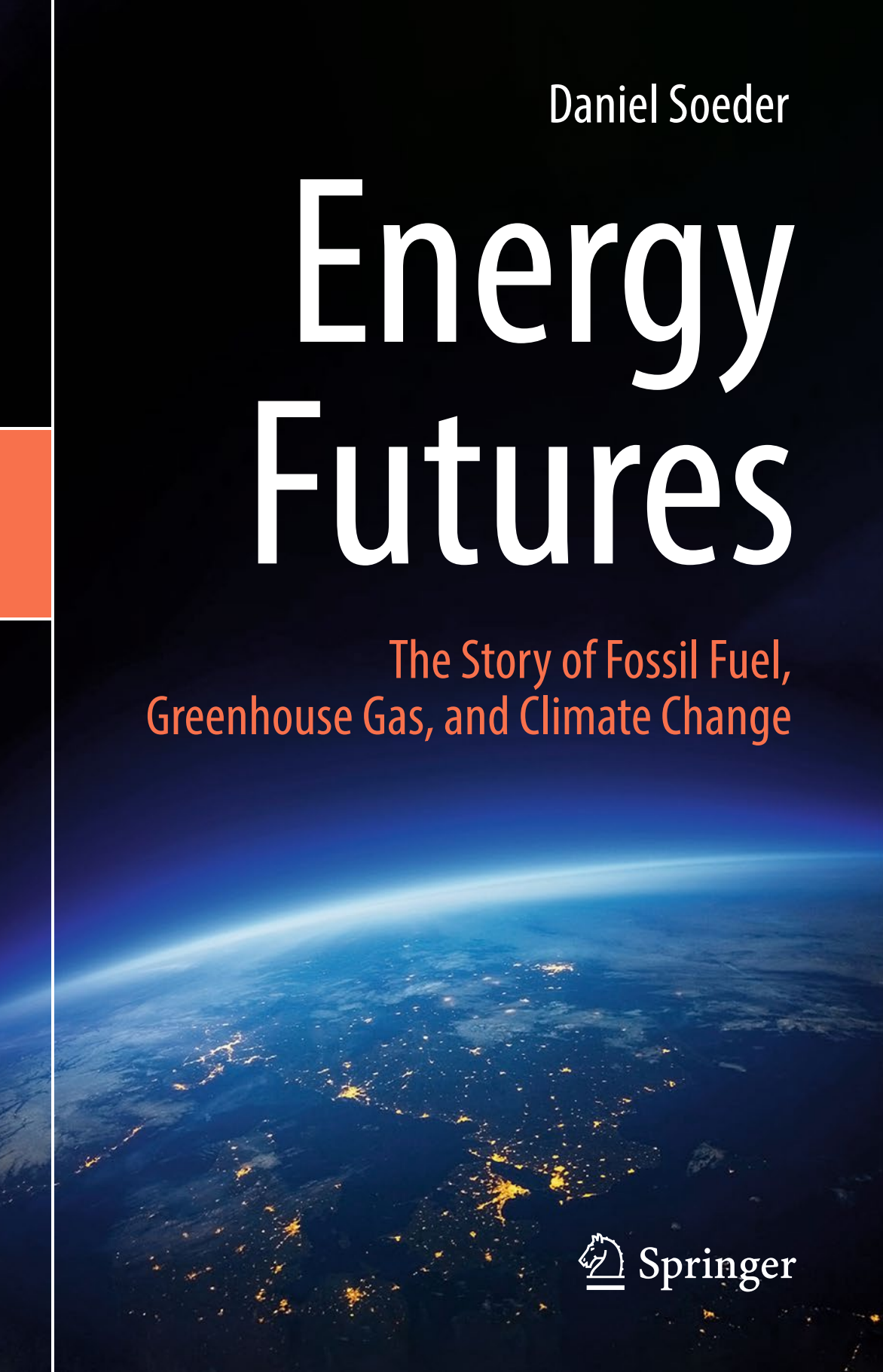
Daniel Soeder

Energy Futures

The Story of Fossil Fuel, Greenhouse Gas, and Climate Change



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The Story of Fossil Fuel, Greenhouse Gas, and Climate Change

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To my grandson, Riley James.

Preface

Energy "futures" are commodities that are bought and sold by stockbrokers. This book is not about those kinds of energy futures, but about the real future of energy, and the choices we have to make. Human civilization is currently on an energy path that is not sustainable. We are eventually going to run out of fossil fuels, but long before we burn the last lump of coal or pump the last drop of oil, we will severely impact the climate and degrade the environment. Decisions we make over the next decade will determine our future a century from now.

Climate change is not a hoax, despite those who claim it is. Burning fossil fuel increases the amount of heat-trapping gases in the atmosphere that warm things up and change the climate. The evidence is clear and compelling. Stronger storms, retreating glaciers, more intense and longer-lived droughts, killer heat waves in unusual places like Siberia, blizzards in unusual places like southern Texas, and huge wildfires are all signs of human influence on climate. Given that humans have changed the flow of rivers, modified coastlines, contaminated vast swaths of groundwater, polluted the oceans with plastic, created hazardous air in cities, and radically changed landscapes, how can anyone doubt that our actions are also affecting the climate?

Climate issues are complex, politically charged, and often either innocently or deliberately misunderstood. There are copious amounts of both information and disinformation on social media, blogs, podcasts, and in old-fashioned written documents. Sorting it out can be a challenge. Ordinary people need to understand climate because the issue affects us all. Most existing books and articles on climate change tend to approach it with either overly simplified stories (that are sometimes inaccurate) or dive deeply into complex technical explanations that almost require a PhD to understand. My entry into this field attempts to accurately explain the causes and effects of climate change in a manner understandable to most members of the general public along with providing some suggestions for practical solutions to fix the climate crisis.

Denial and resistance from the fossil fuel industry and their political supporters are intended to delay climate actions and maintain our dependence on fossil energy. Their goal seems to be for society to continue filling industry coffers with profits

until civilization collapses. What we are all supposed to do after that is never quite made clear in the narrative.

Some people react to the climate crisis with indifference, while others wring their hands in despair and say we're all doomed. The problem with both of these extremes is that nothing gets done. On the one hand, ignoring the climate crisis won't stop heatwaves or drought-driven wildfires. On the other, I will remind those in despair that every doomsday prediction throughout history has been wrong and this one almost certainly is wrong as well.

The climate can be fixed, and it must be fixed. We know exactly what caused the problem and we know exactly what must be done to address it. The cause was technology, and technology can solve it. First, we must replace fossil fuels with clean, sustainable energy to keep the problem from getting worse. Many of these clean energy technologies either already exist or will become practical quickly with an infusion of funding. A process called geoengineering can then be used to employ existing technology to reduce the concentrations of greenhouse gas in the atmosphere to pre-industrial levels. A determined effort backed by undeniable facts is needed, and research on both clean energy and geoengineering would move faster if governments gave it the funding and the urgency they give to defense programs. We are in big trouble here, and every delay adds challenges and costs.

In the four decades since the issue of human-induced climate change became widely understood, neither the fossil fuel industry nor the "free market" took any action to address it. The only option remaining to make the changes necessary to avoid the worst consequences of the climate crisis is government policy. Thus, it is critical for the concerned citizens of all nations to be informed and knowledgeable about the details of fossil fuels, greenhouse gas, and climate change. We have seen time and again that when enough citizens demand that their government do the right thing, changes are made. Indeed, in the United States, civil rights, gender equality, voting rights, workplace safety rules, environmental laws, affordable medical care, and the lifting of racial and gender marriage restrictions all came about because people demanded them from political leaders. The climate crisis requires the same level of commitment, if not more.

An informed populace can push on government officials to act. Politicians of all stripes and all parties everywhere have a tendency to dodge or change the subject when asked difficult questions. Knowledgeable constituents give them less room to maneuver. There is no doubt that dealing with the climate is challenging and will cause some political pain. Many political leaders seem eager to produce a sound bite about the urgency of the climate crisis but then leave the politically unpopular and hard decisions for someone else. This is unacceptable, and we need leaders who will take a stand today to address climate change.

It is impossible to write a book about climate and government policy without expressing some opinions. I have been careful to identify my opinions as such, and separate them from the straight, factual information. The more important facts are referenced, but I've tried to use these sparingly because I find excessive references distracting when reading a book. Climate science, like most science, has a lot of specialized acronyms and terms. Hopefully, these are kept to a minimum – so

readers are not swimming in alphabet soup – and each is defined at first use. There is also a glossary included at the end for quick reference. The only acknowledgement I want to offer is to the readers of this book. Thank you for making the investment in time, money, or effort to learn about the climate crisis. It's important.

Maybe you've heard of me; maybe you haven't. I spent 45 years as an Earth science researcher and educator, and I have explained a lot of things to a lot of people. I think I've gotten pretty good at it, including publishing three other books prior to this one. I've worked on oil and gas, nuclear energy, groundwater, and environmental issues. I know a few things about energy and climate. If you don't trust me, trust the references. I have tried to keep the text accurate, but as they say when there is a flaw in a Persian carpet, "Only Allah is perfect." Since this is the first edition, there will be an opportunity to correct mistakes in future editions, and I would appreciate knowledgeable readers pointing these out.

The climate crisis is the existential threat of our times. Certainly, people have survived some bad things in the past like world wars, pandemics, and economic downturns, but the climate crisis could overshadow all of these. The only equivalent thing I can think of is a full scale nuclear war. Both will leave large swaths of the planet literally uninhabitable.

Unlike many of the other crises, we know this one is coming. If we don't act, we have no one to blame but ourselves. Advance warnings about climate were being forecast by primitive computer models in the 1980s, most of which under-predicted the severity of the effects. Things have actually turned out to be worse, and our current, much more sophisticated computer models show some really bad scenarios in the future if we don't change.

A smart deer in the road recognizes that the headlights of an oncoming car are an obvious, imminent danger and gets out of the way. The not-so-smart deer ends up as roadkill. Which one are we?

Tunnelton, WV, USA Daniel Soeder

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About the Author

Daniel Soeder has 45 years of experience as a research scientist and geologist working on issues related to energy and the environment. His background includes a decade of research on the geology of natural gas resources at the Gas Technology Institute in Chicago, followed by 18 years with the U.S. Geological Survey (USGS) coordinating hydrologic and geologic fieldwork at the proposed Yucca Mountain high-level nuclear waste repository site in Nevada, and researching coastal hydrology, wetlands, water supply, and water contamination in the Mid-Atlantic. He chaired the Scientific and Technical Advisory Committee (STAC) for the Delaware Estuary Program for 3 years. He transferred from the USGS to the U.S. Department of Energy (DOE) National Energy Technology Laboratory in Morgantown, West Virginia, in 2009 where he spent 8 years performing energy and environmental research on gas shale and other unconventional fossil energy resources. He took an early retirement from the government to direct the Energy Resources Initiative at

the South Dakota School of Mines & Technology in Rapid City, South Dakota, from 2017 to 2020, and he currently runs a consulting firm primarily engaged in the geologic sequestration of carbon dioxide. He has authored multiple reports, scientific papers, and three books on shale development and hydraulic fracturing. He has a B.S. degree in geology from Cleveland State University, and an M.S. degree in geology from Bowling Green State University (Ohio). He has three adult children and a grandchild who deserve a better world.

The author at left leading a public tour group on the crest of Yucca Mountain in May 1996. (Photograph by Chuck Savard, U.S. Geological Survey. Used with permission.)

Chapter 1
The Controversy

Keywords Climate change · Climate skeptics · Fossil fuel

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The hot-button question in the first quarter of the twenty-first century is the following: are humans responsible for changing the Earth's climate or not? Nearly all scientists, including me, are fully convinced that burning the fossil fuels that provide 80–90% of our energy emits combustion products into the atmosphere that are contributing significantly to changes in the climate of Planet Earth. This claim is supported by abundant evidence that is obvious, clear, compelling, aligned with the known laws of physics and chemistry, internally consistent, and reproducible. These are all hallmarks of good science. Estimates for the potential future impacts on climate range from "moderate" to "calamitous."

This alarming notion is vigorously rejected as hyperbole by some politicians and business people who claim that human activities are not affecting the Earth at all. They declare that any change in the climate is a natural event that has nothing to do with the combustion of fossil fuels. Those who deny that humans are affecting the climate prefer the term "climate skeptic" to "climate denier." I would like to point out that in order to be a climate skeptic, you must first deny the validity of substantial amounts of detailed and internally consistent climate science. However, I will use the term skeptic instead of denier if it will avoid offending people. Climate skeptics are not going to be happy with this book in any case.

Some scientists aligned directly or indirectly with the fossil fuel industry are among the climate skeptics, providing a veneer of scientific legitimacy to the climate science denial arguments.[1] Pseudo-technical discussions from these people claiming that carbon dioxide emissions from humans are insignificant or that CO_2 emissions don't actually trap heat only serve to confuse the public. This is exactly the purpose. Confusion produces uncertainty, which prevents climate action, preserves the status quo, and allows the fossil fuel industry to continue selling their products at a profit. We will explore the evidence in detail in Chap. 5, but it is

[1] Koonin, Steven E., 2021, Unsettled: What Climate Science Tells Us, What It Doesn't, and Why It Matters: Dallas, TX; BenBella Books, 320 p.

D. Soeder, *Energy Futures*, https://doi.org/10.1007/978-3-031-15381-5_1

important for readers to understand that there are huge amounts of data supporting the notion of human-induced climate change, and very little data that refute it.

Although climate skeptics by and large are closely associated with the very fossil fuels that are the root cause of the problem, they will often present the issue as being unfairly biased in favor of climate change activists. A typical response is to call for a more "balanced" approach to invoke a notion of fairness for allowing equal time arguments on each side, even though one side has way more evidence than the other. Skeptics will also promote a sense of uncertainty about the validity of the data and urge caution about not jumping to conclusions with so much that is unknown. Their arguments often finish off with a claim that "the science is not settled" in response to climate scientists supposedly saying that it is.

If this playbook sounds familiar, it should. This is the same approach used for years in religious arguments against teaching evolution and the true age of the Earth in public schools, by anti-vaxxers against vaccine effectiveness, and others opposed to certain aspects of established science. Even the Flat Earthers have used these tactics in the face of overwhelming evidence that the Earth is, in fact, a sphere. We have photographs to prove it.

The truth is that scientists have never claimed that climate science is settled because that is not the way science works. Scientists acknowledge that there is always some uncertainty in science, and human-induced or "anthropogenic" climate change is no exception. The public often equates uncertainty to a lack of knowledge because there are many instances in everyday life where uncertainty is considered a bad thing. For example, I doubt anyone would want to get on an airplane with pilots who were uncertain if they had enough fuel to reach the intended destination. However, uncertainties in science are expected and part of the process. There is always the possibility that some new discoveries will come along and change your conclusions. So most scientists leave room for argument and rarely speak in absolutes, but that doesn't mean we are clueless.

The uncertainties in climate result from complex atmospheric models and the varying probability of different kinds of responses to a warming atmosphere. There isn't much doubt that anthropogenic climate change is happening, and that things will be getting bad, but it is more of a question along the lines of "just how bad are they going they get?"

The phrase about climate science being "settled" is a misquote from former President Bill Clinton, who actually said, "The science is clear and compelling: We humans are changing the global climate." Clear and compelling is not the same as settled. Nevertheless, a strawman argument ginned up in the 1990s by climate skeptics claimed that arrogant scientists, biased media, and lying politicians were saying the science was settled to cash in on public concerns. Casting the climate scientists as bad guys allowed the climate skeptics to then pursue *ad hominem* attacks against their opponents rather than argue about the scientific merits of the issue. Dr. Michael Mann at Penn State has been the subject of many of these assaults because of his early warnings about the climate crisis. Attack publications with titles like "Mann-Made Climate Change" have relentlessly criticized the professor. Other prominent climate scientists like Dr. James Hansen at NASA and Dr. Katharine Hayhoe at

Texas Tech have faced similar assaults. The best response I've found for these attacks is to defuse them by agreeing with the person, and then return to the issue at hand. For example, if someone says, "You're an idiot," the reply is "That may be true but it's a different discussion. So how do you explain these temperature data?" If your ego can handle this approach, it is very effective.

Former President Clinton was correct in saying that the science is clear and compelling. Several decades worth of environmental data show that combustion products from the human use of fossil fuels are accumulating in our atmosphere and affecting climate. A review of 88,125 climate-related papers published in the mainstream scientific literature since 2012 found that more than 99% of these publications link climate change to humans.[2] In fact, the claims that there are no links between fossil fuel combustion and climate change are so lacking in supporting evidence that it suggests to me the people who continue to deny the reality of anthropogenic climate change are not motivated by honest scientific disagreements but by something else.

Some climate skeptics claim that such a consensus on the science doesn't necessarily validate it. There are certainly past examples like the seventeenth century consensus that the Earth was 6000 years old and had been subjected to a world-wide flood. These beliefs were widely held based on what was in the bible but did not hold up under actual, physical observations. By the eighteenth century, scholars were developing the "scientific method" still in use today, which requires repeatable observations, interpretations based on multiple working hypotheses, empirical testing, and evidence-based conclusions.

The scientific method was invented because many of the things people were accepting on the basis of religious faith or from the thought experiments of ancient philosophers were flat-out wrong. As a case in point, the ancient Greek philosopher Aristotle thought that it was quite reasonable for a heavier object like a rock to fall faster than a lighter object like a stick. Galileo proved him wrong during the Renaissance by dropping two different size balls from the Leaning Tower of Pisa and both hit the ground simultaneously. Could Aristotle have performed the same experiment from a tower 1900 years earlier? Yes, but he preferred logical discourse instead.

Today, long-standing principles like Newton's laws of motion, Einstein's mass-energy equivalence, and Darwin's rules for natural selection have so much compelling evidence that few people question the validity of the underlying theories. In these cases the science receives wide consensus precisely because it has been so thoroughly validated. Nevertheless, there is always an opportunity to prove Newton wrong and establish a new theory. Such an undertaking would require substantial amounts of new evidence that contradicts everything Newton and those who came after him observed to support his theories. As Carl Sagan often said, "extraordinary claims require extraordinary evidence." Skeptics who claim that the human

[2] Lynas, M., Houlton, B.Z., and Perry, S., 2021, Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature, *Environmental Research Letters*, v. 16, no. 11

combustion of fossil fuels has no effect on the climate need to provide compelling evidence for their case. So far they have not done so.

This is not just an academic debate. The latest climate assessment from the United Nations Intergovernmental Panel on Climate Change (IPCC) has declared a "Code Red" emergency for the world on climate. Climate skeptics are stoking levels of false uncertainty that only confuses poorly-informed citizens and gives political leaders an excuse to delay the tough actions that are needed to avert the worst parts of this looming disaster. Climate change is often described as crossing a threshold that we didn't know existed until after it was crossed. I think a better analogy is a boulder rolling down a hill. The longer we wait, the more momentum it gains and the harder it is to stop. Most climate scientists agree that it is too late at this point to avoid climate change completely, but at least we can make it less bad.

Climate science appears inexact to the average person because the atmospheric circulation system that drives climate is incredibly complex. Climate changes occur naturally over geologic time periods and are caused by solar fluctuations, shifts in the Earth's orbital cycles, drifting continents that change ocean circulation, and erupting volcanoes that affect the atmosphere. Anthropogenic climate change is imposed over this natural background variation and can be hard to single out, although in recent decades the human influence has become more obvious. Climate predictions are based largely on the outputs of sophisticated computer models that analyze and correlate input data to chart the probabilities of future climates. Probability outputs by their very nature provide a range of answers rather than a single, precise answer, and this creates some uncertainty. Climate skeptics exploit these uncertainties in an attempt to get the unwary to question the validity of the entire anthropogenic climate change hypothesis.

Climate and weather are often confused. Weather is an event and climate is a trend, and to understand climate you have to look at weather trends over time instead of single events. For example, abnormally hot temperatures in Siberia in the summer of 2020 were followed by a very unusual and devastating snowstorm that reached as far south as the Texas-Mexico border in February 2021. The following summer, hot and dry Siberia became the location of the largest forest fire on the planet. Places like British Columbia experienced record high temperatures while the western U.S. fell into an intense drought. The Greenland ice sheet is undergoing record melting and the highest point on the ice experienced rainfall for the first time on record instead of snow. Are these events weather or climate? Looked at individually, they could be considered extreme but still normal ranges of weather. Observed as a trend, however, I believe they point to significant changes in the Earth's climate system. When combined with other observed phenomena like the loss of polar sea ice, retreating mountain glaciers, devastating floods, massive forest fires, and record-setting hurricanes, the pattern indicates that these events are related and represent more than just "weather."

Probability and risk are important concepts for understanding climate change. Climate predictions are probabilities, and in my experience the public has an abysmal level of ignorance when it comes to understanding probability. People regularly buy million-to-one lottery tickets because "someone has to win, and it could be me."

Thousands of visitors to Las Vegas arrive with high hopes of hitting the jackpot, ignoring the fact that those fancy hotels were not financed by giving away money in the casinos. They are, in fact, money factories for the owners.

The casino operators understand probability quite well and know that with the odds in favor of the house, even though the players might win some of the time, if a person keeps playing long enough the casino will eventually get all their money. This is why casinos are timeless places with no clocks or windows. They never close. Midnight and noon under the bright lights inside a casino look almost exactly the same. Probability works through repetition: the more often a coin is flipped, the closer the results of heads versus tails will be to the theoretical odds of 50/50. Players receive rounds of free drinks to keep them rooted to the gaming tables or slot machines. The longer you play, the closer you come to the house odds.

I used to live in Las Vegas, and when people seated next to me on airplanes discovered that, they would often ask me for advice on how to win at gambling, or gaming as it is called there (clearly ignoring the fact that a successful high-roller would have been sitting in first class, not in a cramped coach seat next to them). My initial advice was always "don't play" and just enjoy the extravagant shows, lavish buffets, free drinks, and discounted hotel rooms paid for by other people's gaming losses. If they insisted on gambling, I told them to "quit when you're ahead." But of course almost no one does. They keep playing, lose their winnings and more on top of that, and the casinos prosper. Las Vegas is indeed a vacation destination for people who can't do math.

As poorly as probability is understood by the public, I think risk is even less well understood. Risk is defined as the probability of an event multiplied by the consequences. A high probability mishap with minimal consequences such as taking a tumble while ice skating is considered a low risk (although having done that, I can report it is a bit hard on the knees). On the other hand, a high probability mishap with severe consequences, such as driving a car at extreme speeds down a wet highway with sharp curves is considered such a high risk that it is reckless. Even actions with lower probabilities of mishap still can be risky if the consequences are severe. Although skydiving has been done safely by many people for many years and the odds of a parachute failure are low, the consequences of such a failure are so catastrophic that it is still considered risky. As comedian Steven Wright has said, "If at first you don't succeed, skydiving is not for you."

Risk can be lowered two ways: by reducing the probability of a mishap occurring in the first place or by reducing the severity of the consequences if it does happen. Flying used to be considered a high risk back in the 1930s when airplanes crashed on a regular basis. The consequences of an airplane crash still remain severe and in fact may have gotten even worse because of the higher speeds of modern jets, but the commercial airlines have taken so many steps to reduce the probability of a crash that flying is now rated as the safest form of travel.

In contrast, even though the probability of getting into an automobile wreck has not dropped much in the past 50 years, the addition of seatbelts, airbags, and energy-absorbing auto body construction have all reduced the consequences of a collision. A friend of mine's daughter was recently involved in a head-on collision that put her

in the hospital with relatively minor injuries. After extracting her from the wreck, the police stated flatly that if she hadn't been wearing a seatbelt and the airbags hadn't deployed properly, they would have been taking her to the morgue instead of the hospital. Thus, the white-knuckle flier who drives to the airport without wearing a seatbelt clearly does not understand risk.

The IPCC has predicted[3] that if current fossil fuel emissions continue, there is a one in six chance over the next century that the mean global temperature will increase by less than 2.0 °C (3.6 °F) with moderate consequences for the climate. This is not cheery news, because there is also a one-in-six chance that temperatures will increase by more than 5.4 °C (9.7 °F) and cause serious climate disruptions such as killer heat waves and the likely melting of the polar ice sheets that could raise sea levels as much as 80 m (260 feet). This one-in-six probability of a bad outcome has the same odds as Russian roulette, which most people would not consider a low-risk activity. Keep in mind that risk assessment considers both the probability and the consequences. Like Russian roulette, the true risk from climate change is the one-in-six chance of severely bad consequences. In my opinion, that alone justifies doing something about it.

Economics are another important concept in climate discussions. Climate change to date has been addressed primarily with technology such as wind turbines and solar panels to replace fossil fuel electricity, and electric cars to replace gasoline and diesel engines. Despite making some modest inroads, these technologies face an uphill economic battle because fossil fuels are cheaper. This is partly because of the inherent inefficiencies in renewable power supplies versus the economics of scale in large fossil fuel plants. Part of it also stems from tax breaks and subsidies governments give to the fossil fuel industry. As long as fossil is the cheapest energy source, it will be favored. A tax on carbon or increased subsidies for renewables can help level the playing field.

Few people would agree to willingly pay a higher electric bill just because it is good for the environment. However, if humanity is serious about addressing climate change, fossil has to get more expensive to compete with renewables, and the bottom line is that energy prices will increase. Economists call this the "social cost of carbon" and they have been debating for years[4] about how various national economies might be adversely affected by restricting fossil fuels and requiring higher-cost renewable energy. However, when costs of climate change are considered, including more frequent and intense storms, sea level rise, crop failures from droughts, fatalities from heat waves, wildfire losses, and the refugees resulting from these events, the social cost of carbon actually looks relatively cheap. Not dealing with climate change will be a lot more costly than dealing with it.

[3] IPCC, 2018: Global warming of 1.5 °C: An Intergovernmental Panel on Climate Change Special Report (Summary for Policymakers): Geneva, Switzerland, World Meteorological Organization, 32 p., ISBN 978-92-9169-151-7.

[4] Nordhaus, W.D., 2017, Revisiting the social cost of carbon: *Proceedings of the National Academy of Sciences,* v. 114, no. 7, p. 1518–1523; DOI: 10.1073/pnas.1609244114

Another important economic concept is "externalized cost." The combustion products of fossil fuel are vented directly into the atmosphere where they negatively affect the climate. It is the cheapest way of getting rid of them, but the damage being done to the environment is borne by everyone on the planet, not just those using the fossil fuels. This "externalizes" the cost. The release of fossil fuel combustion products into the air could be halted by using carbon capture and storage (CCS) technology that removes carbon dioxide from the flue gases and places it deep underground, away from the atmosphere. This would stop greenhouse gas (GHG) emissions and transfer the externalized cost of carbon back onto the fossil fuel users.

Higher fossil energy prices are not necessarily a bad thing. Renewable energy technology development over the past five decades has been focused on improving efficiency to bring down the cost of renewables to levels that are economically competitive with fossil fuels. Raising the price of fossil fuels is another way to achieve economic competitiveness, while higher energy costs overall will encourage conservation.

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Some environmental advocates are quick to condemn the oil companies as greedy business entities that relentlessly push their products and willingly sacrifice the environment for profit. Coal producers are cast as corporate behemoths that callously forfeit the lives of workers and tear apart the landscape to extract their product, leaving the mess for others to clean up. As with most stereotypes, there is a kernel of truth to these, but also like most stereotypes, the real story is more complex and nuanced.

I know many people working in the fossil fuel industry, and by and large they are decent human beings who do care about the future. Coal mining and the extraction of oil and gas are well-paying jobs, and people often become locked into careers that they can't easily leave. Most fossil energy workers do recognize that the industry is likely to face some downsizing in the future, and many are casting about for new job opportunities in environmental fields such as CCS that can utilize their skill sets. In any case, individual fossil energy workers are no more responsible for climate change than fast food workers are responsible for the increase in obesity across America or pharmaceutical workers are responsible for the opioid epidemic.

That being said, it is clear that the fossil fuel industry itself has been promoting climate skepticism to continue making profits. Fossil fuel producers claim that they are just meeting a market demand, which is true. The demand for fossil fuel remains high because the industry nurtures it. Gas-guzzling, full-size pickup trucks and behemoth sport-utility vehicles are the most popular automobiles sold in America, encouraged by abundant and relatively cheap gasoline. Cheap natural gas and coal produce 70% of U.S. electricity.

Americans are anxious about energy supplies and tend to panic at the first sign of a gasoline shortage; witness people filling up empty milk jugs with gas (not recommended) when an East Coast oil pipeline was temporarily shut down by hackers in the spring of 2021. Fossil energy has become so tightly woven into our economy

that switching to other energy sources will be disruptive and challenging no matter how it is done.

Although fossil energy companies have been aware internally for decades about the potential impacts of their products on climate, they donate heavily to political candidates who deny climate change. The industry-affiliated scientists claiming to be climate skeptics provide cover for the politicians who call climate change a hoax. Even some legislators who agree that climate change is real have not taken any significant action for fear of jeopardizing their own oil industry contributions or the support of their constituencies. Climate science has evolved from a technical debate into a tribal issue through what is called "cultural cognition," where information that may go against someone's personal beliefs is contorted to match their cultural values. The division is symptomatic of the many other divisions that rip apart the fabric of American society.

Passing off climate change as a hoax is becoming increasingly difficult as glaciers melt, storms and droughts become more frequent and more intense, killer heat waves occur in places like Siberia and the Pacific Northwest, wildfires are more common, and temperatures rise. Most people worldwide believe their own eyes that things are changing and agree that humanity must do something very soon to avoid a climate calamity.

The fossil fuel industry has responded by changing tactics from outright denial into what are known as "discourses of climate delay.[5]" These consist of redirecting responsibility for GHG emissions onto consumers instead of the fossil fuel industry. In this narrative, people are at fault for driving cars and heating homes with fossil fuel and the industry is only supplying a product. The discourse states that individuals can do nothing meaningful about climate change and perhaps we'd all be better off just giving up on any idea of mitigating it and continue using fossil fuels to the profit of the industry. Related claims suggest that higher levels of GHG are good for agriculture and warming up the planet is good for humans. The resulting heat waves and sea level rise from melting ice sheets are also presumably good, although not specifically mentioned.

A social justice argument called "wokewashing" is a common strategy of climate skeptics that warns poor and marginalized communities of being the most adversely affected by a transition away from fossil fuels. This states that ending the use of fossil fuels will lead to radical, disruptive change that will be detrimental to society and the economy. It claims that affordable, renewable energy is out of reach for disadvantaged communities or poor nations, and that these communities receive more benefits than problems from cheap fossil energy. This is patently untrue and will be addressed in more detail later.

It is important to recognize that these denials about the existence of the climate crisis are not just an honest disagreement among scientists. An organized effort is attempting to discredit climate science using $64 million in annual funds from 140

[5] Lamb, W.F., Mattioli, G., Levi, S., Roberts, J.T., Capstick, S., Creutzig, F., Minx, J.C., Müller-Hansen, F., Culhane, T., and Steinberger, J.K., 2020, Discourses of climate delay: *Global Sustainability*, v. 3, e17; DOI: https://doi.org/10.1017/sus.2020.13

different conservative foundations, who generally conceal donations through the use of donor-directed philanthropies.[6] The money goes to think tanks and institutes that use tactics developed for the tobacco industry (by some of them, as a matter of fact) to convince the American public that climate change is neither real nor serious. Like the fossil fuel industry, the tobacco industry was fully aware of the hazards of their products but created enough uncertainty and doubt to maintain robust cigarette sales until governments finally addressed secondhand smoke and banned indoor smoking, prompting many people to quit. Thus, anyone who believes that "climate change is a hoax" should also remember that "4 out of 5 doctors smoke [*insert brand name here*] cigarettes."

One of the recipients of this anti-climate funding is the Heartland Institute, an Illinois-based think tank that has moved to the forefront of climate skepticism after downplaying the health hazards of tobacco in the 1990s. It views climate change as a conspiracy by world governments to control people's lives. "The global climate agenda, as promoted by the United Nations, is to overhaul the entire global economy, usher in socialism, and forever transform society as one in which individual liberty and economic freedom are crushed," reads an event description for a recent climate skeptics conference sponsored by the institute. Their message that climate change is nothing more than a construct of an evil liberal agenda is contradicted by wildfires, droughts, heatwaves, melting glaciers, and fierce storms.

Another conservative institute that is at the forefront of climate skepticism is the Washington, D.C. -based Heritage Foundation. Their approach is generally a bit softer than the Heartland Institute, asserting that we don't really understand all the uncertainties of climate and have no hard data to show just how much warming the increase in GHG emissions will actually induce. According to Heritage, government policy decisions are supposedly being based on the IPCC "unrealistic" worst-case scenarios (I will remind readers that the "worst case" scenario in both Russian roulette and climate models can actually be quite bad). Whether or not one chance in six should be considered "unrealistic" is up for debate. The Heritage Foundation claims their climate skepticism serves as an "antibody to flawed assumptions and preconceptions" as if those who support the notion of anthropogenic climate change are afflicted with some kind of disease. In the early 1990s, an organization called the Global Climate Coalition (GCC) representing the oil and coal industries engaged E. Bruce Harrison to build a campaign sowing doubt about the science of climate change. Harrison's previous successes included discrediting research on the toxicity of pesticides for the chemical industry, discounting the hazards of smoking for the tobacco industry, and campaigning against tougher emission standards for the auto industry. His firm was considered one of the best. The tactics he developed for the GCC included claims that the science was unsettled and reducing fossil fuel use would negatively affect American jobs, trade, and prices. Harrison specifically

[6] Brulle, R.J., 2014, Institutionalizing delay: foundation funding and the creation of U.S. climate change counter-movement organizations: *Climatic Change*, v. 122, no. 4, p. 681–694

sought spokespeople who were scientists, economists, academics, or other experts because they carried greater credibility than industry representatives.

In 2016, U.S. Senator Sheldon Whitehouse (D-RI) called out this chicanery in an effort to expose "the web of denial" about climate change. In his remarks on the Senate floor, he said his purpose was to "spotlight the bad actors who are polluting our American discourse with phony climate denial." He called their actions a disgrace and said, "our grandchildren will look back at this as a dirty time in America's political history." The press release is available on Senator Whitehouse's web page.

The end result of all this conservative foundation and oil money being used to promote the denial of anthropogenic climate change is divisiveness, confusion, and political dithering in national governments that has stalled out any significant policy initiatives on climate. Little or nothing is actually being done to deal with climate change, except to talk about it. This is exactly the point. The delay in implementing measures to address climate change means that most of our technology remains directly or indirectly powered by fossil fuel. With government climate actions on hold, the fossil fuel industry continues to rake in the profits as they keep on selling their products. It is all about the money and always was.

To be fair, the fossil fuel industry is not the only one that uses campaign contributions and lobbying practices to tie up policies in knots. Stall tactics by the insurance industry have stymied most political efforts to reform health care costs. Insurance providers have even come close several times to rescinding the Affordable Care Act. Likewise, the gun lobby and the National Rifle Association have fought tooth and nail against every proposed limitation on guns from universal background checks to banning assault weapons to restrictions on large magazines. This has resulted in wide open access to guns, including for a lot of people who should not have them, and a rash of tragic shootings. Firearms are now the leading cause of death for children in the United States, surpassing automobile accidents and poisonings.[7]

In my opinion, America has become a republic where corporations and capitalism have taken precedence over the wishes of the majority of citizens. Most people support some kind of gun restrictions. Most people want access to medical care that won't leave them bankrupt. And most people are concerned about the climate crisis and want alternative clean energy. Self-serving corporations driven by greed are pouring tons of money into political campaigns to elect candidates who will look after their best interests and profit margins. What is good for the corporations is not necessarily good for the nation.

Some free market proponents and libertarians claim that government climate policies are unnecessary because industry will develop some miraculous carbon-free energy technology to replace fossil fuel. If nuclear fusion, zero point energy, antimatter, di-lithium crystals, black holes, or some other exotic energy source comes about in the future, it would be terrific, but we can't wait for it. The climate crisis is urgent, and we must work with what is available now.

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[7] Goldstick, J.E., Cunningham, R.M., and Carter, P.M., 2022, Current Causes of Death in Children and Adolescents in the United States: *New England Journal of Medicine*, v. 386, May 19, p. 1955–1956; DOI: 10.1056/NEJMc2201761

It has also become clear over the past half-century that a breakthrough in technology or economics to replace fossil energy with decarbonized sources will not happen in the investor-driven free market. The financial risks are too high, the unknowns are too great, and venture capitalists have plenty of safer places to put their money. Even near-term solutions to replace coal, oil and natural gas with sustainable, carbon-neutral technologies such as nuclear and geothermal still require some significant development to become commercial and competitive. This may happen in the near future with strong government support, but it almost certainly won't happen in the free market.

I believe that government policy and support is the only tool that can provide the incentives and penalties to force industries, utilities, and consumers to adopt new energy behaviors that can help mitigate climate change. Relying on the fossil fuel industry to end our dependence on fossil fuels is like asking the dairy industry to ban ice cream. Relying on the free market to address climate concerns expects famously skittish investors to drop a familiar and fiscally safe energy technology and adopt something new, unproven, and with unknown risks. Although it is clear that fossil fuels must go if we hope to stop making the climate crisis even worse, the industry and investors are not going to do it voluntarily or out of the goodness of their heart. There is just too much money involved for them to walk away from fossil fuels on their own. It has to be a government policy.

These government policies have been a long time coming as the climate crisis continues to slowly worsen. Former U.S. President Barack Obama has pointed out that "most people who serve in Washington have been trained either as lawyers or as political operatives; professions that tend to place a premium on winning arguments rather than solving problems."[8] This is true not only in Washington but worldwide among most of the elected and appointed government officials who would be responsible for implementing climate policies. It may explain why some political leaders have been so slow to take action against climate change, despite talking up a good game.

The lack of global progress on climate suggests that many politicians are dodging the hard choices that must be made to deal with climate change. Political leaders generally want to keep their jobs, and I think they recognize that subjecting constituents to economically painful climate policies would cost votes or support. A far better strategy for a politician is to kick the can down the road and let some future prime minister or president deal with it. In this view, the ongoing climate "debate" provides cover for timid leaders who insist that the uncertainty in climate science prevents bold actions. Nothing gets done and the fossil fuel industry cheerfully continues to dominate the energy economy.

So if we agree with the IPCC and the 99% of mainstream scientists who believe that climate change is a real thing that must be taken seriously and acted upon immediately, how do we fix it? The IPCC recommends doing two things: (1) stop burning fossil fuels and making it worse; and (2) reduce the existing CO_2

[8] Obama, Barack, 2006, The Audacity of Hope: New York, Crown/Three Rivers Press, 362 p.

concentrations in the atmosphere to pre-industrial levels. These are simple to say, but in fact are complicated and challenging to carry out.

For example, the amount of electricity generated by fossil fuel combustion in the United States is approximately 273 billion watts, or 273 gigawatts. It would take at least 140,000 two megawatt wind turbines to replace this. We currently have around 70,000 such wind turbines. The IPCC says that 700 billion tons (700 gigatons) of carbon dioxide must be removed from the atmosphere by the year 2100. If we start in 2030, that is ten gigatons per year until the end of the century. The situation is not hopeless, but it is still daunting.

Technologies are being developed to replace fossil fuel with geothermal or nuclear heat in existing electrical generating plants. New types of carbon-neutral biofuels can replace petroleum and natural gas. The technology for wind and solar power, and that for electric vehicles keeps improving. Both biological and engineering solutions are being explored for removing and sequestering atmospheric CO_2. Given the potential consequences from the climate crisis, readers might be surprised to learn that governments so far have not thrown huge research budgets at these technologies in crash programs to fully develop and implement them. Although the funding for atmospheric carbon dioxide removal (CDR) has recently increased in the United States, the research on engineered geothermal and new nuclear technology is minimally funded and proceeding slowly.

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The scientific principles behind human-induced climate change are not particularly difficult to understand, which makes the success of climate skeptics even more remarkable. These are explored in more detail in later chapters, but in brief, burning fossil fuels such as coal, petroleum, and natural gas adds CO_2 into the air as a combustion product. CO_2 absorbs infrared (heat) radiation and warms up the atmosphere.

The Earth has natural, trace amounts of carbon dioxide in the atmosphere that warm the planet and are used by plants during photosynthesis. Fossil fuel carbon was trapped underground and isolated from the atmosphere for millions of years. Releasing it into the air as a fossil energy combustion product is putting additional carbon dioxide into the atmosphere on top of what was already there. This has increased the concentration of atmospheric CO_2 far above historic levels, resulting in more heat absorption and a warmer atmosphere.

Mathematical climate models show that a warmer atmosphere leads to unstable climates. The models predict that melting polar ice caps will alter ocean currents and raise sea levels, which is already happening. Basic physics states that warmer air holds more water vapor than cold air; thus a warmer atmosphere will result in more intense droughts along with more intense storms, which we are also seeing.

There is a difference between doubt and distrust. Doubt can be overcome by facts and evidence. Distrust cannot. Some of those denying climate change are asserting that the very science itself cannot be trusted and it's all a hoax, despite the fact that the heat-trapping properties of CO_2 were discovered and documented back in 1824. Others say scientists are self-serving and untrustworthy, and that scientific claims

about an onrushing climate calamity are only being used to create panic so scientists can profit off large sums of research grant funding. If this really was just a strategy for obtaining grant money, I would have to call it an abject failure because the research has been woefully underfunded for decades, especially with respect to non-fossil energy sources. A few climate skeptics have called CCS research a "welfare program for geologists" and several have even said that if the climate scientists are wrong, humanity will have cleaned up the planet for nothing (!).

Trying to reason with climate skeptics who distrust science is often fruitless and frustrating. As author Lee McIntyre[9] has stated, "Whatever evidence is presented to debunk these claims is explained as part of a conspiracy: it was faked, biased, or at least incomplete, and the real truth is being covered up. No amount of evidence can ever convince a hardcore science denier because they distrust the people who are gathering the evidence." According to McIntyre, the only way to reach these people is to talk to them calmly and respectfully—to put ourselves out there and meet them face-to-face. This can be especially challenging when your conspiracy-loving uncle is only interested in trying to get you riled up during Thanksgiving dinner. People refuse to acknowledge the facts because of two factors identified by psychologists. One is called "belief perseverance," where folks refuse to give up a long-held belief despite new evidence. The second is called "confirmation bias," where people only accept evidence that supports their beliefs and ignore anything contrary.

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A brief explanation about how science works might be helpful for readers to understand why some scientists can assert that a thing is true, while other scientists will look at the same data and say it is false, and nearly all scientists will hedge a bit on a conclusion. Scientists are human and like most humans they have both conscious and unconscious biases. The scientific method itself is constructed to overcome these biases by requiring rigorous proof of any findings and allowing other scientists to observe and investigate such evidence. This is necessary because human beings are remarkably good at convincing themselves of a great many things.

Questions and arguments are meant to be an integral part of the scientific process and are actually designed into it. The role of "devil's advocate" becomes important when validating observations and interpretations. Observational data can often have more than one explanation, so the concept of "multiple working hypotheses" is used. This basically means that everything is on the table until enough data are gathered to zero in on the most likely explanation. Depending on its nature, new data can alter the conclusions or even change the entire underlying hypothesis. Non-scientists often do not understand the details of this process and commonly dismiss valid disagreements among scientists as, "Those people don't really know anything."

Data sets can lead to a wide range of interpretations about what they mean, and debates among scientists are usually over the interpretation of the evidence. No one

[9] McIntyre, Lee, 2021, How to Talk to a Science Denier: Conversations with Flat Earthers, Climate Deniers, and Others Who Defy Reason: MIT Press, Cambridge, MA, ISBN: 9780262046107, 280 p.

questions, for example, that the western U.S. is subject to droughts, and these droughts have been increasing in frequency and intensity over the past several decades. Is this unprecedented and due to climate change, or is it part of a natural cycle that includes the dustbowls of the 1930s? Were the dustbowls themselves "natural" events or just an earlier manifestation of the climate change phenomenon? Two scientists can look at the same data and reach two different conclusions. The polite way to start a scientific debate is "I disagree!"

However, to the public, scientific findings may sound tentative, equivocal, or even wishy-washy. Scientists tend to be cautious about making absolutist statements because all results are subject to change in the light of new evidence. "Sticking to your guns" at all costs is not a very productive way to do science.

The history of science is littered with carefully constructed models that fell apart after someone came up with new observations, or sometimes just a better interpretation of existing data. For example, the ancient Greek philosopher Ptolemy viewed the Earth as the center of the universe surrounded by a nested series of crystal spheres that controlled the motion of the sun, moon, stars, and planets across the sky. During Greek and Roman times, and even through much of the Middle Ages, elegant models of cycles and epicycles were constructed to track and explain these celestial motions, including the complex Antikythera mechanism discovered in 1900 in the wreck of an ancient Roman cargo ship. Nicolaus Copernicus came along in 1510 and pointed out problems with Ptolemy's system of crystal spheres that simply could not be fixed mathematically. He put the sun in the center of the universe with the Earth and other planets revolving around it, and everything worked much better. Johannes Kepler later refined the shape of the orbits from circles into ellipses, and then Galileo used a telescope to actually observe celestial objects in orbit around another celestial object, in this case the moons of Jupiter.

In the early twentieth century, American astronomer Harlow Shapley demoted the sun from Copernicus' location at the center of the universe to just one star of the billions that make up the Milky Way galaxy. Shapley added insult to injury by showing that the sun is not even at the center of the Milky Way, but halfway out in one of the spiral arms. Edwin Hubble determined a few years later that the Milky Way was not the center of the universe either and in fact there was no center because billions of galaxies are retreating from one another at cosmic speeds as the universe expands. Hubble's findings prompted Belgian cosmologist Georges Lemaître in 1931 to rewind the expanding universe backward in time to a single point and propose the "big bang" theory that shapes our present-day view of the cosmos.

The point of this discussion is that science is not static but evolves over time as new evidence comes to light. It is not absolute and unarguable like religious doctrine or fixed and unalterable like legal documents. The only actual rule in science is "honor the data." Any valid new data must be honored and doing so often requires a shift in interpretation. Data on gravity, orbital mechanics, star lifecycles, galaxies, and cosmic redshifts have completely overwritten Ptolemy and his crystal spheres that dominated human knowledge of the universe for millennia.

I have found that one of the most difficult things to explain to the public is how scientists know what they claim to know. The common misunderstanding of

scientific terms like hypothesis and theory makes this even more challenging. A theory is often thought of in popular terms as only a guess or speculation; thus some people will dismiss evolution as "just a theory." In a true scientific sense, by the time something becomes a theory, it has tons of observations, data, and evidence to back it up. A hypothesis is a conjecture based on data and observations, and a theory is an interpretation of the data, experimental results, and other evidence used to test the hypothesis. A scientific theory is an attempt to construct a coherent explanation from the evidence. In no sense is it a guess.

There is a trope favored in the media and popular culture about the lone scientist standing up against the establishment with his or her own contrary data and evidence that no one will take seriously. This is familiar to most people as the opening premise of almost every Hollywood disaster movie, where someone is warning about zombies, an oncoming asteroid, a volcano that is about to erupt, dinosaurs on the loose, or whatever, and being resoundingly ignored. Of course the rogue scientist turns out to be correct, and mayhem ensues. In real life, scenarios like this almost never happen.

Science is a painstaking, slow, and careful process. Discoveries are usually made gradually and incrementally, typically in collaboration with others. This is especially true in broad fields like environment, ecology, and climate science. Most scientific research these days is multidisciplinary, with a team of specialists in different fields working together on an objective and everyone contributing their area of expertise. There is just too much to know, and one person cannot know everything. Projects are too complex for a single person or even a small group of people to carry out. For example, I've been working on a combined carbon dioxide capture and storage project (described in Chap. 9) with a chemist, a mechanical engineer, an industrial engineer, a business economist, a microbiologist, two geneticists, a civil engineer, and two other geologists. There just aren't that many "rogue scientists" out there any more who are accomplishing anything.

It might surprise readers to learn that scientific ideas are never "proven" to be right. The only actual scientific proof is when they are proven wrong. If the researchers were careful with their measurements and math and gave due diligence to their interpretations and subsequent conclusions, the findings are assumed to be provisionally correct. However, they can be proven wrong at any time by other researchers running tests on the assumptions and trying to reproduce the results. If the results are not proven wrong after others have tested them, they are eventually considered to be correct. The more of these tests and cross-checks the scientific work passes, the more accepted it becomes. Even then, results are still subject to change if any new evidence comes to light. This is called peer review and it is a method for correcting scientific errors.

To save everyone from public embarrassment, scientific peer review is carried out before an article is published. The reviews are performed by recognized experts in the field (known as referees) who review the scientific work and return comments and corrections to the author and editor. Errors are addressed in a revision, or the article never sees daylight. The referee process is good but does not always catch

every flaw, and if there is a problem with the article after publication, researchers can rest assured that someone somewhere will notice it.

I want readers of this book to know that it was peer reviewed prior to publication by two very competent referees, and their comments and suggested changes were incorporated into the revised text. I didn't object to their corrections, or feel slighted, or think they were trying to tell me how to rewrite the book. Just the opposite - I am grateful for the time and effort these two reviewers put in to read the entire text, and their suggestions improved the book significantly. Peer review should be taken with the spirit in which it is intended, and that is to improve the document, correct any flaws or typos, and ensure that the science is correct.

Many scientific articles issue "errata" statements after being published to correct small errors that have slipped through review. For major errors, the retraction of the entire scientific paper is sometimes required. A well-known example of a significant retraction a few years ago was an engineering process called "cold fusion" that was supposed to produce nuclear energy by tightly binding hydrogen atoms together chemically in a metal matrix until they fused. Scientists were skeptical when the article was published, because the only way humans knew how to make hydrogen fusion was with the intense heat and pressure of an atomic explosion. If cold fusion worked, it would be a major energy technology breakthrough. Despite multiple attempts to duplicate the cold fusion design described in the paper, no one else could ever repeat the results. The original work was found to contain some serious measurement flaws, and in the firestorm of recriminations that followed, the paper was withdrawn. The authors and their university were accused of rushing the article into publication to try cashing in on the technology.

An even more infamous paper was published describing a supposed link between human vaccines and autism. In this case, the "data" were found to have been straight-up faked, the study was thoroughly debunked, the paper was withdrawn, and the medical license of the author was revoked. Both of these papers created a great deal of interest when initially released, and the authors became world-famous, which seemed to be their motivation. However, once the facts caught up to them, they were forced to withdraw the papers from the literature. Each has suffered significant professional disgrace within the scientific community.

The point is that if anthropogenic climate change was indeed a hoax, a cold fusion-level of ruckus would have been raised by the scientific community over such false information. Instead, significant amounts of research have been published in refereed journals that show strong links between fossil energy use and climate change. Scientific evidence has been presented to support this connection and the critically important scientific papers contain solid data and findings. People who have repeated the measurements have been able to readily duplicate them. Still, because scientists generally avoid absolute statements in the conclusions, this hesitancy to say human influence on climate is 100% certain is interpreted by some climate skeptics and the news media as proof that the science is "unsettled."

Some commentators have suggested that scientists should just end the debate by saying that the climate crisis is absolutely certain, but that is not the way science works. The best I can offer is that the climate skeptics have not produced any

compelling evidence as yet to refute the findings that humans are causing climate change. A search on Amazon shows that there are a number of books[10] by climate skeptics and "contrarians" attempting to debunk the whole idea of anthropogenic climate change, but as far as I can tell, none of these rise to the level of peer-reviewed scientific literature. Unless and until someone finally does prove this wrong and backs it up with solid science the findings stand.

I experienced something similar in recent years in the debate over hydraulic fracturing ("fracking"), a technique that uses pressurized water to crack open low permeability rocks like shale to obtain natural gas. Environmentalists were up in arms over this, claiming it was contaminating vast swaths of groundwater, exposing people to dangerous chemicals and making them sick. Multiple investigations were run by many different groups of scientists, including myself, to document these supposedly horrific environmental effects of fracking.

The evidence for this was essentially zilch. The frack fluids stay deep underground, never come anywhere close to drinking water aquifers, and while there are instances of surface spills and local environmental contamination, it is by no means systemic or widespread. Literally hundreds of papers were published that investigated the environmental effects of fracking, along with several large reports from the U.S. Department of Energy, U.S. Geological Survey, and Environmental Protection Agency. None of them reported any widespread contamination. More than a few good scientists approached this subject convinced that they were going to find all sorts of problems and were rather surprised when they didn't. But as honest brokers, they admitted there was no evidence to support the hysteria and that was that.

Not so for some environmentalists. A few were infuriated at the EPA for publishing a report that didn't condemn fracking. Others insisted that the practice be banned, evidence or no evidence, and it was in fact banned in a number of states, including New York. There is still a push to ban fracking nationally by people like Senator Bernie Sanders (I-VT) and Representative Alexandria Ocasio-Cortez (D-NY). I will concede that fracking is a climate concern because it has increased the production of natural gas and crude oil in the United States and maintained our dependence on fossil fuels for at least an additional decade. But a misguided fracking ban is likely to result in gas shortages and send electric utilities right back to coal, which is far worse than natural gas for the environment in general and for the climate in particular. There is no evidence that fracking as an oilwell completion practice is any more harmful to the environment than any other oilwell completion practice. Industry has been saying this all along, and it turns out that they were correct.[11]

My stance on fracking cost me a lot of environmentalist friends. Some people that I used to hike and camp with basically disowned me for not supporting their

[10] Wrightstone, G., 2017, Inconvenient Facts: The Science That Al Gore Doesn't Want You to Know: Silver Crown Productions, LLC, Itasca Books, Minneapolis, MN

[11] Soeder, Daniel J., 2021, Fracking and the Environment: Cham, Switzerland: Springer Nature Switzerland AG, 279 p. (https://link.springer.com/book/10.1007/978-3-030-59121-2)

side of the fracking debate. But what could I do? The evidence was against them. As Mahatma Gandhi said, "Never apologize for being correct." The facts always have a way of winning in the end. Fracking is discussed in more detail in Chap. 4.

It is important to understand that the evidence supporting human-influenced climate change is strong, and evidence against it is weak. The initial skeptics reviewed the data, repeated the observations, re-ran the models and reached similar conclusions. The strongest scientific theories are the ones that have been tested and retested and found to hold up. Fracking has been through this testing. So has climate change. Those who insist that they are still skeptical about either one have ulterior motives. It is not the science, because the science was done right.

Unfortunately, like the "ban fracking" enthusiasts, there have been a few cases where the proponents of anthropogenic climate change have pushed their conclusions beyond the bounds of the data. These were politically-motivated attempts to bias the results in favor of the climate agenda, and they were called on it by other scientists. Climate skeptics of course pounced on this as proof that all climate data are exaggerated and biased against the fossil energy industry. However, the literal handful of people championing a pro-climate agenda with biased data were a very small minority compared to the thousands of researchers performing good-faith climate-related investigations. The actions of a few unethical scientists by no means invalidate the bulk of the data showing that human induced climate change is real no matter how much the climate skeptics would like to discredit it.

A generally overlooked aspect to the climate debate is that climate skeptics could easily resolve the issue in their favor by using the scientific method. If they produced solid scientific evidence showing that the links between fossil energy, greenhouse gas, and the climate crisis do not exist, climate scientists would readily change their minds because the scientific method always honors the data. So far, however, no convincing data have been forthcoming. Those who claim to have evidence contrary to a scientific conclusion have only one obligation: Prove it.

The skeptics respond by saying that the arguments they do try to present are dismissed or covered up by mainstream science. The claim of a dismissal or cover-up is a standard tactic for conspiracy theories (and also for disaster movies, come to think of it). International scientific journals generally do not have a political agenda, and there are no shadowy groups trying to suppress information about the climate. To what end? Are the solar power companies supposedly in cahoots with the scientific journals to promote the climate crisis to sell more solar panels? This is as ridiculous as it sounds. Cover-ups are usually to hold onto money or power and climate had neither of these when the problem was first publicized in the 1980s. All the money and power was with the fossil fuel industry. So which side has an incentive to cover up something here?

The integrity of international scientific journals relies on them being trustworthy enough to publish true findings backed up by solid data no matter where those findings lead. Journals also have an editorial board or committee that makes decisions on what to publish, not just one Perry White-type editor spiking stories he or she doesn't like. Every publisher in the scientific publishing world that I know of would be eager to publish a paper with major, ironclad proof that anthropogenic climate

change is false. This would be huge news and an enormous scoop much bigger than debunking cold fusion. The journal would gain prestige, advertisers, increased circulation, and more world class scientists submitting articles. Suppressing such findings for a supposed kickback from a solar panel manufacturer has far less value.

So where is the proof from the climate skeptics that this is all a hoax? Their supposedly contrary data have not been published in any peer-reviewed, refereed journals that would give it legitimacy, or if it has, it was not widely circulated. As far as I know, nothing significant has turned up in Nature, Science, EOS, AGU Atmospheres, Geological Society of America Bulletin, Environmental Science & Technology, International Journal of Greenhouse Gas Control, Climatic Change, or a host of other legitimate international scientific journals where this would certainly have made front page news.

Instead of scientific proof, we get websites from groups like the CO2 Coalition (https://co2coalition.org/) that requests contributors to "join us in our love for CO_2." The organization insists on its "Climate Facts" page that elevated levels of carbon dioxide in the atmosphere are perfectly normal, and in fact are beneficial for increasing the yields of corn and other crops. There are claims that greenhouse warming slows down and stops with increasing CO_2 concentrations (satellite data show it gets worse), the current warming trend is "good" for humans (anthropological evidence suggests that it is not), and over timescales of tens of millions of years, the current high CO_2 levels are not that unusual (although when compared to the last 400,000 years, they are indeed unusual). Some of these claims are backed up with modeling studies from relatively obscure journals while others are cited as "personal communications." I can't find much rigorous science in it anywhere. My contrary statements in the parentheses above are all backed up by peer-reviewed references in this book.[12]

This type of material used to appear mainly on blogs. A new tactic seems to be submitting it to "pay to publish" open access technical journals or producing it as self-published books to give it a veneer of acceptability. Many open access journals are technically rigorous and adhere to peer review standards. They charge a publishing fee to authors so the information can be freely disseminated, especially to lower income people in Third World nations who can't afford expensive journal subscriptions.

Unfortunately, some other journals have rushed to cash in on the open access model and appear willing to publish just about anything for money, especially those that promise a quick turnaround and need a large volume of articles. Self-published books these days have become clever at concealing the fact that they are self-published. It is hard for readers who are not engaged in the field to know which publications are legitimate and which are not.

An open access paper that I recently reviewed contained a claim that the absorption of infrared radiation by carbon dioxide actually cools the planet. This defies the

[12] See respectively, Kramer et al. (2021), Raymond et al. (2020) and Xu et al. (2020), and Climate.NASA.gov