CHAPTER 3

Climate Scientists Are Conspirators

We run carelessly to the precipice, after we have put something before us to prevent us from seeing it.

Blaise Pascal

On Tuesday, August 23, 2005 the US National Hurricane Center detected a low-pressure system southeast of the Bahamas and quickly classified it as tropical depression 12. Initially, there was nothing noteworthy about this storm. But by mid-morning the next day, as the depression traveled northwest toward the Bahamas, data from Doppler radar, satellite, and aircraft reconnaissance indicated winds reaching tropical storm speed. The National Weather Service promptly christened it in accordance with the alphabetized naming system for tropical storms and hurricanes. The next name had been used twice previously, once for a 1999 hurricane that swept Central America and once for a 1981 hurricane that hammered Cuba. But this would be the last run for the name Katrina. After 2005, it would be officially retired, just as professional sports teams retire the numbers of memorable players.

With its winds accelerating, Katrina turned west, heading straight for the Florida coast near Miami. The weather service issued a hurricane warning. With winds reaching 130 kilometers (80 miles) per hour on the 25th, Katrina passed the threshold to Category 1 hurricane status. Soon after, it made landfall, battering southern Florida over the next 20 hours as it crossed the peninsula, inflicting modest structural damage and 14 fatalities. Since hurricanes weaken over land, Katrina's winds abated, and when they fell below 110 kilometers per hour, the National Hurricane Center demoted it back to tropical storm status.

In satellite photos, hurricanes look like galaxies, with arcs of clouds spiraling from the center. At ground level, moist air is racing in toward the low-pressure eye. Dragged in by the rapidly rising warm air near the center, the inward-spiraling air picks up evaporating ocean moisture as water vapor, which heats from friction as it races over the ocean. As this moist warm air rises up the sides of the eye, it cools with altitude and its water vapor starts condensing into heavy rain. At heights above 12 kilometers it deflects away from the center, continuing to cool and condense. At this height, the air in the hurricane eye can be 15 degrees Celsius (30 degrees Fahrenheit) warmer than the surrounding air at that altitude. This temperature differential is the powerful 'heat engine' that produces the whirling clouds seen from above, and the torrential rains and screaming winds experienced below.

The warmer the ocean, the more powerful the hurricane. Warm ocean water more readily evaporates, which increases the moisture content of the air, the speed at which air rises near the hurricane's eye, the speed of air sucked in over the ocean, and the amount of energy released from condensation at higher altitudes. As Kerry Emanuel of MIT described in his book, *Divine Wind*, ocean temperatures of at least 30 degrees Celsius (85 degrees Fahrenheit) can produce powerful hurricanes.[1]

When Katrina entered the Gulf of Mexico on August 26, its eye passed directly over the Loop Current, a warm water current that originates between Cuba and the Yucatan, heads north into the Gulf, and then loops back down the west coast of Florida before passing out into the Atlantic. In August 2005, the current's surface water temperature was an abnormally hot 30 degrees Celsius. On contact, Katrina's heat engine throttled into super-charger mode.

Realizing what was happening, the National Hurricane Center reinstated Katrina as Category 1, issuing a warning that it would reach Category 3 or higher given the very warm sea. On Saturday morning, August 27, Katrina was upgraded to Category 3, with winds of 200 kilometers (120 miles) per hour. It was heading straight to New Orleans.

That afternoon, New Orleans Mayor Ray Nagin announced a state of emergency and called for voluntary evacuation. New Orleans captured the attention of the nation, for once not because of Mardi Gras. Still, it is the Big Easy, which might explain a government bulletin noting that bars in the French Quarter were rocking on that Saturday night before the storm, and witnesses later claimed that patrons on Bourbon Street showed a preference for a powerful cocktail called 'the Hurricane.'

After midnight, Katrina revved up to 230 kilometers per hour (145 mph) with gusts over 300. With winds extending 200 kilometers from its eye, Katrina was now one of the five strongest Atlantic hurricanes ever recorded: a heat engine poised to unleash its tremendous force on a vulnerable, ill-prepared US metropolis.

The rest of the story is well known. On Sunday, the mayor mandated evacuation of the city and offered the Superdome stadium as a refuge-of-last-resort. This was critical since 100,000 residents had neither personal vehicles nor the financial means to afford transportation and accommodation away from the hurricane's path. By Sunday evening, 20,000 people had entered the Superdome. Others found the safest place they could think of and hunkered down.

In a hurricane, one might assume that the safest place is the cellar. In low-lying coastal areas like New Orleans it's not. Onshore winds raise water levels, and low air pressure near the eye enables the water to rise even higher. This 'storm surge' can reach 7 meters (20 feet) as the hurricane's eye crosses the coastline. Statistics for the last century show that drowning causes 90% of hurricane-related fatalities.

If the shoreline is steep, the spatial impact is limited. But on a flat coastal plain, extensive flooding can occur as the surge combines with heavy rains to inundate lowlands. If the coastline is also a delta, it must contend with water from three sources – a storm surge from the sea, torrential rain from the sky, and the inflow of the river whose run-off is blocked by the rising sea. The Mississippi River carries the greatest water volume of any river in North America, and New Orleans lies in the middle of its delta. The sediments on which the city was built have compacted during 300 years of settlement, leaving most districts more than 2 meters (6 feet) below the river and nearby Pontchartrain Lake, which are at sea level. Tucked in a bowl below sea level, New Orleans' survival depends on the performance of its levees.

Katrina made landfall southeast of New Orleans early Monday, August 29. Fortunately, its wind speeds had ebbed to about 200 kilometers per hour, back to Category 3. The hurricane's eye missed the city, passing to the east. Even so, its winds battered buildings and structures, ripping off part of the Superdome roof to the terror of the drenched people below. Major media reported that New Orleans had dodged the bullet yet again, just as with Andrew in 1992, George in 1998, and Ivan in 2004. But over the next 12 hours, 80% of New Orleans flooded as storm surges breached its levees, causing 3 meters of flooding on average, double that in some wards.

In the following days, Coast Guard, National Guard, federal troops, city police, state police, and rescue services extricated tens of thousands of survivors stranded by the flood. The death toll reached 1,500, mostly from drowning.

Then the blame-game started. Federal, state, and municipal politicians pointed at each other, initially for why it took so long to rescue people, then for who was at fault for the flooding, and then for who would pay for clean-up, repairs, and reconstruction. About 80% of buildings in the city's low-lying wards were destroyed or severely damaged from the flood. Total damages were estimated at $80 billion.

Today, the debate still rages over who to blame for what has been called the worst civil engineering disaster in US history. Is it the fault of the Army Corps of Engineers, who built the city's levee system? Is it the rapid loss of delta wetlands of the last few decades, increasing the exposure to storm surges? Or, is the city simply unsustainable, given rising ocean temperatures and sea levels, both of which scientists attribute to climate change?

Of the books written about Katrina, I've read Jed Horne's *Breach of Faith*[2] and Douglas Brinkley's *The Great Deluge*.[3] These are substantial, engaging works. Both devote considerable space to assessing and allocating blame for the disaster. But neither book explores the contribution of climate change to this and future hurricane disasters. To climate scientists, this oversight is incomprehensible.

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In 1824, Jean-Baptiste Fourier (1768–1830), a French mathematician and physicist, published an essay on the earth's temperature with the French Royal Academy of Sciences.[4] He had been trying to explain why incoming solar radiation didn't make the earth inhospitably hot, and why it wasn't immediately reflected back into space, which would make the earth inhospitably cold. He speculated that the atmosphere's gases allow solar radiation to reach the earth more easily than they allow it to reflect back into space. This delay in the dissipation of heat sustains the earth's surface air temperature at an average of 14 degrees Celsius (52 degrees Fahrenheit) instead of minus 20 degrees Celsius. For this insight two centuries ago, Fourier is recognized as one of the discoverers of the atmosphere's greenhouse effect.

While other scientists were receptive to Fourier's idea, it attracted only minor attention for three decades. Then, in 1859, Irish scientist John Tyndall (1820–1893), working in his laboratory at the Royal Institute in London, calculated the heat-absorptive properties of the individual GHGs in the earth's atmosphere, these being water vapor, carbon dioxide, nitrous oxide, methane, and ozone.[5] Tyndall's findings supported Fourier's hypothesis. Some of the incoming solar energy that penetrates our atmosphere as ultraviolet radiation is reflected back from the earth as infrared radiation. This latter is more easily absorbed by GHGs, and while it is eventually reflected back into space, the delay raises the temperature in the atmosphere and on the earth's surface to higher levels than if there were no GHGs.

Ironically, Tyndall's curiosity was piqued by fears that the earth might enter another ice age, given the contemporary discovery by geologists that the earth's climate had oscillated between ice ages and warm periods. Tyndall suspected that millennial changes in the atmospheric concentrations of GHGs were somehow linked to the temperature changes that caused the ice ages. Thanks to his work in measuring the effect of each GHG, it became possible to associate these gases with their differing contributions to the earth's greenhouse effect. But the numerical equation linking the atmosphere's GHG concentration and a specific temperature on earth was still unknown.

It would be 36 years before the Swedish scientist, Svante Arrhenius (1859–1927), tried to estimate this relationship. He focused on carbon dioxide (CO_2) because this was the GHG whose atmospheric concentration humans were changing by burning coal in ever-greater amounts. In 1896, he used Fourier's greenhouse theory and Tyndall's measurements of the heating effect of each GHG to hypothesize that doubling the CO_2 concentration in the atmosphere would increase the earth's surface air temperatures by an average of 4 to 6 degrees Celsius (8 to 11 degrees Fahrenheit).[6]

This relationship is now known as 'climate sensitivity,' the estimated temperature change caused by a change in the atmospheric concentration of GHGs, especially CO_2. Amazingly, Arrhenius' somewhat crude calculation of climate sensitivity is still within the range of current estimates, these latter produced by climate models with thousands of equations running on powerful computers grinding through huge quantities of data.

The first researcher to test Arrhenius' climate sensitivity estimate against temperature data was Guy Callendar (1898–1964), a British mechanical engineer. By the 1930s, meteorological records were sufficient in some locations to statistically detect 100-year temperature trends, which on average were found to be rising. Callendar related the temperature trend data to the rising rate of human-generated CO_2 emissions from burning coal and increasingly oil. In 1938, he presented a paper to the Royal Meteorological Society which integrated CO_2 from burning fossil fuels, the resulting rise in CO_2 atmospheric concentrations, and historical temperature records to estimate climate sensitivity.[7] His synthesis is the basis of modern climate science and the consensus that combustion of fossil fuels increases global temperatures by an amount we can roughly predict.

This consensus is as solid as the scientific consensus that we can predict lung cancer rates from smoking. And it materialized from the same process of scientific inquiry. Independent researchers kept finding evidence that supported rather than refuted the theories of Fourier, Tyndall, Arrhenius, Callendar, and other climate science pioneers. Some researchers tracked the rising concentrations of CO_2 in the atmosphere since the start of industrialization and compared these to past periods of high CO_2 concentrations by using ice cores to develop prehistoric records going back hundreds of thousands of years. Others developed protocols for combining multiple spot temperature readings to estimate an average temperature for the surface of the earth. Some developed techniques for estimating temperature records covering thousands of years from fossilized plants.

As always, there were scientists who disputed certain aspects of the emerging consensus. They developed alternative interpretations and tested these by collecting and analyzing data. In the case of climate science, this normal skepticism and the research it triggered has caused minor adjustments, but nothing that undermines the central conclusions of Fourier, Tyndall, Arrhenius, and Callendar.

As scientists informed the popular media and political leaders about the risks of climate change, governments began to respond as they had with the emerging scientific consensus on smoking. They established scientific panels and multi-author assessments, asking leading scientists to collaborate on reports that explained areas of agreement and areas of remaining dispute or uncertainty. In the United States, the *National Academy of Sciences* produced several reports on climate change, the first in 1979.[8]

Moreover, since preventing further climate change requires a global effort, political leaders and international agencies recognized the importance of international cooperation in assessing the state of scientific knowledge. Getting every country to act together is easier if every country's experts agree on the evidence. In 1988, the World Meteorological Organization and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change (IPCC) to produce periodic assessments of climate change science. The IPCC produced assessments in 1990, 1995, 2001, 2007, and 2014.[9] The next is scheduled for 2022.

Each of these assessments summarizes the state of the science. With the accumulation of evidence over the past two decades, the IPCC's consensus conclusions have become more definitive with each report. The early reports explained why scientists agree that human GHG emissions would cause temperature rise and ocean acidification, thus justifying GHG-reducing actions. But with our ongoing failure to act effectively since the first report in 1990, more recent reports focus on what it was hoped could be prevented. They show how much climate change is now happening, including the human, biological, and earth system impacts. The language has gradually shifted from urging preventative action that would avoid impacts to explaining what is actually now happening because of our failure to act – rising average temperatures, ocean acidification, destruction of coral reefs, accelerated melting of ice caps and glaciers, rising sea levels, pest infestations, increased malaria, and rising instances of extreme events like droughts, heat waves, floods, wildfires, and powerful hurricanes.

The IPCC assessments also forecast the atmospheric GHG concentrations and global temperatures in 50 and 100 years if humanity continues on its current trajectory of burning fossil fuels, reducing forest cover (which means less carbon stored in plants and in the soil), and other activities. The latest estimates suggest that by 2100, global average surface temperatures will increase between 1.5 and 4.5 degrees Celsius (3 and 12 degrees Fahrenheit). And once this increase approaches 2 degrees Celsius, we may pass tipping points after which global warming may accelerate.[10] For example, melting permafrost in the Arctic could release more methane, which, as a potent GHG, would raise arctic temperatures faster, thus melting permafrost faster and releasing even more methane in a self-propelling cycle. As the science progresses, the IPCC reports have become more confident in predicting a rising rate of extreme events like hurricanes. With powerful computer models that simulate hurricane development under different ocean temperatures and other factors, scientists now simulate the mechanisms which drove Katrina's quick acceleration to a Category 5 hurricane. Thus, scientists can now confirm that many extreme weather events have been made worse by rising GHG emissions.

The strange-sounding discipline of paleo-tempestology studies coastline soils to measure the hurricane-revealing sediments left by storm surges over the past millennia. Not surprisingly, warmer periods are associated with more hurricanes, especially more intensive ones. In other words, evidence from the past confirms what scientists know about the physics of hurricane intensity. Warmer ocean water increases the likelihood of more ferocious hurricanes. From this knowledge, scientists predict that 40 years from now, if we continue to increase global emissions, an ocean that is 1.5 degrees Celsius warmer than at the time of

Katrina would, with all other conditions similar, produce a hurricane with peak winds 25 kilometers per hour (15 mph) faster than Katrina and a storm surge several meters higher. In explaining the future effects of global warming, commentator Bill Maher depicted future hurricanes as "Katrina on steroids."[11] It is difficult to imagine the scene if a hurricane of this intensity scores a bullseye on New Orleans.

The steroids analogy is a good one for explaining the probabilistic relationship between rising GHG emissions and hurricanes like Katrina. We know that a baseball slugger on steroids will hit more home runs, but we cannot attribute any particular home run to the steroids. Sluggers who don't take steroids also hit home runs, just less. Likewise, we know that more GHGs in the atmosphere will heat the ocean and a warmer ocean increases the likelihood of hurricanes of the intensity of Katrina. Scientists are extremely confident of this relationship, as the climate scientist James Hansen explained in his aptly titled 2009 book, *Storms of My Grandchildren.*[12] And people who do not have a self-interest motive to reject this science easily understand this probabilistic relationship between global warming and extreme hurricanes, just as they eventually recognized the relationship between smoking and lung cancer. It's a question of the willingness to accept inconvenient evidence, not the mental capacity to understand changing probabilities.

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The IPCC reports explain how rising atmospheric concentrations of GHGs impact the earth's geophysical and biological systems, and what this means for humans. The reports also explain what is needed to reduce GHG emissions, thus also involving researchers in engineering, economics, and other social sciences.[13] This might seem complicated, but it doesn't need to be. If we focus on the global energy system, which produces over 70% of GHG emissions, and an even higher percentage of the emissions we have the best political means of reducing, our options can be understood with the following relationship. It says that energy-related GHG emissions result from the GHG intensity of the energy we use (GHG/Energy), multiplied by the energy intensity of our economy (Energy/$ of Income), multiplied by our per capita income (Income/Person), multiplied by the population.

GHGs = GHG/Energy x Energy/$Income x Income/Person x #People

Scanning from right to left, if the number of people increases, while everything else stays the same, GHG emissions rise. Thus, one way to reduce emissions is to reduce population. But except for China's one-child policy in the 1990s and 2000s, no governments have been willing to push this agenda, and certainly not as a means of tackling climate change. Thankfully, demographers note that increased education for women is strongly linked to falling birthrates, suggesting that the total global population will stop growing later this century. While growth may stop, a dramatic reduction of the global population won't happen any time soon, at least not for peaceful reasons.

If income per person grows while everything else stays the same, emissions also increase. But convincing governments to stop economic growth to reduce emissions is just as difficult as getting them to reduce population. Certainly, it won't be easy to convince over one billion people who have negligible access to electricity and modern fuels that we should forgo the economic growth that offers them a means to access valuable services that most of us take for granted.

Continuing to the left in the equation, another possibility is to reduce energy use per dollar of income (the energy intensity of the economy). For the last two centuries, energy intensity has declined in industrialized countries. But this trend has been offset by economic growth, such that total energy use has grown. Over the last several decades, however, wealthy countries with stable populations, such as western Europe and Japan, have seen stable or declining energy consumption, which has not been the case for wealthier countries with growing populations, such as the US, Canada, and Australia.

In most developing countries, energy use is rising rapidly, where growing populations and incomes outstrip reductions in energy intensity. And since much of the industrial output from developing countries like China is destined for rich countries, one could argue that energy use in these latter has also risen if we count energy embodied in the goods we import.

The final option shown on the left of the equation is to reduce the GHG emissions intensity of our energy system. This means substituting away from fossil fuels and, wherever we still use them, capturing and storing GHGs to prevent them from reaching the atmosphere. In switching from burning coal, oil, and natural gas to renewables, and possibly some nuclear and fossil fuels with carbon capture, we would transform the global energy system to one dominated by technologies and fuels with low or zero carbon emissions.

These last two categories – reducing energy intensity and reducing energy-related emissions – are widely recognized as critical for addressing climate change. The good news, as we shall see, is that we already have the technologies and energy alternatives to make this happen. So even though this will not be easy, it is much easier than stopping population and economic growth in just a couple of decades.

I should add a qualification to the equation. It focuses on GHG emissions from the global energy system. But there are also CO_2, methane, nitrous oxide, and other GHG emissions from a variety of activities including forestry, agriculture, the treatment of municipal solid wastes, and some industrial processes, like the production of aluminum and cement. The IPCC investigates all of these GHGs and all options for reducing them. But we must not forget that CO_2 from coal, oil, and natural gas accounts for over 70% of human-produced GHG emissions. If we don't reduce these dramatically, we won't succeed with the climate-energy challenge.

But just as the scientific consensus on the risks of burning tobacco threatened the profits of the tobacco industry, the scientific consensus on the risks of burning fossil fuels threatened the profits of the fossil fuel industry. What has ensued is predictable and disturbing.

As with tobacco, people and organizations associated with the fossil fuel industry devote time and money to manufacture the delusion that climate scientists are in a conspiracy to fabricate the climate change threat. Some of these people propagate this delusion for self-interest, as recipients of fossil fuel industry revenues. These include executives and investors, politicians receiving political donations from the industry, paid lobbyists, and advertisers. Others align themselves with these direct beneficiaries for various ideological reasons, such as the fear that reducing emissions will increase the size of government, constrain individual freedom, and slow economic growth. Finally, there are those who for personal reasons disbelieve the scientific consensus, perhaps from a psychological need to be contrarian.

Key players in the fossil fuel industry publicly promote and financially support individuals with real or pretend expertise in climate science who claim that the scientific consensus is wrong. They help these so-called experts present inconsequential uncertainties as somehow devastating to the fundamental scientific consensus. Strategies include trying to undermine the reputation of leading climate scientists and key institutions like the IPCC.

Naomi Oreskes and Erik Conway explained in *Merchants of Doubt* how the same so-called scientists masqueraded through the years as experts innocently denying the risks, and thereby helping to delay policies, on acid rain, second-hand smoke, the hole in the ozone layer, and climate change.[14] A report of the Union of Concerned Scientists stated that ExxonMobil funneled $16 million between 1998 and 2005 to think tanks and individuals seeking to undermine climate science in the eyes of the public.[15] In *Private Empire,* his book on ExxonMobil, Steve Coll concluded that effective actions on the climate risk "will come later than they might have due to the resistance campaigns funded by oil and coal corporations – particularly ExxonMobil's uniquely aggressive influence campaign to undermine legitimate climate science."[16]

In *Climate Cover-Up,* James Hoggan and Richard Littlemore detailed the tactics of entities like the Heartland Institute, funded by the Koch brothers.[17] The starting argument is that evidence of a rising CO_2 concentration is incorrect. If that doesn't work, then the evidence of global warming is incorrect. If that doesn't work, then the warming detected by scientists is attributed to the oscillations of the earth's temperatures through the millennia. Finally, if this too fails, then we must recognize that fossil fuel use is inevitable, and we can adapt to a cozier, more productive planet.

When he was the CEO of ExxonMobil, former US Secretary of State Rex Tillerson acknowledged in a public speech in 2012 that burning fossil fuels is warming the planet, but assured the audience that "we'll adapt."[18] He conveniently failed to elaborate on those future conditions to which humans could adapt, since scientists claim we have enough burnable fossil fuels to raise oceans almost 35 meters (100 feet) and temperatures to scorching levels approaching those of the planet Venus. Which is why scientists respond to the "we can adapt" argument with catchphrases like "come hell and high water," and "first Venice, then Venus."

Another strategy is to undermine the credibility of leading climate scientists and the IPCC. One sophisticated operation produced 'climate-gate,' when a hacker penetrated a server at the Climate Research Unit in the UK, and released e-mail excerpts just before the 2009 climate negotiations at Copenhagen. Removed from their context, with no explanation of scientists' slang expressions, these excerpts were cleverly selected by conservative media outlets like Fox News to imply that global warming was a fraud perpetrated by a conspiracy of climate scientists. Climate-skeptical politicians, like former Republican Senator James Inhofe, referenced climate-gate in support of his claim that "global warming is the greatest hoax ever perpetrated on the American people."[19]

Ultimately, eight separate entities, including the UK House of Commons and the US Environmental Protection Agency, conducted independent inquiries into the climate-gate allegations.[20] All found no evidence of scientific misconduct. Not surprisingly, the conservative media ignored or downplayed these findings. For the hackers and their backers, it was mission accomplished, as polls showed an increase in public skepticism of climate science.

Michael Mann, a leading climate scientist, described climate-gate and similar efforts to vilify climate scientists in *The Hockey Stick and the Climate Wars*.[21] As an expert in long-term temperature trends, he was an originator of the 'hockey stick' graph of the global average temperature since 1000, estimated from tree rings, corals, ice cores, and historical human records. The graph shows the temperature almost flat and then rising after 1900 (the stick blade). While climate scientists accept the shape of the stick, this didn't deter fossil fuel-funded experts from repeatedly claiming to refute it, which conservative elements of the US media slavishly reported.

Figure 3.1 on US climate science beliefs parallels Figure 2.1, which showed public views about smoking and lung cancer. As with smoking, the US public's willingness to accept the findings of science depends on self-interest and convenience, namely if one lives in a region that

	Believe humans cause global warming (%)		
Year	Fossil-fuel focused regions	Other regions	All (average of both)
1990	25	35	30
1997	40	60	50
2001	45	65	55
2007	50	70	60
2012	35	55	45
2018	55	70	65

Figure 3.1 Climate science beliefs

produces oil, coal, or natural gas (such as Texas, Wyoming, and West Virginia) or that heavily depends on coal for electricity generation (such as the US southeast and midwest). The greater the self-interest benefit from rejecting a scientific fact, the greater the likelihood of that rejection. Hence the different polling responses between people living in "fossil fuel-focused regions" and those living outside these regions.

The table differs from the smoking surveys in showing a period in which public acceptance of climate science actually declined, from 2007 to 2012, before returning to its upward trend in recent years. One explanation for this reversal in the US is that climate science got caught in partisan battles between Democrats and Republicans. Polls show that while the percentage of Democrats believing climate science is high and steadily rising, the percentage fell among Republicans, especially in the period 2005 to 2015. For one thing, campaigners against climate policy threatened Republican politicians with losing fossil fuel industry political contributions and with internal challenges during Republican nomination campaigns if they failed to back the anti-climate science position. When almost all Republican political leaders are singing from the same song sheet about climate, it increases the chance that Republican voters will believe their party's leaders when they discredit the evidence from climate scientists.

Another explanation is that it might be easier to undermine climate science than smoking science. With smoking, the process is fairly simple.

We gradually notice that the people who get lung cancer are often smokers, sometimes family and friends. Once we open our eyes, the causal link gets increasingly obvious. In contrast, we may notice some changes in the weather, but it's always variable, and as long as those changes are not yet hurting us, we can sustain our delusion.

Unfortunately, the honesty of scientists about the complexity of the earth's climate helps the deniers. Many phenomena are interconnected and complex. Higher temperatures cause more droughts. Droughts cause more forest fires. More forest fires increase CO_2 in the atmosphere, which increases temperatures. But more forest fires also increase soot in the atmosphere, which can decrease temperatures temporarily. Imagine trying to build a high precision model with all these confounding effects. The honesty of scientists about this complexity is used by the denier industry to distract the public from the fundamental scientific consensus.

So while scientists are certain that we are warming the planet, which will melt ice, raise sea levels, and cause major impacts, they will remain uncertain about the timing and location of specific repercussions, right up to when they actually happen. The planet will warm. Climate will change. Weather will change. Ecosystems will change. Oceans will change. How much, when, and where? Scientists cannot be certain.

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In a 2012 episode of his *Colbert Report* TV show, comedian Stephen Colbert commented on the real-life response of North Carolina politicians to a state agency's prediction that sea levels will rise 39 inches by 2100 because of global warming.[22]

"North Carolina Republicans have written a new bill that would immediately address the crisis predicted by these climate models – by *outlawing* the climate models!"

"The law makes it illegal for North Carolina to consider scenarios of accelerated sea-level rise due to global warming. To fix that problem, GOP lawmakers want scientists to take the sea-level rise over the last 100 years and use that to predict what will happen in the future. That changes a scary 39-inch rise into a much more pleasant 8-inch rise."

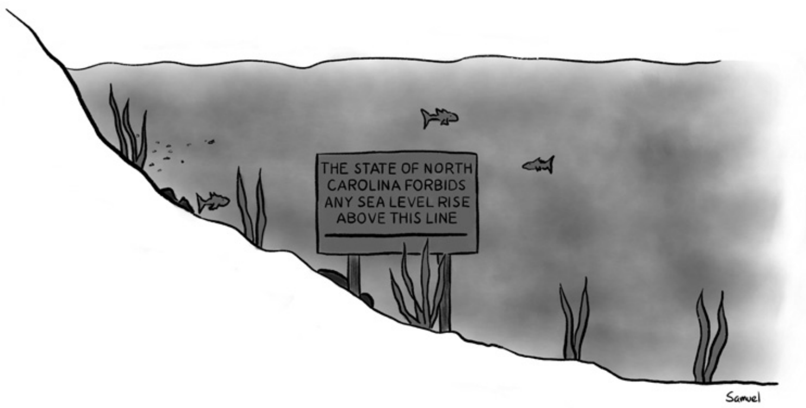

Figure 3.2 Cartoon by Jacob Fox

"I think this is a brilliant solution. If your science gives you a result that you don't like, pass a law saying that the result is illegal. Problem solved."

"I think that we should start applying this method to even more things that we don't want to happen. For example, I don't want to die. But the actuaries at my insurance company are convinced that it will happen, sometime in the next 50 years. However, if we consider only *historical* data, I've been alive my entire life. Therefore, I always will be! So I say bravo North Carolina. By making this bold action on climate change today, you're ensuring that when it actually comes, you'll have plenty of options – or at least two: sink or swim."

With the support of influential media personalities like Stephen Colbert, scientists are fighting back, in a multiplicity of ways. One obvious strategy is for climate scientists and science writers to appeal directly to the public with accessible books.

Bill McKibben's *The End of Nature* in 1989 was the first climate book to reach a wide audience.[23] In the 1990s, international efforts to address the threat seemed likely to succeed, and so less was written. But this hope faded in the early 2000s with the election of President George W. Bush, the failure of the Kyoto Protocol, and the shift in global focus to wars in the Middle East after the 2001 terrorist attacks on the US. Hence the appearance of many more books after 2004. I have already mentioned Al Gore's movie and book, *An Inconvenient Truth*, Jim Hansen's *Storms of My*

Grandchildren, and Michael Mann's *The Hockey Stick and the Climate Wars.* Tim Flannery's *The Weather Makers* was not just a best seller, several influential political leaders claimed it played a role in motivating their climate policy efforts.[24] And Jared Diamond applied his skill at depicting how geo-ecological factors affect human survival in *Collapse: How Societies Choose to Fail or Succeed.*[25] While many of these books, as best sellers, were translated into other languages, an impressive list of similarly themed books were published first in languages other than English.

These talented writers provided clear and effective descriptions of climate science for non-experts. Yet many climate scientists are, like other types of scientists, poor communicators when it comes to the public. In the daily cut-and-thrust of conventional and social media, this leaves them seriously outmatched against the sophisticated and well-funded climate science denial campaign when required to explain the causes of extreme events, like floods and wildfires, and climate science uncertainties.

To help correct this imbalance, Randy Olson abandoned a professorship at the University of New Hampshire and moved to Hollywood to study film production and apply its techniques to the public communication of scientific controversy. In his book, *Don't Be Such a Scientist*, he suggested techniques to help scientists become better communicators.[26] His provocative chapter titles include: "Don't be so cerebral," "Don't be so literal minded," "Don't be such a poor storyteller," and "Don't be so unlikeable." Olson has produced documentaries on evolution and global warming as demonstrations of the approach he espouses. Nancy Baron provides additional tips for scientists in the use of stories and metaphors and in their public engagements, be it in writing or on camera, in her book, *Escape from the Ivory Tower.*[27]

The ongoing failure with the climate threat has motivated some of these writers to return to the issue, this time focused less on climate science and more on technological solutions, civil and political efforts to raise public concern and activism, and strategies for survival under climate change. Three prominent examples are Bill McKibben's *Eaarth*,[28] Tim Flannery's *Atmosphere of Hope*,[29] and Michael Mann and Tom Toles' *The Madhouse Effect.*[30]

No matter how good scientists and science communicators are at explaining the climate threat, they won't achieve complete success if too many people decide about climate science based mostly on the opinions of people they trust.[31] Which takes us full circle to the interplay of myths, evidence, and social cognition that I explored in Chapters 1 and 2. Frustration with the inability to convince everyone about the climate threat has focused the minds of social scientists and climate activists, leading to a host of books on the interplay of human cognition and scientific evidence, such as Mike Hulme's *Why We Disagree on Climate*,[32] George Marshall's *Don't Even Think About It*,[33] and Andrew Hoffman's *How Culture Shapes the Climate Change Debate*.[34]

Strategies for applying this knowledge cover a wide range. James Hoggan interviews psychologists and political scientists for suggestions to improve public discourse between interests in *I'm Right and You're an Idiot*.[35] A 2019 article in *Nature Climate Change* organizes the methods for combating scientific misinformation into four categories: public inoculation, legal strategies, political mechanisms, and financial transparency.[36] Inoculation involves better informing the public, as with the books I have listed above. The shortcoming of this approach on its own explains the necessity of combining it with the other more aggressive strategies.

Another strategy is ridicule, perhaps even more aggressively than that of Stephen Colbert. The TV personality, Bill Nye the science guy, has long been willing to debate climate science in unfriendly venues, such as on the Fox News Channel. But he turned it up a notch in 2019 on the TV show, *Last Week Tonight with John Oliver*. In a skit in which he lit a globe on fire, he angrily expressed his exasperation with climate science deniers, culminating in "the planet is on f***ing fire and we need to grow the f*** up."[37] This tactic might not sway hard-core climate science deniers, but it may boost the morale of climate-concerned scientists and citizens who are often told that their poor communication skills, rather than the stubborn motivated reasoning of climate science deniers, is why some people still don't get it.

If we are honest, climate science denial is not the fault of scientists or science communicators. If they want to be, most humans are pretty good at understanding probabilistic causality. When scientists say that smoking killed about 400,000 people in the US in 2015, surveys show that most people understand that not every lifelong smoker will get lung cancer, and not every incidence of lung cancer is caused by smoking. They understand that the causal relationship is probabilistic, even though they may use a common poker-playing term like ‘the odds’ when explaining these probabilities.

Will we get to this same understanding with GHG emissions and climate change? We seem to be getting closer. Perhaps it helps, sadly, that climate change impacts are increasingly experienced, with more and more people willing to attribute these impacts to climate change. Perhaps school science teachers are having an impact. As the years pass, an increasing percentage of the adult population has learned basic climate science in school. And unlike the challenge of teaching evolution to people belonging to fundamentalist religions, the teaching of climate science poses less of a direct challenge to most religious beliefs.

Most importantly, experts in communications are adamant that stories and anecdotes can help us grasp new information and reappraise our assumptions. I have followed this advice in writing this book. While I try to be faithful to the leading research on how citizens can contribute to climate-energy success, I sometimes present this information by recounting historical events and the experiences of individuals. Some of these latter stories present specific people I know (albeit with some of their names changed), while some are fictitious characters who represent an amalgamation of two or more people. From my decades of discussing these issues with concerned citizens, I am confident that the stories of both my fictive characters and real acquaintances will remind many readers of their own experiences in navigating the issues of the climate-energy challenge.