an explicit relationship between anthropogenic GHGes and global warming.

Implicit in educating the American public about the technical aspects of both nuclear weapons and climate change are the implications of the misappropriation of scientific knowledge. Both issues, in their own historical moments, represent a time in which there is an urgency to act on the knowledge that one has in order to inform decision making. The epistemic and ethical components of both the development of nuclear weapons and climate change are unique moments in the history of the United States when public awareness of science and familiarity with science concepts have become central to how people within the U.S regard the full impact of modern human civilization. Nuclear weapons are an example of a specific technology that presented, and still presents, a uniquely incomprehensible threat to our collective way of life. With regards to anthropogenic climate change, this phenomenon is not the result of any one technological advancement, but rather it is the cumulative effect of the rapid expansion in the use of fossil fuels.

The American public is most likely unconcerned with how these two issues are related and why comparing them is useful for communicating the urgency of either issue. The threat of nuclear weapons exists in most American's minds as a prominent feature of the Cold War, a past conflict between two geopolitical powers with diametrically opposed political ideologies. Anthropogenic climate change is one of the most pressing issues that humanity currently faces, but the fear surrounding it and what it means for human civilization is shrouded in the uncertainty of whether the current climate models accurately predict how the Earth's various physical systems will be impacted. Unlike climate change, the threat of a nuclear winter and the end of our world as we know it as a result of an all-out nuclear war is a potent and tangible image. After all, nuclear weapons have been used in warfare before. John Hersey's *Hiroshima* provides us with an emotionally vivid account of the consequences of using nuclear weapons. Hersey's collection of stories from survivors of the blast is underscored by a deep sense of understanding about how nuclear weapons represented a fundamentally new era of, not just warfare, but of humanity. He writes,

> About a week after the bomb dropped, a vague, incomprehensible rumor reached Hiroshima—that the city had been destroyed by the energy released when atoms were somehow split in two. The weapon was referred to in this word-of-mouth report as *genshi bakudan*—the root characters of which can be translated as "original child bomb." No one understood the idea or put any more credence in it than in the powdered magnesium and such things. Newspapers were being brought in from other cities, but they were still confining themselves to extremely general statements, such as Domei's assertion on August 12th: "There is nothing to do but admit the tremendous power of this inhuman bomb." Already, Japanese physicists had entered the city with Lauritsen electroscopes and Neher electrometers; they understood the idea all too well. [46]

[46] John Hersey, "Hiroshima", *The New Yorker* (New York: August 23, 1946), 29.

Hersey articulates in relatively accessible terms how the physical destruction of Hiroshima by the first atomic bomb used in warfare was brought about by an incomprehensible force that was unknown to most of humanity at the time.

In a matter of seconds, humanity was forever changed. From Hersey's account, we see how scientists in the United States, who in collaboration with European allies, played an uncomfortable role in making nuclear technology a reality while at the same time Japanese physicists are providing the clarity that is needed to explain and understand what exactly had befallen Hiroshima. The survivors of this attack had experienced what just five years before was an abstraction in the minds of physicists like Leo Szilard, Enrico Fermi, and Robert Oppenheimer.[47] The immediacy and instantaneous destruction wrought by "*genshi bakudan*" can be quantified in many ways, but the decision to manufacture, and subsequently use, nuclear weapons had an immeasurable impact on the human psyche and has forced us to confront the realities of our fragile existence.

The consequences of anthropogenic global warming and climate change are not as comprehensible or obviously perceivable as the awesome destruction wrought by thermonuclear nuclear weapons. Thus, from an epistemic standpoint, it is more difficult to illustrate the urgency with which the US and the global community needs to act to stave off the worst predicted effects of climate change illustrated by the IPCC, particularly in the face of entrenched skepticism and denialism which continues to cast doubt on the uncertainties about the future of Earth's climate. In order to further demonstrate the need for a more holistic approach in improving the scientific literacy of the American public with the goal of raising awareness about the urgency of climate

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[47] See Richard Rhodes, "The New World," in *The Making of the Atomic Bomb,* 1001-123. Rhodes discusses the central figures involved in the design and manufacture of the first atomic bomb.

change, approaches to scientific communication need to be geared towards promoting productive skepticism whilst simultaneously engaging with arguments put forward by entrenched skeptics and denialists. Productive skepticism of the scientific process ultimately serves to produce a more nuanced and extensive understanding about how the inner workings of scientific communities, like those of climate scientists, shape how epistemic claims made within scientific literature are evaluated. Promoting productive skepticism works to buttress the integrity of the scientific process and exposes how claims made by entrenched skeptics and denialists against prevailing scientific findings or assessments usually do not cohere with the structures of scientific reasoning or acknowledge the innate social character of science.

Chapter 2 : The Scientific Enterprise

In our contemporary moment, resistance to scientific findings has enormous consequences. However, productive skepticism about scientific claims can have a positive role in challenging people to think more critically about a given issue in order to more fully substantiate a burgeoning scientific finding. Given the history of resistance to newly formed scientific theories and observations, it is apt to discuss how modern science, which is represented by the institutions who fund, publish, and review scientific research, functions on a large scale. In order to rebuke science denialism, it is paramount that we understand how scientists in our contemporary era arrive at their conclusions and how this process is not infallible. This is not to suggest that *all* scientific research is, by nature, flawed, but rather that the manner in which uncertainties within scientific research and the value systems of those who disseminate science influence how science is reported to policy makers and the public. Galieo's Galilei's conflict with the Roman Catholic Church is a potent historical example of a powerful institution to censuring a highly respected scientist whose theories contravened or challenged their authoritative account of the physical world. This clash of values and differential theories of knowledge can be observed throughout scientific history and thus is relevant to the discussion of how and why the United States in the 20th century finds itself divided over the issue of anthropogenic climate change.

In this chapter I argue that in order to improve the scientific literacy of the American public, using the definition by the NAS for the purpose of communicating the urgency of climate change, a more comprehensive understanding of the scientific process needs to be squared with the positions of entrenched skeptics and denialists who propose that the epistemic value of the findings of scientists can be rejected on the grounds that personal moral values undermine scientific integrity and future predictions of the impact of scientific phenomena like climate change are inherently unreliable.

We will begin by looking at the historical example of the conflict between Galileo and the Cathlolic Church, where scientific discovery and progress was challenged on the basis of an alternative epistemological outlook. In 1633, Galileo Galilei was officially sanctioned by the Roman Catholic Church for his acceptance of the Copernican Theory, which stated, in simplified terms, that the Earth is a planet which revolves around the Sun, overturning the Ptolemaic understanding of our solar system.[48] Galileo was determined to push science in a new direction and was met with fierce resistance from the Church because it contradicted their doctrine about humanity's significance in relation to God, despite the legitimate scientific reasoning that Galileo employed to justify his theories. The Catholic religious doctrine during the seventeenth century regarded principles about the physical world as being of divine providence and not the product of human reason, which stood at odds with the development of scientific reasoning within Western Europe in the century following the Italian Renaissance.[49] A contemporary of Galileo, Francis Bacon, writes in *The New Organon*, first published in 1620, that

> The *illusions* and false notions which have got a hold on men's intellects in the past and are now profoundly rooted in them, not only block their minds so that it is difficult for truth to gain access, but even when access had been granted and allowed, they will once again, in the very renewal of the sciences, offer resistance and do mischief unless men are forewarned and arm themselves against them as much as possible.[50]

[48] Gregory Dawes, *Galileo and the Conflict between Religion and Science* (New York: Routledge, 2016), 74.
[49] Ibid, abstract.
[50] Francis Bacon, "The New Organon: Book I: Aphorism XXXVIII." (Cambridge: Cambridge University Press, 2000), 40.

Bacon details the mechanism through which resistance to new findings takes root in an individual. During a time of scientific enlightenment, Bacon identifies that refusal to consider how theories of the physical world developed in the past ultimately impedes advancements made through scientific reasoning. In this sense, Bacon is advocating for a productive skepticism that encourages a scientific investigator to reconsider the explanatory power of past conceptual frameworks. This way of thinking acknowledges that the goal of science is to develop a *truer* understanding of the world in which we do not unilaterally work to develop a self-justified argumentative framework for all knowledge claims, but rather evaluate the likelihood that our explanations of the physical world conform to reality. This is the fundamental and primary goal of all scientific investigations.

In their latest Assessment Report 6, published in August 2021, the IPCC stated in Chapter 11 of their Technical Summary that anthropogenic greenhouse gas emissions are unequivocally influencing global and local weather patterns.[51] The American public has yet to widely accept the scientific explanation of how anthropogenic GHGes are the primary drivers of climate change. Anthony Leiserowitz and colleagues, who research climate change communication, conducted a national survey that found that 63% of the respondents stated that they believed that global warming, using the IPCC's definition, was occurring, while 50% of respondents understood that global warming was caused by human activities.[52] An even more alarming finding from the Leiserowitz et al survey is that, "Thirty-nine percent [of respondents] (39%) say that most scientists think global warming is happening, while 38 percent say there is a lot of disagreement

[51] IPCC Sixth Report, *Technical Summary*, 2021, 82-4.
[52] Anthony Leiserowitz, Nicholas Smith, and Jennifer Marlon. "Americans' Knowledge of Climate Change." Survey Results. (New Haven, CT: Yale University, 2010), 3.

among scientists whether or not global warming is happening."[53] These results indicate that not only is global warming not widely understood as being anthropogenically driven, but there is also a popular understanding amongst the American public that there is disagreement among scientists about whether global warming is occuring or not. Most recent surveys conducted in 2016 by the Pew Research Center estimate that among US adults, 48% believe that global climate change is "due to human activity", 31% believe that it is "due to natural causes", and 20% believe that there is "no evidence."[54] Cumulatively, these surveys show that there are major differences in beliefs about climate change within the US population that are not consistent with the consensus of the climate science community that strongly suggests that anthropogenic GHGes are primarily responsible for global warming trends.[55]

The U.S. public's understanding of science and scientific research is largely limited to the dissemination of specific studies by mass media such as print, TV, and radio outlets which, more often than not, are selected for their provocative and topical findings. In our contemporary moment, the COVID-19 pandemic has necessitated the rapid publication of scientific research concerning the efficacy of vaccines, the transmission of the novel coronavirus, the rise of new variants, and the effectiveness of public health measures in preventing transmission.[56] Public health officials in the United States have used this research to guide their decision-making. This massive production of scientific research is one example of how science progresses, specifically

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[53] Ibid.

[54] Cary Funk and Brian Kennedy, "The Politics of Climate Change," Survey Results (Pew Research Center, October 4, 2016), 19.

[55] See John Cook, et al, "Consensus on Consensus: A Synthesis of Consensus Estimates on Human-Caused Global Warming," *Environmental Research Letters* 11, no. 4 (April 13, 2016), 1-7. https://doi.org/10.1088/1748-9326/11/4/048002.
See also, Krista Myers, "Consensus Revisited: Quantifying Scientific Agreement on Climate Change and Climate Expertise among Earth Scientists 10 Years Later," *Environmental Research Letters* 16 (October 20, 2021): 1–10. https://doi.org/10.1088/1748-9326/ac2774

[56] Ewen Calloway and Heidi Ledford, "COVID and 2020: An Extraordinary Year for Science," *Nature* 588, no. 7839 (December 14, 2020): 550–52, https://doi.org/10.1038/d41586-020-03437-4.

when, either in times of crisis or for the purpose of providing an explanation for a lesser understood topic or concept in the physical world, the scientific community is called upon to enrich our collective understanding about a particular phenomenon. This includes understanding the spread of viruses, the evolution of life, geological phenomena, or climate science.

The aforementioned subjects are by no means fully understood by the researchers in those specific fields, given that there is always some uncertainty of how well the conceptual frameworks that structure our understanding of the physical systems studied in these fields conform to reality. The process of developing a conceptual framework to explain physical phenomena is a matter of assessing the probability or likelihood that these concepts are representative of reality. I want to emphasize the importance of the process of science being framed as an ongoing assessment of probabilistic outcomes, principally based on the criticism levied against the inductive process of science by 18th century British empiricist David Hume. Hume articulated the problem with induction in his *Enquiry Concerning Human Understanding*, writing,

> In a word, then, every effect is a distinct event from its cause. It could not, therefore, be discovered in the cause, and the first invention or conception of it, *a priori,* must be entirely arbitrary. And even after it is suggested, the conjunction of it with the cause must appear equally arbitrary; since there are always many other effects, which, to reason, must seem fully as consistent and natural. In vain, therefore, should we pretend to determine any single event, or infer any cause or effect, without the assistance of observation and experience.[57]

From Hume's perspective, proving the truth of a universal axiom about the nature of any physical phenomenon is impossible. Hume's critique of the process of induction has had significant epistemological ramifications for the physical sciences. He shows that within scientific investigations about physical phenomena, the notion of empirical evidence giving rise

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[57] David Hume. *An Enquiry Concerning Human Understanding*. (Indianapolis: Hackett Publishing, 1977), 41.

to absolute understanding, in the form of principles about the physical world, is untenable. Thus, built within the process of scientific inquiry is this powerful idea in which scientists do not claim that their explanations are representative of an absolute truth about the physical world, but are probabilistic theories that carry with them different epistemic weight.

Paramount to understanding the process of scientific reasoning is recognizing that the central goal of science is to construct frameworks based on theories which have high informative content because of their high predictive power.[58] Twentieth century philosopher of science Karl Popper emphasized that the testability of scientific theories is owed to their predictive power, in that theories which are highly *improbable* of conforming with reality, but nonetheless are close to the truth, have high explanatory power in demonstrating the realities of the laws and principles which dictate the physical world.[59] Thus, we should be concerned with how improbable it is that a particular explanatory framework is not a true characterization of reality. A central feature of the scientific enterprise is gauging the degree of uncertainty that an explanatory framework is not consistent with reality as opposed to an alternative framework.

Productive skepticism in the scientific process encourages quantifying the uncertainty of the scientific findings in order to interrogate the veracity of different scientific claims. In the context of anthropogenic climate change, we must recognize that while it is important to scrutinize the findings of climate science, implicit within scientific modes of inquiry is the notion that observations without uncertainty are not valuable to the scientific enterprise and only further alienate investigators from providing a truer understanding of the physical world.

[58] Stephen Thorton, "Karl Popper," in The Stanford Encyclopedia of Philosophy (Stanford University, Fall 2021): §6. https://plato.stanford.edu/entries/popper/.
[59] Ibid.

This raises the question: how is production of knowledge within the scientific community regulated and how are claims made by researchers verified? Ultimately, in order for someone to trust the information that is produced through the research process, familiarity with the concepts that are explored within any scientific study are important, but acquisition of content knowledge alone does not allow for someone to evaluate the validity of scientific claims. One must first recognize that the process of scientific discovery is not a singular event, where one publication is unequivocally accepted by researchers within a scientific field.

Investigations into physical phenomena are not constructed with the goal of defending positive conclusions, which speaks towards the anti-dogmatism that is built within scientific inquiry. Productive skepticism entails that an investigator is committed to eschewing dogmatic positions in favor of developing a line of reasoning where the fewest, untested assumptions are used to justify their method of analysis or experimentation. Defending a positive claim is not consistent with establishing a criterion of truth which can be widely understood and taken up by those engaging with a specific argument, but at the same time rigorously tested with the use of new empirical evidence and observations.

The positions of entrenched skepticism and science denialism are largely focused on the varying degrees of uncertainty that characterize the magnitude of the future consequences of climate change. Of course, there is also the fact that people outright deny that climate change is occurring and that it is caused by human activity. Rooting out denialism is a manifold process that is not simply remedied by any singular piece of evidence or line of reasoning generated by an individual or small group of researchers. Instead, a successful challenge to entrenched skepticism and denialism involves getting those who doubt the epistemic integrity of the scientific process to recognize that the epistemic strength of scientific claims lies in being able to characterize the uncertainty of one's findings under a framework specified by research communities who have collaborated across space, both geographical and cultural, and time.

If we consider Thomas Kuhn's *Structure of Scientific Revolutions*, he articulates that scientists work in communities where they propose theories to explain empirical realities but also establish the social values and the methodological and intellectual practices that they adhere to.[60] These components of scientific research are what Kuhn refers to as the "paradigm" under which a scientific community operates, showing that science is an active process in which individuals do not just simply make empirical observations in order to propose uncontested claims about the physical world. Rather, these communities self-regulate and scrutinize the claims made by their peers based on these shared values. Kuhn writes that paradigms such as Newton's *Principia,* Lavoiser's *Chemistry*, and Lyell's *Geology*

> …were sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity. Simultaneously, [they were] sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve….The study of paradigms, including many that are far more specialized than those named illustratively above, is what mainly prepares the student for membership in the particular scientific community with which he will later practice. Because he there joins men who learned the bases of their field from the same concrete models, his subsequent practice will seldom evoke overt disagreement over fundamentals. Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, i.e., for the genesis and continuation of a particular research tradition.[61]

Here, we can see that science is a social endeavor in which a value system informs the research process. Kuhn's use of the term "normal science" identifies that scientific fields are

[60] Oreskes, *Why Trust Science*, 39.
[61] Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: The University of Chicago Press, 1962), 41-2.

traditions characterized by a complex history of achievements and discoveries that have shaped the scientific process, not merely laws and principles proposed in foundational texts that he refers to.[62] Kuhn identifies the importance of describing the scientific enterprise as a historical process of community building around shared values and established fundamentals, where across time and space different scientists have worked collaboratively to produce more robust scientific knowledge. Kuhn emphasizes the practice, rather than the method, of science to help contextualize the manner in which new ways of thinking about scientific concepts arise and locates the source of scientific knowledge as being from communities, rather than individual researchers.

Naomi Oreskes, historian of science and climate scientist, augments Kuhn's community-based understanding of scientific research when she explains that one's trust in science is largely "based on the social character of scientific inquiry and the collective critical evaluation of knowledge claims."[63] Entrenched skeptics and denialists would likely counter argue that evidence of errors made within past scientific research and poor judgment within the scientific community are damaging to scientific integrity. In her book, *Why Trust Science,* Oreskes identifies historical moments when scientific communities disagreed about the epistemic basis for concepts like continental drift proposed by Alfred Wegner and the field of eugenics.[64] Oreskes shows that these moments reveal how scientists are not impervious to ideological differences and bias. However, she also emphasizes that the process of peer review and deliberation ultimately led to future research into Alfred Wegner's theory of plate tectonics,

[62] Ibid, 41.
[63] Orekes, 68.
[64] See Oreskes, "Science Awry" in *Why Trust Science?*, 80-104.

which subsequently substantiated his claims.[65] Contemporaries of prominent eugenicists also voiced their opposition to eugenics in highly credible scientific publications, like the journal *Nature*, casting light on how the scientific process is a pluralistic endeavor.[66] Oreskes essentially illustrates that disagreements within science may arise from different biases that individual researchers may have, but scientific discourse still maintains some effectiveness in rejecting deeply skewed subjective reasoning.[67]

As climate scientists make predictions, they find themselves in a place where they are attempting to envision a future for which there is no corollary historical experience. The uncertainty that surrounds our understanding the current trends in atmospheric carbon concentrations creates a situation where not knowing how the climate will respond could place humanity in a dangerous position.[68] The uncertainty presented within scientific assessments of climate change can ultimately be identified as a feature of what drives entrenched skepticism about climate change and subsequent inaction on widespread decarbonization. Nationally representative Gallup polls taken between 1997 and 2010 show that Americans are hesitant to accept that climate change will pose a serious threat or risk to them or their way of life within

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[65] Oreskes, 146.
[66] Ibid.
[67] The scientific community is fallible and can overlook the social consequences of ubiquitous applications of scientific knowledge further necessitates the formation of socially interconnected communities with a shared interest in discovering new scientific truths but in being mindful about the ethical implications of their work. Scientific advancements within the fossil fuels and energy sector as well as in other parts of industry has undoubtedly allowed the United States to achieve a higher quality of life in the 20th century, but these developments have disproportionately increased the environmental burden of pollution on communities that lack the political power to deter acts of negligence from threatening their drinking water and the air they breathe. Thus, a complex relationship exists between our desire to use science to improve our quality of life, but at the same time do so sustainably and without placing inequitable burdens on historically marginalized communities.
See Stephanie Malin, Stacia Ryder, and Mariana Galvão Lyra, "Environmental Justice and Natural Resource Extraction: Intersections of Power, Equity and Access," *Environmental Sociology* 5, no. 2 (June 25, 2019): 109–16, https://doi.org/10.1080/23251042.2019.1608420. Malin et al address how the deleterious environmental effects of extractive industries, particularly fossil fuel extraction, are inequitably distributed in the US based on socio-economic demographics.
See also Laura Pulido, "Geographies of Race and Ethnicity II: Environmental Racism, Racial Capitalism and State-Sanctioned Violence," *Progress in Human Geography* 41, no. 4 (August 1, 2017): 524–33, https://doi.org/10.1177/0309132516646495. Pulido identifies environmental racism as a central component of racial capitalism.
[68] Weber and Stern. May 2011, 316.

their lifetime, with the percentage of respondents who endorse the aforementioned statement having never exceeded 40 percent.[69] Although this is a limited representation of public opinion, the responses to these surveys are indicative of a larger problem where assessments of climate change published by scientific bodies are not perceived as reliable. The IPCC has consistently stated in their assessment reports the exigent and serious consequences of anthropogenic climate change in the form of sea level rise and increasingly unpredictable and intense weather events.[70] However, these assessments are viewed by mass media outlets as being "overstated," which further undermines efforts to challenge the entrenched skeptics and denialists who are focused on if the uncertainty of scientific claims about anthropogenic climate change really justifies drastic steps to reduce anthropogenic GHGes.[71]

There are various degrees of uncertainty which characterize the nature of scientific claims and ultimately speak towards the manner in which researchers present their findings. Washington and Cook speak to this line of thinking, writing,

> The scientific method is about *probability* rather than certainty. It can thus not be seen as the road to absolute truth. The Universe is not certain, nor is the world or our lives. We may fool ourselves into believing in 'certainty', but it is a delusion. We are all at the mercy of fate or, to put it another way, there is always uncertainty. That is the nature of reality, one that many people tend to deny. Indeed this uncertainty is scary unless one accepts it. Uncertainty is not tidy, it is not black and white, cut and dried. It is messy and pretty random.[72]

This perspective emphasizes that an absence of a collective understanding of scientific uncertainty amongst entrenched skeptics and outright climate change deniers is the product of a

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[69] Ibid, 318.
[70] See IPCC Sixth Report, "Summary for Policymakers," 2021, 8. The IPCC explicitly states in paragraph A.3 that human induced climate change is already occurring in 2021.
[71] William Freudenburg and Violetta Muselli, "Global Warming Estimates, Media Expectations, and the Asymmetry of Scientific Challenge," *Global Environmental Change* 20, no. 3 (2010): 8. https://doi.org/doi:10.1016/j.gloenvcha.2010.04.003. Freudenburg and Muselli show that all IPCC assessments present a confidence interval, essentially a gauge of the uncertainty of their findings, wherein the physical reality
[72] Haydn Washington and John Cook. *Climate Change Denial: Heads in the Sand*. (New York: Routledge, 2011), 6.

rigid framing of the nature of truth in science. Various fields within science and mathematics acknowledge that the randomness and chaos present within the physical world are observable phenomena in *themselves* and are constitutive elements of the Universe.[73] Thus, these ideas inform the formal methods and practices employed in research that seek to provide a more accurate, but not an absolute picture of how we, as humans, view and understand the physical world. With regards to climate change specifically, the research that has been conducted to establish a connection between anthropogenic activity and climate change is premised on the idea that observations of atmospheric carbon concentrations and the global carbon cycle have yet to suggest that humans are unequivocally *not* responsible for the increases in atmospheric carbon levels, rather than the idea that we are *certain* that this is the case.

Providing a robust analysis of uncertainty in climate predictions is generally a complicated task given the fact that in order to make informed policy decisions, political leaders within the United States differ in their approach towards seeing how the scientific data should inform decision making. An entrenched skeptical approach towards using scientific data to inform decision-making is largely concerned with whether or to what extent scientific findings actually demand a social or economic response.

A particularly potent example of an ecological issue that gave rise to great debate is that of acid rain in the northeastern United States. Acid precipitation is attributed to the byproducts of fossil fuel combustion, nitrogen and sulfur, in which these emissions are released into the

[73] See Hena Rani Biswas et al, "Chaos Theory and Its Applications in Our Real Life," *Barishal University Journal* 5, no. 1 & 2 (2018): 123–40. Biswas et al define chaos theory as "a mathematical field of study which states that non-linear dynamical systems that are seemingly random are actually deterministic from much simpler equations" (Biswas et al, 123). Many natural phenomena such as weather patterns, the solar system, and plant and animal populations exhibit chaotic behavior.

atmosphere and return to the landscape in the form of nitric (HNO_3) and sulfuric (H_2SO_4) acid diluted in precipitation.[74] The ecological problem that this pollution presented had economic implications for the forested ecosystems of the Northeastern United States and parts of Canada, in which said ecosystems provided valuable resources for stakeholders, such as tourist attractions and stable watersheds that formed the drinking water supply of thousands of communities. However, the scientific assessment of this issue was met with political opposition from the Reagan Administration, who characterized the science in mass circulation outlets as not being a significant problem and too expensive to fix. This perspective disregarded the fact that the evidence of acid precipitation and its deleterious effects on forested and aquatic ecosystems was compiled by a broad swath of scientists from industry, government, and academic backgrounds, in the White House Office of Science and Technology Policy (OSTP), who had come to a strong consensus about the causes and prescient severity of acid rain.[75] This context gives a more nuanced perspective of how scientists from across different sectors had collaborated to evaluate a pervasive and burgeoning ecological issue and recommended sensible changes that could be made to mitigate further consequences.

Scientific advisors to the Reagan Administration who opposed the policy suggestions for limiting damaging effects of acid rain emphasized that the uncertainties around the extent of the damage that acid precipitation could cause did not warrant more regulation of the actors identified as being responsible for this problem, namely that of electric power plants. The scientific conclusion reached by scientists with a variety of different backgrounds was essentially

[74] Oreskes, *Merchants of Doubt*, 68.
[75] Oreskes and Conway, 78.

being challenged based on the notion that the effective solutions to acid rain did not consist of more regulation of the energy sector, stalling any comprehensive legislation from being drafted to address the problem.[76] In this sense, action on acid precipitation was stymied because opponents to the findings of the OSTP report on acid rain believed that the scientists involved were motivated by a desire to enact more control of the energy market, when in reality, they were simply trying to advocate for the protection of invaluable ecological resources.

An examination of the role of values in science by philosopher of science Helen Longino will help us to understand, in real terms, the social dimension of scientific investigation and interrogate what this means for the integrity of scientific claims. Longino writes that,

> …the values generated from an understanding of the goals of science [are] *constitutive* values…[in] that they are the source of the rules determining what constitutes acceptable scientific practice or scientific method. The personal, social, and cultural values, those group or individual preferences about what ought to be,…[are] *contextual* values…[in] that they belong to the social and cultural environment in which science is done.[77]

The distinction that Longino makes between *constitutive* and *contextual* values suggests that scientific integrity and the epistemological grounds for scientific claims are difficult to square with the explicitly socially defined values that might appear to affect the autonomy of a given researcher. However, when we consider the role of social values in scientific research, specifically in the case of acid precipitation, the scientists involved in characterizing the phenomenon were undoubtedly concerned that it could have wide-reaching consequences. Longino explains that the influence or use of *contextual* values on the justification of scientific claims could undermine the rationality of the scientific argument.[78]

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[76] Ibid, 101.
[77] Helen Longino. *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry*. (Princeton: Princeton University Press, 1990), 4.
[78] Longino, *Science as Social Knowledge*, 9.

Opponents of the scientific reports and assessments of acid precipitation were ultimately arguing that the *contextual* values, such as the concern for protecting forested and aquatic ecosystems, undermined the justification that the scientists employed to legitimize their claims. This perspective does not recognize or appreciate the fact that implicit in the methodology of scientists and the production of knowledge is the social character of the scientific process where interactions between individual researchers are "shaped by social relations existing among those individuals."[79] These interactions are unequivocally influenced by these "individual[s'] social and cultural context[s]" and thus should not be regarded as necessarily damaging to the credibility and truthfulness of the claims of the scientific community.[80] The framework for critically evaluating scientific claims will not effectively address the explanatory or epistemic power of said claims if the grounds for refuting them are entirely based upon the notion that science as a whole is corrupted by *contextual* values. At a time when American society finds itself polarized over the nature of truth in issues of great import for our ecosystems and the Earth's climatic regime, a simultaneous consideration of the role that both *contextual* and *constitutive* values within different scientific disciplines generates a much more enriching and productive discussion about scientific integrity and the autonomy of researchers.

Employing productive skepticism about what constitutes scientific integrity entails that we have a pluralistic perception of the scientific enterprise, wherein we do not fall into the trap of believing that any semblance of contextual values detected in motivations for scientific research means that we cannot trust a researcher's findings. Initial questions about the

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[79] Ibid, 231.
[80] Ibid.

phenomena of anthropogenic climate change did not begin with a desire to dismantle the fossil fuel industry and stymie economic prosperity within the United States. One of the first official warnings about the potential consequences of greenhouse gas emissions, with an emphasis on carbon dioxide, was published in the 1965 report *Restoring the Quality of Our Environment: Report of the Environmental Pollution Panel* by President Lyndon Johnson's Science Advisory Committee.[81] Appendix Y4, titled Atmospheric Carbon Dioxide, of this report was devoted to discussing the implications of burning fossil fuels based on the scientific understanding of the Earth's atmosphere at the time.

The authors of Appendix Y4 directly identify the burning of fossil fuels by humans, which they note have been locked within sedimentary rock for an excess of five hundred million years, as contributing to increases in the concentration of atmospheric carbon in the form of carbon dioxide.[82] This observation comes out of a rudimentary understanding of the chemical composition of fossil fuels; such as coal, natural gas, and crude oil; and therefore what the byproducts of the combustion of said minerals are. The information and measurements that the authors of this section use to illustrate this phenomenon of atmospheric carbon were produced by researchers over the course of close to one hundred fifty years. Using this information, which was derived from atmospheric scientists from across the globe and several different time periods, the authors conclude that "fossil fuel combustion has been the only significant source of CO_2 added to the ocean-atmosphere-biosphere system."[83]

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[81] Roger Revelle et al., "Restoring the Quality of Our Environment: Report of the Environmental Pollution Panel President's Science Advisory Committee: Appendix Y4" (White House, November 1965), 111. https://www-legacy.dge.carnegiescience.edu/labs/caldeiralab/Caldeira%20downloads/PSAC,%201965,%20Restoring%20the%20Quality%20of%20Our%20Environment.pdf.
[82] Ibid, 112-3.
[83] Revelle et al, "Restoring the Quality of Our Environment," 131.

At the time, the authors of Appendix Y4 could only speculate as to what the potential deleterious consequences that an increase in the concentration of CO_2 would have on Earth's climate, but ultimately what this publication illustrates is that establishing the scientific basis for understanding how combustion of fossil fuels is connected to the concentration of atmospheric CO_2 was, and still is, built upon an understanding of earth's geological history. There are several different positions that one could hold on the matter of anthropogenic climate change. Entrenched skeptics may acknowledge that the scientific observations may be accurate, but are not convinced that the climatic trends extrapolated from climate data are predictive of future changes to the global climate. Climate deniers reject scientific explanations of the primary mechanisms driving climate change and do not agree that major changes to their personal, or our collective way of life in the United States, are warranted, let alone necessary, to stave off some of the worst-predicted effects of climate change. Since the 1965 Appendix Y4 report, it has become increasingly clear that these positions against anthropogenic climate change are not rationally defensible, given that the basic scientific concepts which structure our understanding of how concentrations of carbon in the atmosphere result in warming and thus influence climatic trends have remained relatively unchanged in the last 50 years.

The IPCC is an example of a body of scientists and government officials who, using the cumulative knowledge of our Earth's planetary systems that has been developed by humanity over the course of our collective history, are guided by a firmly-established value system. More specifically, their epistemology and methodology by which they measure the uncertainty of their predictions about the potential impacts of atmospheric climate change is informed by the understanding that their claims have wide-reaching implications for our civilization and the ecosystems that sustain us. The IPCC's most recent assessment from 2021, their Sixth Assessment Report, stands as a testament to the scientific community's ever-louder calls for action to be taken against anthropogenic climate change. The *Summary for Policymakers* is a list of definitive statements about several aspects of the current state of the Earth's climate in which the authors use specific phrases to communicate the uncertainty of their claims regarding the connection between anthropogenic greenhouse gas emissions and observed and predicted changes to Earth's atmosphere, oceans, and land. Critical to communicating these observations to a broad audience is establishing a basis for which the uncertainty of said claims is measured. They write that

> Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or result: virtually certain 99–100% probability; very likely 90–100%; likely 66–100%; about as likely as not 33–66%; unlikely 0–33%; very unlikely 0–10%; and exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%; more likely than not >50–100%; and extremely unlikely 0–5%) are also used when appropriate.[84]

The IPCC defines confidence "a qualitative measure of the validity of a finding, based on the type, amount, quality and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement" and likelihood as a quantified measure of confidence that is expressed probabilistically.[85] From an epistemological standpoint, these likelihoods indicate with a specific degree of uncertainty that phenomenon A is directly responsible for phenomena B. Thus, this establishes a concrete basis for the claims that the AR6 authors make. For example, the authors of the *Summary for Policymakers* state,

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[84] IPCC Sixth Report, "Summary for Policymakers," 2021, 4.

[85] IPCC Sixth Report, "Technical Summary," 2021, 13.

> Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO2), 1866 parts per billion (ppb) for methane (CH4), and 332 ppb for nitrous oxide (N2O) in 2019. Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO2 emissions from human activities over the past six decades, with regional differences (*high confidence*).[86]

The authors explicitly state that, based on widespread agreement and the judgment of climate scientists, that human activities, taken here to mean the combustion or release of fossil fuels, are directly responsible for the observed increases in the aforementioned greenhouse gasses. The epistemic framework which supports this claim is not merely the observation of the atmospheric concentration of GHGs in conjunction with measuring anthropogenic GHG emissions. An entrenched skeptic might accept this statement as being consistent with reality, but go on further to doubt that these observations should animate widespread and swift societal changes for the purpose of reducing GHG emissions. A climate denier may reject that human activities and atmospheric GHG concentrations are even connected to begin with, under a painfully flawed assumption that humanity does not wield such an influence over the Earth. It is important to acknowledge that examining these positions reveals an unwillingness on the part of entrenched skeptics and denialists to reconcile with the capabilities of humanity to understand and subsequently control the natural world.

This explanation of how the authors of the Sixth Assessment Report, or AR6, define “likelihood” is given via a more developed understanding of how anthropogenic greenhouse gas emissions contribute to climate change than what was discussed in Appendix Y4 of the 1965 Report of the President’s Science Advisory Committee. The connections that are drawn between

[86] IPCC Sixth Report, “Summary for Policymakers,” 2021, 4.

greenhouse gas emissions and atmospheric, oceanic, and land surface temperatures are not merely explained correlatively.

Epistemically, the physical science basis for the mechanics of anthropogenic climate change is built upon a more complex understanding of the physical world where various laws and scientific principles work in concert to characterize the causative elements of this phenomenon. There exists an interwoven web of well-tested theories and systems of thought within science which is solely the product of collaboration between individual researchers across space and time. If one thinks of science as a social process imbued with a system of values that emphasize the importance of quantifying uncertainty in ones' findings, this understanding of scientific process shows that science is equipped to make informed suggestions which can guide policy measures meant to protect, preserve, and improve humanity's collective lifeways. The entrenched skeptics and denialists who refute that anthropogenic climate change exists, especially with regards to humanity's responsibility for the phenomena, are either not aware of or do not acknowledge the self-regulating mechanisms built into scientific research which evaluate the epistemic strength of different claims.

Productive skepticism encourages us to question how and why we can state what we have held to be the truth about anthropogenic global warming. Herein lies the complicated endeavor of showing why consensus in the scientific community is epistemically valuable. Principally, we can see that the scientific enterprise is characterized by the idea that a single investigator within the scientific community is ultimately beholden to the, using Kuhn's term, paradigm which has been established before them. They operate within this paradigm. Thus far, no other paradigm has successfully challenged the existing climate science paradigm, or gained currency with a group of climate scientists, which upends the prevailing theory that anthropogenic GHGes are the primary drivers of observed global warming trends. Thus, we can explicitly see how the consensus that exists across several scientific bodies, with the IPCC representing one of largest groups of scientists from across the world, about the distinctly anthropogenic causes and the observed effects of global warming offers a strong rebuke to any alternative theory of global warming. If any such alternative theories existed, we could almost certainly expect to see them vigorously debated in scientific literature, however this is not the case.[87] A productive skeptical outlook cannot possibly reject the scientific consensus on anthropogenic global warming on the presumption that all climate scientists justify their findings based on their contextual values. A pluralistic view of climate science and the scientific enterprise in general illustrates that while there are constitutive values within these communities, it is unreasonable to think that all of these scientists from all over the world use their diverse contextual values to justify their scientific claims.

We also must acknowledge the fact that the personal motivations, social values, and ethical predispositions of scientists absolutely play a role in the focus of their research. However, this does not automatically mean that their findings are thus biased and unreliable. Such a proposition is ultimately a demonstration of the myth of objective science, in which scientists

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[87] See Naomi Oreskes, "The Scientific Consensus on Climate Change: How Do We Know We're Not Wrong?," in *Climate Change: What Is Means for Us, Our Children, and Our Grandchildren*, ed. Joseph DiMento and Pamela Doughman, 2nd ed. (The MIT Press, 2014), 105–48, https://www.jstor.org/stable/j.ctt9qf76d.8.
See also John Cook, et al, "Consensus on Consensus: A Synthesis of Consensus Estimates on Human-Caused Global Warming," *Environmental Research Letters* 11, no. 4 (April 13, 2016), https://doi.org/10.1088/1748-9326/11/4/048002.
See Krista Myers, "Consensus Revisited: Quantifying Scientific Agreement on Climate Change and Climate Expertise among Earth Scientists 10 Years Later," *Environmental Research Letters* 16 (October 20, 2021): 1–10.

have stressed that trust in scientific findings is built upon a value-neutral, or value-free, framework when, in fact, it is quite the opposite. On this matter, Oreskes asks,

> Would you trust a person who has no values? The answer is obvious: you would not…Nor would you trust a person whose values you considered to be an anathema to your own. But if you thought that person shared at least some of your values–even if perhaps not all of them–you might be willing to listen. And you might accept some of what you were hearing.[88]

When conducting scientific research that could have broad implications for human, ecological, or planetary health, researchers will make claims that contradict or are seemingly incommensurate with someone's personal beliefs. Identifying shared values between people is ultimately a more effective way of promoting meaningful communication and building trust between otherwise ideologically opposed groups. Additionally, the value-fact distinction within epistemological discourses about the veracity of scientific findings becomes clearer when one considers how constitutive and contextual values, by nature of the social dimension of scientific investigation, are integrated within scientific inquiry.

Scientific literacy amongst the general public has been stymied by the lack of attention paid towards educating the American public about the scientific process itself. The dissemination of operational or technical knowledge of the phenomena of the physical world does not accomplish the goal of helping non-scientists to contextualize and view in a nuanced manner the active, or continual, process of scientific investigation. There is also the critical idea that the public, and especially elected officials, must acknowledge that practitioners of science belong to the same cultural and social communities that non-experts do and thus possess some of the same social values. Helen Longino articulates the epistemological framework upon which scientific

[88] Oreskes, *Why Trust Science?*, 154.

knowledge is generated to elucidate the physical world particularly well. By emphasizing that science is a social process, Longino explains that,

> What is called scientific knowledge, then is produced by a community (ultimately the community of all scientific practitioners) and transcends the contributions of any individual or even any subcommunity with the larger community. Once propositions, theses, and hypotheses are developed, what will become scientific knowledge is produced collectively through the clashing and meshing of a variety of points of view.[89]

Here, Longino speaks towards an understanding of scientific investigation as a process where no single figure within their respective field takes precedence over others when one considers that all work is subject to the scrutiny of their peers. Longino uses the phrase "clashing and meshing" to describe the arduous process of critical evaluation within the sciences to produce what can then be viewed as preliminary results of an analysis of a particular phenomenon or complementary to other lines of investigation into burgeoning topics of consideration. Ultimately, what we can see is that scientific knowledge is not produced in a vacuum or discursive manner. This is not to say that contentious disagreements over explanations for certain phenomena do not occur within the sciences, but rather that we should recognize that implicit in the methodology of critical analysis of scientific literature is the desire to challenge arguments that lack rigorous lines of reasoning or employ tenuous modes of empirical observation, such as how a study is designed based on the hypothesis that is proposed.

Elke Weber, professor of psychology at Princeton University, and Paul C. Stern, president of the Social and Environmental Research Institute, explain that public understanding of climate change in the US is unlikely to be improved by simply introducing more scientific information to expand the breadth of an individual's understanding of this phenomenon. They write,

> U.S. adults who doubt that climate change is happening, is anthropogenic, or presents serious risks should be assumed not to have a deficit of knowledge but rather to have different understandings.

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[89] Helen Longino. *Science as Social Knowledge,* 69.

> Individuals holding mental models that conflict with the available scientific evidence are not a blank slate, as the metaphor of illiteracy suggests, so the needed educational process is not one of adding to knowledge but one of inducing conceptual change.[90]

Weber and Stern further substantiate the idea that science literacy should not be reduced to simply the acquisition of knowledge. Rather, they believe that improving the American public's understanding of climate change should happen on an epistemic level where people are encouraged to engage with the scientific frameworks which justify the existence and reported implications of anthropogenic climate change.

Expanding scientific literacy in the American public unequivocally involves ubiquitous science education. However, focusing science communication and education efforts solely on the acquisition of what some might refer to as "settled" scientific knowledge does not adequately address the social and practical dimensions of scientific research and how said research becomes knowledge. Supplying the public with the tools to be able to engage with scientific literature directly will help to dispel inaccurate summations or interpretations of scientific studies whilst working towards rooting out entrenched skepticism and science denialism. This should be done primarily with the goal of addressing the urgency of anthropogenic climate change and challenging the entrenched skeptical and denialist positions that are adopted against this phenomenon.

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[90] Elke Weber, and Paul Stern. "Public Understanding of Climate Change in the United States." *The American Psychologist* 66, no. 4 (May 2011): 323.

Conclusion : Scientific Literacy (Re-emphasized)

This project demonstrates that the normative response to climate change from the American public and from some political leadership within the United States has not given sufficient credence to the plethora of scientific assessments from international scientific bodies like the IPCC and committees from domestic bodies like the NAS. These bodies have consistently advocated for an international commitment to drastically lower anthropogenic GHG emissions in an effort to slow the observed, and predicted, rate of global warming.

Entrenched skepticism and denialism within the American public is a product of great missteps which have been made in science communication efforts to improve science literacy. The "knowledge-deficit" model used to characterize the perspectives of individuals who embrace entrenched skepticism or denialism towards certain explanations of scientific phenomena, like anthropogenic climate change, fails to fully incorporate the methodologies employed in scientific investigations and the conceptual frameworks which structure our understanding of physical science.[91] Additionally, the social character of scientific knowledge is largely not identified in discussions of scientific literacy as a critical aspect of how the epistemic strength of scientific claims are evaluated.[92] I have argued that communicating the urgency of anthropogenic climate change and the threat that it poses to human civilization requires a reevaluation of the

[91] Weber and Stern, "Public Understanding of Climate Change in the United States.", 323.
Weber and Stern also propose that there are other means by which people can be motivated to limit fossil fuel consumption that do not involve improving their scientific understanding of the phenomenon of climate change (Weber and Stern, 325).
See also Emily Howell and Dominique Brossard, "(Mis)Informed about What? What It Means to Be a Science Literate Citizen in a Digital World," *Proceedings of the National Academy of Sciences of the United States of America* 118, no. 15 (April 5, 2021): 8, https://doi.org/10.1073/pnas.1912436117. Howell and Brossard illustrate that efforts to improve science literacy should work to educate people about the "science information lifecycle", especially with regards to "civic science literacy which should include understanding of the many elements that shape the production of scientific knowledge, such as the people, institutions, training, resources, methods, and norms of science" (Howell and Brossard, 1-2).
[92] Weber and Stern, "Public Understanding of Climate Change in the United States.", 318.

American public's relationship with the scientific enterprise. Thus, my concluding question is: how do we use a more comprehensive understanding of science literacy to challenge the epistemic positions of entrenched skeptics and denialists on anthropogenic climate change?

Historian and sociologist of science Susan Lindee, offers an extensive analysis of how scientific knowledge is applied ubiquitously across many domains of modern life in the United States, yet distrust in scientific findings is still persistent.[93] Lindee believes that this is a leverage point in debates about the contentious scientific issues given that, presently, in our everyday lives

> We depend deeply on science that works and we traditionally do not think about this fact. We often casually "naturalize" the technological world derived from knowledge systems, in practice severing things like frozen peas from the systems of laboratory knowledge that make them possible. But the systems of knowledge implicated in frozen peas are vast, almost astonishing: Modern geological sciences in the oil and gas industry, the chemical development of plastics, scientific agriculture and the genetic modification of crops, chemical understandings of the freezing process…Frozen peas are saturated with reliable truth.[94]

Lindee effectively shows that divorcing technology from the scientific discoveries and theories that helped to make said technology possible is a naïve perspective of the scientific "reach" of humanity, in that common features of our contemporary lives are testaments to the explanatory power of science. The complex web of scientific concepts that Lindee describes is an overwhelmingly powerful statement about the interconnected nature of the physical sciences. These systems are reliable and, in another sense, trustworthy.

Lindee uses the example of frozen peas to argue that distrust in science on contentious issues like climate change exists in tandem with a deep, but subconscious, trust in the scientific principles which are applied to everyday technologies, creating a state of cognitive dissonance. It

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[93] Susan Lindee, "The Epistemology of Frozen Peas: Innocence, Violence, and Everyday Trust in Twentieth-Century Science," in *Why Trust Science?* (Princeton: Princeton University Press, 2018), 163.
[94] Ibid,165.

seems as though Lindee herself is perplexed by this fraught relationship that people have with trusting science when she writes,

> One of the struggles of all social theory is to find a perspective from which the waves and gravity can be detected, the water we swim in experienced–a problem Einsteinian in its dimensions. Where should we stand to understand the problem of trust? What are the right questions?[95]

Lindee evokes the sentiment of the parable of the fish told by literary great David Foster Wallace in his commencement address to the 2005 graduating class of Kenyon College, in which he implores the graduates to consider the "banal platitudes" of "day to day life."[96] In this sense, Lindee's metaphor of "the water in which we swim" is symbolic of the "banal platitudes" of our deeply technological world, but seemingly we are still confused by what exactly the existence of this technology represents and the knowledge that informs it. In essence, we are faced with the larger issue of how to establish trust in science amongst non-scientists when the principles and concepts which we regularly engage with are not readily knowable. Lindee argues that "Many who question climate change or vaccines are more than happy to deploy drones as technologies of war…Drones depend on historically layered and clustered types of scientific theory and practice going back many decades."[97] The acceptance of scientific concepts and the explanatory power of science is implicit in the use of technology, but individuals still selectively trust and mistrust science. Thus, we should recognize that the "legitimacy [of] the enterprise of

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[95] Lindee, "Epistemology of Frozen Peas," 175.
[96] See David Foster Wallace, "Transcription of the 2005 Kenyon Commencement Address" (Address, May 21, 2005), https://web.ics.purdue.edu/~drkelly/DFWKenyonAddress2005.pdf.
Wallace's parable of the fish: "There are these two young fish swimming along and they happen to meet an older fish swimming the other way, who nods at them and says 'Morning, boys. How's the water?' And the two young fish swim on for a bit, and then eventually one of them looks over at the other and goes 'What the hell is water?'" (Wallace, 1).
[97] Lindee, 179.

science-in-general" cannot be overturned based purely on, to use Longino's term, contextual values.[98]

Recognizing humanity's achievements on the technological front also demands that we acknowledge the consequences of the awesome power that our understanding of the physical world can yield. The advent of nuclear weapons is a particularly potent example of how humanity has reached a point in our collective history when, almost instantaneously, we could cause the extinction of our species and concomitantly a great deal of life on Earth. This total destructive capability that we possess is terrifyingly irrational. The scientific process, characterized by a deep commitment to reason, has given rise to monumental discoveries such as quantum mechanics and special relativity, both enormously powerful conceptual frameworks that expanded the breadth and depth of our understanding of the physical world. However, in a twisted sense of what many would consider to be scientific progress, these discoveries had also led humanity to the grossly irrational position of being capable of true self-destruction. The Trinity Test, the first detonation of an atomic weapon, was yet another juncture in human history when scientific discovery and research had led to technological innovations that could cause incomprehensible human suffering.

In order to fully acknowledge how scientific concepts are capable of explaining physical phenomena, we must fundamentally accept that nuclear weapons are morbid testaments to the power of scientific reasoning and the scientific process. However, we must also recognize the voices and perspectives of the scientists who helped to develop nuclear weapons and subsequently, following the bombing of Hiroshima and Nagasaki in August 1945, called for

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[98] Lindee, 179..

nuclear weapons to never be used in warfare as this would almost certainly result in a mass extinction event.[99] Implicit in these perspectives is the function of the social character of scientific communities, in which scientists employ their epistemologies to help guide the decision making process around scientific issues with massive social implications.

Anthropogenic climate change represents yet another issue, with definitive consequences for human civilization, that the global community faces in the 21st century. The response of American society to scientific assessments made by the IPCC about the future of the global climate given warming trends primarily driven by anthropogenic GHGes is heavily influenced by persistent entrenched skepticism and outright denialism which rejects or strongly challenges the different aspects of the broad scientific consensus on climate change. The potential for anthropogenic global warming due to GHGes has been evaluated for close to 60 years, with one of the first official warnings about the phenomenon being published in 1965 by climate scientist Roger Revelle and colleagues on President Lyndon Johnson's Science Advisory Committee.[100] Since then, the IPCC has published five assessment reports, with the first in 1990 stating that "unrestricted fossil fuels use would produce a 'rate of increase in global mean temperature during the next century of about .3ºC per decade; this is greater than that seen over the past 10,000 years.'"[101] The scientific consensus around anthropogenic global warming has only become more robust 30 years since the publication of the IPCC's Assessment Report 1 (AR1),

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[99] See Rhodes, "Tongues of Fire" in *The Making of the Atomic Bomb*, 958-1053. Rhodes details the final stages of the deployment of Little Boy and Fat Man to their respective targets, Hiroshima and Nagasaki in Japan in August, 1945.
[100] See Revelle et al., "Restoring the Quality of Our Environment: Report of the Environmental Pollution Panel President's Science Advisory Committee: Appendix Y4," 112-33.
[101] Oreskes and Conway, 189.

with following reports, such as the recently published AR6, essentially confirming the predicted warming due to anthropogenic GHGes.[102]

Entrenched skeptics might be convinced that anthropogenic global warming is occurring, but to disregard or challenge the proposition that this will affect the Earth's overall climate and oceans, particularly with regards to sea level rise, is to ignore the scientific understanding of our Earth's atmospheric systems.[103] Of course we cannot unequivocally state that the Earth's climate *will* respond in the way that we believe, based on geophysical concepts and mathematical modeling, to be true. Then again, the American public regularly exercises trust in scientific practices, particularly in the form of precipitation models which are generated using some of the same modeling principles and model selection frameworks employed by climate scientists.[104] In this sense, we find ourselves at another point where we are surrounded by examples of scientific knowledge which is passively trusted and has great utility in our lives, where in the previous example there is a direct connection between weather and climate modeling. Emphasizing these points of connection between scientific disciplines is likely to be effective in uplifting the notion that the "enterprise of science-in-general," using Lindee's term, can be found in all different areas of our daily lives.[105]

If we seek to expand our conception of what it means to be scientifically literate, we must work to understand the implications of scientific findings and research in the 20th and 21st centuries. This requires us to acknowledge the role of scientific communities in deliberating

[102] IPCC, "Summary for Policymakers," 6. Figure SPM1(b) identifies how observed warming until 2020 has largely been consistent with previously modeled warming trends.
[103] Ibid, 15. Paragraph B.2 states that changes in the climate system, such as the frequency and intensity of hot extremes and heavy precipitation, become larger with global warming.
[104] Goldsby and Koolage, "Climate Modeling: Commenting on Coincidence, Conspiracy, and Climate Change Denial," 237.
[105] Lindee, "The Epistemology of Frozen Peas," 179.

about and gauging the uncertainties of our current knowledge about the physical world. We must also acknowledge the power of the explanatory frameworks which scientists have developed to operationalize and interact with the physical world. Productive skepticism on the part of all scientific investigators is what drives the development of these frameworks in that questioning the epistemic depth of scientific knowledge ultimately produces a more rigorous understanding of the physical world.

Rooting out entrenched skepticism and steadfast denialism around anthropogenic climate change inherently involves engaging with how the scientific enterprise characterizes their uncertainty of the causes of observed climate phenomena. Entrenched skeptics are not necessarily closed off to engaging with the scientific reasoning employed within climate research. Thus, it is likely that if entrenched skeptics recognize the embeddedness of the scientific concepts in our everyday lives, they might realize that trust in climate science is not very different from their trust in the reliability of the technology that they regularly interact with. Deniers differ from entrenched skeptics because they are likely to believe that the scientific process employed to characterize climate change is flawed in ways that compromise the epistemic basis of scientific assessments. Again, this position exists in contradiction to the reality that we depend upon the explanatory power of science throughout our lives. Practicing productive skepticism will help to realize that the scientific concepts which we often unknowingly engage with, are ubiquitous across scientific disciplines. The urgency of climate change demands concrete actions be taken to reduce anthropogenic GHGes. This cannot be accomplished on a societal level if such vast disagreements about the causes and, most importantly, the implications of climate change for human civilization exist between non-scientists and the scientific community.

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