BOOK REVIEW

Joseph Romm. 2022. *Climate Change: What Everyone Needs to Know. Third Edition*. Oxford University Press, New York, N.Y. xxv + 322 pp., paperback. ISBN 978-0-1976-4713-4. $18.95.

David Ray Griffin. 2015. *Unprecedented: Can Civilization Survive the CO_2 Crisis?* Clarity Press, Inc., Atlanta, Georgia. 515 pp., paperback. ISBN 978-0-9860769-0-9. $34.95.

Mark Maslin. 2021. *Climate Change: A Very Short Introduction. Fourth Edition*. Oxford University Press, New York, N.Y. xxix + 166 pp. ISBN 978-0-19-886786-9. $11.95

There are numerous books for the general reader that explore many individual aspects of climate change: the basic science, description of projected impacts, denialism, adaptation, alternative energy solutions, political and policy solutions, economics. The books under review here, on the other hand, each present an overview of the entire topic.

The book by Joseph Romm is the most recent of these and is a clearly-written and reasonably comprehensive place to start. The author earned a doctorate in physics from the Massachusetts Institute of Technology and has been a student of climate change for several decades. He served as an Assistant Secretary of Energy in the Clinton administration where he oversaw the development and deployment of low-carbon technology. The major topics are covered in six chapters—basic climate science, extreme weather, projected climate impacts, avoiding the worst impacts, climate politics and policies, and the role of clean energy. A final chapter briefly explores the impact of climate change on the individual reader. The text is divided into 97 questions, each concerning a particular issue, and most of these are answered in one to four pages. All are listed in the Table of Contents, which makes it easy for the reader to go immediately to any point of interest. Typical questions are: "What is the greenhouse effect and how does it warm the earth?"; "How does climate change affect wildfires?"; "What kind of droughts can we expect this century?"; and "What is carbon capture and storage (a.k.a carbon sequestration) and what role can it play?" Throughout, Romm relies exclusively on published research and reports of climate scientists or on interviews and correspondence with them for the aspects of the book dealing with the science of climate change and its physical and biological impacts.

The basic science of global warming is treated briefly at the outset. It is important to understand the difference between the terms "global warming" and "climate change." The term "global warming" refers to the increase in the *average* temperature as measured over the entire surface of the earth over a period of time, for example, one year. Absent global warming, the average global temperature varies by only a small fraction of a degree from year to year, despite much larger local daily and seasonal temperature changes, even of as much as several tens of degrees. In effect, the average global temperature is a measure of the energy in the world's climate system. Thus, increases of even one degree in the average global temperature represents the addition of significant amounts of energy to the system. The term "climate change," on the other hand, refers to the climatological changes caused by the increased energy in the system. Climatological effects of the added energy include more powerful storms, alterations in precipitation patterns, and similar changes, even possibly colder than normal temperatures in some areas for certain periods of time.

The basis of global warming is what is known as the "greenhouse effect": radiation from the sun hits the earth's atmosphere, where one-third is reflected back into space by the atmosphere or the surface of the earth. The land, the oceans, or the ice all absorb the rest. A portion of the absorbed energy is reradiated, primarily as infrared radiation. Certain gases in the atmosphere, called greenhouse gases—especially water vapor, methane (CH_4), and carbon dioxide (CO_2)—are able to trap some of the reradiated energy, which thereby heats the atmosphere and provides warmth for the planet. Greenhouse gases in the atmosphere are necessary to keep the earth at a temperature that is more conducive to life. Without any, the earth would be about 33 degrees Celsius (60 degrees Fahrenheit) colder than it is now. At the beginning of the industrial revolution, the CO_2 level in the atmosphere was about 280 parts per million (ppm). Since then, humanity has poured large amounts of CO_2 into the atmosphere, raising the level to 422 ppm as of July 2023 (NASA 2023). This increase in atmospheric CO_2 has caused the global average temperature to rise by 1.1°C (2.0°F) over the past 200 years, that is, since the beginning of the industrial revolution, most of which has occurred in the last 50 years.

One of the results of global warming is sea-level rise. Sea level has risen several inches since 1900, and, during the past 30 years, has risen ca. 0.3 cm (0.12 inches) per year, which is double the rate of increase during the previous 80 years. The principal contributors to sea-level rise are thermal expansion of the ocean (that is, as the water warms, it expands), which currently accounts for about half of the rise, and loss of ice from glaciers and the ice sheets on Greenland and Antarctica. In the future, however, rise from loss of ice will greatly exceed that from thermal expansion. The complete melting of the Greenland ice sheet would raise the sea level by about 20 feet, and the complete melting of the Antarctic ice sheet by about 200 feet. Even now, research shows that the West Antarctic ice sheet, which is melting from below, is unstable. The ocean is also warming, in recent years quite rapidly, because more than 90% of anthropogenic warming goes into the seas.

Romm notes that substantial evidence from many independent sources supports the overwhelming conclusion of climate scientists that global warming is a settled fact and that it is caused by human activity. It is true that climate has changed in the past throughout earth history, sometimes dramatically. The cause of any event of climate change is some sort of external change, referred to as a climate forcing. Forcings can include changes in radiation from the sun, changes in the earth's orbit, the release of greenhouse gases into the atmosphere, or volcanic eruptions, which may emit particulate matter that stays in the atmosphere for a period of time and blocks some of the incoming rays from the sun. Historical natural climate change has been much slower than the current anthropogenic change. Although atmospheric levels of CO_2 have in the distant past been much higher than they are currently, the current level is unprecedented in the experience of the human species, but so is the rate of increase. The rapid increase makes it more difficult or even impossible for humans to mitigate climate change or to adapt. Similarly, plants and animals find it difficult to adapt to rapid change and face possible extinction. Furthermore, although there are slow natural processes that reduce the level of CO_2 in the atmosphere, these will be overwhelmed by rapid increases. In addition, amplifying feedbacks can be triggered.

Amplifying feedbacks are processes that introduce additional forcings that reinforce warming. For example, as warming increases, land and sea ice will melt. The darker earth and sea absorb more heat than the white ice, which reflects a greater amount of radiation back into space. Another example is the greater rate of evaporation, which increases the amount of water vapor (another greenhouse gas) in the atmosphere. Or the increased number and severity of forest fires that liberate CO_2 stored in the vegetation. These amplifying feedbacks, among others, increase warming, which in turn induces further feedback and additional warming.

Another factor that must be considered is the level at which tipping points are reached. Tipping points are levels of greenhouse gases that, when they are reached, trigger irreversible changes in the climate. After a tipping point is reached, the climate change will remain irreversible for 1,000 years or more, even if levels of atmospheric greenhouses gases decrease. These irreversible changes may include droughts and continuing sea-level rise caused by the continuing melting of surface ice. Another is the thawing of permafrost in the arctic that will release methane stored in frozen plant material below the surface. Current evidence is that we are getting close to some tipping points, and may have already passed at least one.

More frequent extreme weather events have been a feature of recent years worldwide. These include heat waves that are more frequent, longer-lasting, and more intense; more severe droughts as well as shifting patterns of precipitation; more frequent wildfires that last longer and burn larger areas; and higher and stronger storm surges in coastal areas resulting from hurricanes and other severe storms. One often hears these events referred to as, for example, 500-year droughts, or 1,000-year heat waves. That means that such extremes would previously have occurred only rarely. Now, we are seeing these extremes much more frequently and, in the space of just a few years, with many more new records than previously.

There are well-understood mechanisms that cause the greater frequency of these extreme events. Envision a normal distribution of summer temperatures, with high temperatures and hot summers toward the right side of the distribution and cool summers toward the left side. As average temperatures increase, the frequency of hot summers will also increase, while cool summers, although still occurring from time to time, will happen less often. In that way, even a small increase in average global temperatures will have an outsize impact. The increased evaporation caused by global warming is one factor in creating stronger droughts, especially in already low-rainfall areas, such as the arid areas in the subtropical belts of the world, including the southwestern US. Rainfall patterns are also shifted by higher average temperatures in a way that expands areas subject to drought. They are also exacerbated by higher average temperatures. Global warming often creates high pressure systems that block air circulation, thereby increasing the length of droughts. Longer summers result in drier fuels and less rainfall, which promotes easier ignition, causing more frequent and more devastating wildfires. These in turn release more carbon into the atmosphere, thereby constituting an amplifying feedback. The evidence is very clear that global warming is a major cause of more extreme precipitation and deluges since a warmer atmosphere can hold more moisture. But climate change also alters the jet stream and other weather patterns in a way that causes storm systems to get blocked, thereby releasing more moisture over a greater period of time in a single location. Though it may seem counter-intuitive, global warming also causes increased snowstorms, or greater amounts of snow, in some areas. The reason is that snow is normally formed only in a narrow temperature range just below freezing; colder temperatures prevent the formation of snow. Thus, as warming increases, there will still be periods of colder weather for many decades in many areas. But the average temperatures in a locality will be warmer, which means that that there will be a greater frequency of subfreezing temperatures in the range in which snow formation is optimal.

As with precipitation in general, the greater tendency of atmospheric systems to create blocks upon increased warming brings about record-setting snowfalls or rainfalls. It is evident that rising sea-levels will cause storm surges to be higher, even if the storms causing them are not more intense. But storms will, on average, be more intense with greater global warming, which will increase the severity of storm surges even more, thereby causing greater amounts of damage. Storm surges are the most damaging aspects of hurricanes, which are also becoming more intense. Although they may not be increasing in frequency, a larger proportion of them are in categories 3–5. The warmer temperature, both of the atmosphere and of the ocean surface waters, increases the intensity of hurricanes and also permits them to hold more water, thereby causing greater rainfall and consequent flooding, another dangerous aspect of these storms.

Scientific studies conclude that most of the warming, and the concomitant climate change, that has occurred since the beginning of the industrial revolution, and all of it that has occurred since 1970, is the result of human activity. The primary sources of greenhouse gas from human activity are burning fossil fuels and deforestation. This is strongly supported by many different lines of evidence. First, the warming that is measured tracks exactly the levels of increase in atmospheric CO_2. In fact, minor changes that can be measured in the rate of increase of atmospheric CO_2 can be correlated with emissions, for example, the decrease in emissions right after the Kyoto Protocol went into effect in the early 1990s and again during the oil crisis on 1974 are each mirrored by a slight slowing of the rate of increase of atmospheric CO_2 (Krauss 2021). Second, studies indicate that possible natural causes of warming, such as changes in the earth's orbit or in solar radiation, would actually have resulted in slight cooling. Third, since carbon exists in more than one isotope, analysis of atmospheric carbon shows that the isotype produced by the burning of fossil fuels is present in the atmosphere in precisely the abundance that would be expected if fossil fuel use is the cause in contrast to the composition of samples of ancient atmospheres taken from preserved ice bubbles buried in polar ice sheets.

Arguably the most important part of Romm's book is a lengthy section describing the impacts that can be expected during the remainder of the twenty-first century under a "business-as-usual" scenario, that is, "no significant action to reduce greenhouse gas emissions trends in the foreseeable future." Very briefly, these impacts can be summarized as (i) very high increase in temperatures, (ii) aridification of many areas, including those with high populations and agricultural areas, creating extensive Dust Bowl regions, including the southwestern US and southern Europe, (iii) extensive loss of biodiversity, both terrestrial and marine, (iv) great increases in extreme weather, (v) food insecurity, making it significantly more difficult to feed the world's increasing population, and (vi) numerous health impacts. Current estimates are that, without mitigation, by the end of the century, global temperatures will reach 4°C (7°F) or more over pre-industrial levels. This would create significant challenges for adaptation. Although there is much uncertainty as to these projections, most of the uncertainty involves even greater warming. A major cause of uncertainty is poor understanding of the sensitivity of climate to feedbacks, such as the melting of ice, increased water vapor, or thawing of the permafrost, which would release carbon (mainly in the form of methane) stored in the frozen tundra. The current path is causing an increase of CO_2 levels in the atmosphere to a much greater extent than the previously predicted 550 ppm. This earlier prediction was based on projections by the Intergovernmental Panel on Climate Change (IPCC), which was established to provide governments with the scientific basis for policy and carried the expectation that its advice would be followed. But that has not happened.

Recent estimates for the range of sea-level rise by 2100 have been 2–6 feet. It now appears that the lower estimate is highly unlikely and that the upper estimate is considerably more than six feet. The estimates of the rate of sea-level rise have also increased, in some cases to as much as one foot per decade after 2050 and two feet per decade after 2100. One major cause for these increased estimates is a greater understanding of the rate of melt of the Greenland and Antarctica ice sheets. This will likely require the displacement of hundreds of millions of people who live near sea shores by the end of the century. It is not merely the submergence of coastal areas that will be a problem, but also the intrusion of saltwater into coastal agricultural areas. Even areas that are not submerged will experience salt water intrusion into subterranean water tables that will make growing crops difficult or impossible. This will also affect the availability of drinking water and water for irrigation and will adversely affect nearby freshwater ecosystems.

Superstorms, such as Hurricane Sandy that devastated coastal New York and New Jersey in 2012, will also become more severe and more frequent. As the atmosphere warms, it can hold more water vapor, which increases precipitation. At the same time, atmospheric blocking patterns will become more frequent, which will hold storms in place for longer periods. Each degree centigrade of global temperature rise increases the frequency of Hurricane Katrina-level storm surges by three to four times. A two degree rise will increase the frequency by ten times.

By the end of the century, as much as one-third of currently habitable and arable land will be subject to near-permanent drying. This will be much worse than the 1930's Dust Bowl—the drying will be longer-term, often lasting as much as several decades. Large portions of the US, Brazil, Africa, Europe, and other areas will be severely affected by the 2060s. The severity will be exacerbated by the confluence of the two causative factors, extreme heat and decreased precipitation, either one of which alone is sufficient to cause a drought.

Devastating health impacts are in store in a business-as-usual scenario. These include increased mortality caused by longer and stronger heat waves and heat stress, as well as malnutrition arising from decreased availability of food and water. Spending time outside in extreme temperatures, which will become common in many areas, will itself be unhealthy. By 2100, up to three-fourths of the world's population will be exposed to deadly combinations of heat and humidity during parts of the year. Increased warming will also enhance the conditions that foster vectors of infectious diseases; in particular, habitats for carriers of tropical diseases will expand, bringing these diseases to areas of the world where they do not currently exist. Large-scale climate-induced migration of human populations will cause civil unrest, which, among other things, will be a factor causing increased disease. Security problems will limit the availability of food, water, and sanitation, as well as medical services in general. Higher temperatures alone will reduce human productivity, especially for those working outdoors, with concomitant negative economic effects.

One-fourth of the CO_2 that is added to the atmosphere becomes dissolved in the ocean, where it is converted into carbonic acid. This increases the acidity of the oceans. Measurements show that the acidity of the oceans has increased by 30% since the beginning of the industrial revolution, and that rate is increasing. An important result of this is the inability of marine organisms to form shells and skeletons in such animals as corals, mollusks, and some plankton. Plankton is an important base of the marine food chain, and its loss will have deleterious effects on the biodiversity of the ocean. This will also impact the availability of marine-based food for humans. Ocean acidification is a significant tipping point, since it is irreversible within tens of thousands of years.

The current extinction crisis results from numerous causes, among them habitat destruction, overfishing, and overhunting. Climate change will become a major additional factor as warming continues, particularly because the high rate at which warming increases will make it difficult or impossible for many species to adapt. As noted in the previous paragraph, ocean acidification will be a contributing factor, but, in addition, as oceans warm, their ability to hold dissolved oxygen will decrease, thereby creating and expanding dead zones and in general smothering many marine animals. Even for many species that may survive this crisis, genetic diversity will be depleted, damaging their ability to adapt and decreasing their chances of long-term survival.

The ability to feed the people of the world will be another major casualty of climate change in this century. As already noted, aridification of arable land, salt-water intrusion into coastal areas, and ocean acidification will be significant negative impacts on food production. As food becomes scarcer, it will become more expensive, in many cases significantly so, which will greatly increase poverty and malnourishment throughout large areas of the globe. This fact, along with massive levels of climate-induced migration, will create security threats, including civil unrest and violent conflict. These, in turn, are major factors that can lead to the establishment of authoritarian governments.

Romm explores best case and worst case scenarios for the remainder of the century. The best case would be keeping temperature increase below 2°C (3.6°F). This would require keeping CO_2 levels in the atmosphere below 450 ppm. Since the level is already above 420 ppm and increases at about 2 ppm per year, this would require a very aggressive effort worldwide to cut emissions. A best case scenario would still result in increased extreme weather events, but more calamitous impacts would likely be avoided. In a business-as-usual scenario (that is, no significant efforts to decrease emissions), the IPCC has projected CO_2 concentrations above 900 ppm by 2100, resulting in warming above pre-industrial levels of about 4.2°C (8°F). This projection, however, does not take into account the potential for significant feedbacks, which means that under this scenario, warming would be even greater. It is also true that we do not know precisely at what point irreversible feedbacks will be triggered. In particular, it is not clear whether even a 2°C limit would be enough to prevent the collapse of the West Antarctic ice sheet.

The IPCC's most recent review of scientific literature shows an upper range of business-as-usual results to be warming of 7.8°C (14°F) by 2100. The worst case scenario would involve widespread drought and desertification, mass extinctions both on land and in the sea, large-scale increases in extreme weather events, sea-level rise significantly greater than six feet, all of which pose significant threats to human health, national security, and food availability, can cause severe economic decline and violent conflicts, and would render large areas of the earth's land surface uninhabitable to humans.

It is important to understand that even if emissions are brought to zero, whatever level of warming has been reached by that time will remain for hundreds of years. That is because CO_2 stays in the atmosphere for a long time. In addition, as noted previously, tipping points can trigger irreversible events that will not be stopped even by reducing emissions.

The worst impacts can be avoided, but only by aggressive action. Romm lays out what must be done to keep warming below 2°C. This is the threshold that most climate scientists and governments believe will avoid dangerous impacts. In reaching this goal, it is important to understand that there is a time lag built into the climate system. Even if atmospheric CO_2 levels are stabilized and emissions are at zero, temperatures will still continue rising for a few decades. Certain impacts, such as the melting of ice sheets will also continue, as will sea-level rise. Therefore, it is necessary to reduce emissions of CO_2 dramatically well before the 2°C threshold is reached. If we wait too long, numerous additional irreversible feedbacks will be triggered.

As a practical matter, keeping below the 2°C threshold, which means keeping atmospheric CO_2 concentrations below 450 ppm, will require immediate action to reduce global greenhouse gas emissions by 50% before 2050 and to continue the decline so that net emissions will reach zero by 2070. Even this may be too little if it turns out that significant feedbacks are triggered earlier than is contemplated in current models.

In a rather short section of Romm's book, he identifies four types of policies that governments use to reduce greenhouse gas emissions: economic, regulatory, technological, and land use policies. The economic category includes policies to increase the price of CO_2 or reduce or subsidize the cost of alternative energy sources. One way of increasing the price of CO_2 is to impose a tax on the emission of greenhouse gases, with two goals: one to select a rate of tax that reflects the social cost of carbon, and the other to increase the cost of emissions in such a way as to disincentivize emissions. The "social cost" of carbon emissions is an estimate of the cost of harm done to society that is not included in the actual cost, which typically reflects only the cost of production plus a profit to the producers and sellers. The goal of subsidizing alternative sources of energy, such as nuclear, solar, or wind, as well as the cost of technological innovation, is to bring their cost down, thereby increasing the use of these sources, which will in turn bring the cost down further. A second economic policy is cap-and-trade or carbon trading. A government agency, such as the EPA, sets an upper limit on emissions for an entire industry. It then issues or sells permits to individual companies. A company is then allowed to produce emissions up to the amount of the permits it has received, but no more. If it produces less, it can sell unused permits on a secondary market similar to a stock exchange. The system works, because the number of permits available each year are gradually reduced, thereby reducing the overall level of emissions. This creates an incentive for long-term technologies and strategies for the reduction of CO_2 emissions. This system has been used in the past successfully to reduce and eventually phase out leaded gasoline and sulfur dioxide, which caused acid rain.

Regulatory policies to increase the use of alternative energy sources or to reduce the use of fossil fuels include such things as fuel economy standards for vehicles, promoting the use of electric vehicles, efficiency standards for appliances, and similar policies. Technological policies include those that promote research into and deployment of clean energy sources, including lowering their cost and improving their performance. Such policies can also improve the efficiency and cost of appliances and other energy uses. Land use policies include lowering the rate of deforestation or the planting of trees.

Romm discusses the use of geoengineering to reduce or halt global warming. Two principal categories of geoengineering have been proposed: removing carbon from the atmosphere and albedo modification. There are serious problems with the deployment of both of these. Carbon removal is deemed to be relatively safe, but the technology does not exist that would permit scaling up to the level needed to remove sufficient carbon from the atmosphere to make a meaningful difference. It would also be prohibitively expensive. More serious, however, are problems with storage of carbon once it is removed (referred to in the literature as carbon sequestration). It requires massive compression of the removed carbon to a liquid form that can then be injected into underground storage places, typically depleted oil, gas, or coal reservoirs. Because this would have to be done at a rate that is at least equal to the annual production of these fossil fuels, the time frame is prohibitive. Furthermore, leakage is a major problem—since effective storage would have to last for thousands of years, even a very small rate of leakage, such as less than 1% per year, would render this useless. There is also the possibility that earthquakes could be triggered by the injection of massive amounts of liquefied CO_2 into these repositories, which, among other things, could result in the release of the stored carbon.

Albedo is the reflectivity of solar radiation by the earth. The idea is that by increasing this reflectivity—albedo modification—warming would be reduced because the earth would then absorb less heat. The principal means for doing so involves injecting massive amounts of aerosols into the stratosphere, which would block a portion of incoming sunlight, similar to the way that volcanic eruptions produce particles that, once entered into the atmosphere, cause cooling. There is, however, no way at present of predicting secondary effects that could be significantly deleterious. Increased reflectivity could disrupt food production, alter precipitation patterns causing droughts or excess rainfall, or further deplete the ozone layer. And there is no way of testing this method of albedo modification short of full-scale execution. But perhaps the most serious problem is that it would do nothing to reduce CO_2 emissions; if warming is reduced by albedo modification, there would be a strong temptation not to reduce the use of fossil fuels. Even though the direct effects of warming might be avoided, there are other effects, such as ocean acidification and its effects on terrestrial ecosystems, that would continue unabated. Furthermore, since aerosols would have very short lifetimes in the atmosphere, massive injections would have to continue at frequent intervals long into the future, perhaps indefinitely. If for any reason this process were to halt or be reduced (and it is impossible to predict with certainty what might cause this—wars, economic emergencies, technological problems), the earth would immediately be subject to the severe impacts of far greater levels of CO_2 in the atmosphere than at present.

It should be clear, therefore, that in order to keep warming below 2°C, steep declines in carbon emissions will be necessary. There must be a 50% reduction by 2050, and that pace must continue until we reach net-zero emissions by 2100. Since the largest component of human source emissions of CO_2—78% in the period since 1970—has been fossil fuel and industrial emissions, deep cuts in fossil fuel use are essential for meeting this goal.

Increasing energy efficiency is one of the most important strategies. It is defined by Romm as “reducing the energy consumption of our products and services, while maintain or improving their performance.” He gives several reasons why it is important: (i) it is the largest resource; (ii) it is by far the least expensive strategy; (iii) it is by far the fastest strategy to deploy; and (iv) it is “renewable”—it never runs out. Examples of energy efficiency include such actions as insulating a home, increasing the fuel efficiency of vehicles, replacing incandescent lighting with LED bulbs, using sensors to time the use of artificial lights, or designing building to make use of more daylight, among many other examples. Studies have shown that aggressive use of efficiency strategies will substantially lower the cost of climate action. In the US, two types of regulatory policies regarding energy efficiency have succeeded in decoupling economic growth from energy demand—that is, increasing gross domestic product (GDP) increased decreasing while energy consumption. The first of these policies is the requirement that utilities deploy a specific level of efficiency practices. The second involves regulations that decouple a utility's revenues from the amount of electricity that is sold.

More importantly, however, achieving sufficient reduction in emissions requires the largescale use of alternative, or carbon-free, sources of energy. Since nuclear power currently (as of 2015) provides the largest share of low-carbon energy, both in the US and worldwide, many people advocate greater use of this source. There are problems with this, however. New nuclear plants are extremely expensive, currently costing as much as $10 billion for one new plant. This is because they must be built to withstand virtually any conceivable risk, since disasters or human error can be catastrophic. For this reason, very few new plants have been built in the last few decades. The disaster at Fukushima in Japan has been a principal reason for the slowdown. Furthermore, the rapidly decreasing costs of natural gas and renewable energy sources, as well as advances in energy efficiency, have rendered half of the US nuclear plants unprofitable. Another problem is that the operation of a nuclear plant requires massive amounts of water—typically 35–65 million liters per day—which will be problematic in a world with increasing droughts.

Natural gas is increasingly used as an energy source, because it is less carbon intensive and burns more efficiently than the other fossil fuels. It is, nevertheless, a carbon-based fuel and will have to be phased out rather quickly if we are to keep global warming below 2°C. There are two additional challenges with using natural gas as a bridge source of energy. Because it is relatively inexpensive, it can delay the conversion to more efficient energy sources. Furthermore, it releases methane (CH_4), rather than CO_2, which is 86 times as potent a greenhouse gas as CO_2, although it remains in the atmosphere for a much shorter time period. Finally, if it used as substitute for nuclear or other renewable energy sources, as it is to some extent, it would be counterproductive as a strategy to reduce greenhouse gas emissions.

The most promising sources of alternative energy are solar power and wind power. There are two principal types of solar energy production: photovoltaic (PV), in which sunlight is converted directly into electricity, and concentrated solar thermal power (CSP), in which electricity is produced from the heat from focused sunlight. In recent decades, the cost of solar power has decreased precipitously so that now it competes favorably with electricity from the power grid, and manufacturing, sales, and installations of solar power facilities have similarly increased. Commitments by countries worldwide, including China and the European Union, to significantly expand the use of renewable energy insure that the cost will continue to drop. The energy required to manufacture a PV system is also decreasing, which makes it more likely that solar power will be a major facture in sustaining a global economy while emissions of greenhouse gases decline. Although PV sources of solar power constitute by far the largest share of solar energy, CSP has important characteristics that may well make it more valuable in the future. These include the fact that the heat produced by this method can be stored much more efficiently and inexpensively than electricity, which means that it can be used to provide energy during high demand times when sunlight is not at its peak. Current projections are that both forms of solar power combined can produce as much as 27% of the world's electricity needs by 2050, provided appropriate policies are in place and technology continues on its current path.

Current projections are that wind power can produce as much as 18% of the world's electricity by 2050. The cost of wind power has decreased significantly in recent years, partly as a result of improvements in the aerodynamics of the blades used on wind turbines. This has enabled effective wind turbines to operate in areas that are less windy than was previously necessary. Also, these improvements have permitted the generation of wind power over a wider range of wind speeds and directions. Cost reductions have been particularly steep with respect to offshore wind farms. These are especially desirable for two additional reasons: they can be sited close to population centers where other sources of alternative energy are less available, and offshore winds are generally stronger and more consistent than over land.

Biomass has also been suggested as a source of renewable energy. However, it is far less efficient than most other forms, and, more seriously, it requires the use of vast amounts of arable land that will be needed for food production. This will be especially critical as the climate warms and drought-stricken areas increase. Other forms of renewable energy that are considered include hydropower and geothermal power. Hydropower, primarily from hydroelectric dams, currently produces about 16% of the world's electricity. Even if power from this source is doubled, it will still produce only about 20% of the world's electricity as energy demand increases in future decades. Geothermal power is provided primarily by two types of facilities. Large geothermal plants extract heat directly from underground hot water or steam to operate turbines to produce electricity. These plants provide large proportions of the electrical needs in certain places, such as Iceland, parts of Central America, Kenya, and the Philippines. Despite this, large plants for geothermal power will likely be a minor player in the production of carbon-free energy. A second form of geothermal power production uses small pumps that use underground heat directly to heat buildings and power certain industrial processes. These systems are highly efficient and can be used in any climate. They will play a useful, but minor, role in future energy production.

Romm emphasizes that the transportation sector will require major attention in the effort to replace carbon-based fuels with alternative energy sources. In the US, for example, transportation has accounted for 69% of the increase in CO_2 emissions since 1990. Vehicles operating on carbon-free fuels are confronted with several market challenges, such as high cost and the difficulties of refueling, and therefore large-scale deployment will require government intervention. However, since they are not currently cost-effective, even government intervention may be problematical. Romm identifies several barriers to the acceptance and success of alternative-fuel vehicles, including high initial cost, limited range, safety concerns, high cost of fuel, limited availability of fuel stations, and competition as a result of improvements in the fuel efficiency of conventional vehicles. The limited availability of fuel stations underscores a conundrum—the reluctance to invest in a wide network of such stations before compatible vehicles are available accompanied by a reluctance to manufacture, sell, or purchase such vehicles before sufficient fueling stations are available. Hybrid vehicles avoid many of these problems and serve as a useful bridge to fully alternative-fueled vehicles. Despite these obstacles, it is nevertheless necessary to cease the use of carbon-based fuels in the very near future, and therefore extensive research and development is this area is ongoing. Indeed, the deployment of electric vehicles has been increasing in recent years, and is expected to continue to do so, especially as prices decline. The cost of batteries, which has been a significant component of the greatly inflated price of electric vehicles, was originally extremely high, but has recently experienced significant decreases.

In a final chapter, Romm discusses how climate change will affect each of us as individuals and our families. Some of the most significant social and personal impacts are ones that may not have been foreseen. Therefore, it will be important to understand climate change impacts and the transition to clean energy. Not only those living on the coast, or contemplating doing so, or investing in coastal properties, but all of us must come to realize that the value of most coastal properties will crash as sea-levels rise. This will have a significant impact on the national and global economy. It is not possible to predict when such a crash is likely to occur, but preparation will be essential. Future changes in habitability, precipitation patterns, and other weather changes will also impact our decisions of where to live, where to work, or where to invest. Younger people starting to give thought to a career may also wish to consider what careers will be needed as we, as a society, confront the challenges brought on by climate change. We must also all consider ways to reduce our own carbon footprints. Even though actions by an individual will have insignificant effect, and since no individual action will be effective without governmental and international action, collective efforts by all will be helpful and necessary in confronting the challenges we face from climate change. In a penultimate section of this chapter, Romm provides responses to several popular climate science myths in a discussion of how we can talk about climate change to those who do not accept the scientific evidence for its reality. Finally, in a hopeful mood, Romm poses the final question of the book: "Do we still have time to preserve a livable climate?" The answer he gives is "for now, yes." It is easy to despair if we focus only on the latest science and the inadequacy of our political leadership. But there are many hopeful signs. Although it will take much more than current efforts to keep warming below 2°C, the nations of the world are making stronger commitments, clean energy technology and deployment is ramping up, and more and more people are making efforts at education and action. And, even if we somehow fail to meet the 2°C threshold, it will still be necessary to continue action thereafter to keep warming as close to that level as possible and not fall into despair and denial.

David Ray Griffin's *Unprecedented* covers much of the same ground as Joseph Romm, often in greater detail. But in addition to the areas of overlap, which I will not belabor here, he covers some important additional areas. The author, who died in 2022, was Professor of Philosophy of Religion and Theology, Emeritus, at Claremont School of Theology and Claremont Graduate University. The basic science of global warming, which is very briefly discussed by Romm, is not covered at all by Griffin, but is taken for granted. As an illuminating exercise, the author sets out three different levels of response by the US in the Introduction, referred to as Plans A, B, and C. He then examines the various types of impact under each of the three levels. Plan A is the world's political leaders simply continuing as they have, that is, business as usual. Plan B is taking aggressive action to keep global warming below the 2°C target, although, citing climate scientist James Hansen for the declaration that 2°C of warming would be a disaster, Griffin concludes that this plan should have an even lower target. Plan C, referred to as wait and see, contemplates that political leaders will delay taking any immediate action, waiting to see if the scientists' predictions are correct and not wanting to cut fossil fuel use for fear of its adverse effect on the global economy. Under this plan, leaders would begin to take action only when there is unambiguous evidence that anthropogenic climate change will have serious deleterious effects. There are serious problems with Plan C, however. One is that once CO_2 enters the atmosphere, it remains for at least 1,000 years, so that even if carbon emissions are halted entirely, conditions will not return in any meaningful amount of time to what they were earlier. In fact, it would be worse, because of the lag time of about 30 years between the emission of CO_2 and the effects caused by the new level of CO_2 in the atmosphere. By the time conditions have reached the point at which Plan C advocates realize that action is needed, considerably worse conditions will have already been irreversibly baked into the mix.

In four chapters devoted to extreme weather, Griffin covers much the same ground as Romm, but makes some useful observations. First, he notes that extreme weather events are best referred to as "climate disruptions," because they are threats that disrupt human life in unprecedented ways. When such extreme weather occurs, the question often arises whether that particular storm, heat wave, or other event is attributable to climate change. Because of the natural variability in weather, many have taken the position that no individual event can be attributed to climate change. However, because extreme events have become increasingly more frequent, we can conclude with high confidence that most such events would not have occurred in the absence of climate change.

Griffin notes that in the absence of global warming, normal variability in weather would statistically produce roughly equal numbers of record low temperatures as record high temperatures. But that is not what has been happening; the evidence is that the number of record highs is statistically greater than the number of record lows.

Under Plan A, the impacts will be severe. By century's end, the average global temperature will reach 6°C higher than preindustrial temperatures, that is 5° higher than it is currently, and there will be no stopping point thereafter. Daily temperatures will commonly reach as much as 122°F in the southern, central, and western US, and even higher in other places. By the next century, areas where half of the world's population now lives will become uninhabitable. A third of the land surface of the world will be under a permanent drought, including much of the US, southern Europe, Africa, Australia, and other areas. There will be significantly more powerful and more frequent storms, deluges, and hurricanes. Sea-levels will rise one foot by 2050, and 4–6 feet, or more, by 2100. It will continue to rise thereafter, ordinarily by 6–12 inches per decade, but the melting of the Greenland and West Antarctica ice sheets will add 39 feet. This will inundate areas that now support populations of 650 million people and include much prime agricultural land. Coastal cities, such as Miami, New York, Seattle, San Francisco, and many others in the US and around the world will be uninhabitable. The loss of mountain glaciers and snowpack means that, in addition to drought and extreme heat, the southwestern US will lack sufficient fresh water to support its present population, at least in late spring and summer. Worldwide, billions of people will be without adequate fresh water and be unable to survive. Agriculture will become impossible in places with extreme heat and drought. Destructive storms, rains, and flooding will adversely affect the availability of wheat, rice, and many other crops, as will salinization of agricultural areas due to sea rise. Ocean acidification will deplete stocks of seafood. It will therefore become difficult or impossible to provide sufficient food to much of the world's population.

Plan B is taking immediate and aggressive steps to cease carbon emissions. However, even if emissions were to stop tomorrow, conditions would still worsen for a while, because of the 30-year lag that is already built into the system. Among these effects are that extreme weather events will continue to worsen, but we will avoid catastrophic temperatures, storms, and sea-level rise. The global average temperature will continue to rise, perhaps to 1.5 or 2°C above preindustrial levels. There will be warmer weather than today, but although unpleasant, it will not be intolerable for most people. Droughts and wildfires will continue to increase, but the affected areas will not become unlivable, and storm damage, while increasing, will nevertheless be limited. Perhaps the worst effects will come from continuing sea-rise, again already built into the system, and there will be much distress, but large-scale migration inland will be avoided. It will be important to take aggressive steps to protect coastal cities and military installations. Many of these steps are described in detail in Goodell (2017), which will be the subject of a future review. Long-term expensive investments in coastal properties will not be wise and must be discouraged, but that may be difficult to explain to many people. In this regard, Griffin describes the recent law in North Carolina, for example, that requires state agencies to base all assumptions about future sea-level rise solely on linear projections from historical data, which will seriously underestimate the amount of rise in the near future. There will continue to be loss of fresh water in many parts of the world, but not so much that would cause the collapse of civilization or massive numbers of deaths. Food shortages will continue to worsen, but the severe conditions that would ensue from a business as usual scenario will be avoided. Since even the immediate cessation of emissions will not magically return the world to what we experienced even a few decades ago, or even keep conditions at the level they have currently reached, it will be necessary to accompany efforts to cease emissions and replace fossil fuels with renewable energy sources with adaptation strategies. Many of these will be discussed in future reviews.

The wait-and-see scenario, Plan C, will result in impacts much closer to those under Plan A than Plan B. To begin with, it will result in warming of at least 4°C above pre-industrial levels by 2100. Even if Plan C efforts succeed in keeping warming within that goal, there will still be irreversible impacts, such as decreased rainfall in dry areas, expanded areas of desertification and dust-bowl conditions that will not be reversible within any meaningful time frame. Even the eventual cessation of emissions will likely not avoid runaway warming as the result of tipping points that will be triggered before that level is reached. As a result, this plan will not be significantly different from Plan A. It will not be possible to avoid the melting of the major ice sheets, and the consequent sea-level rise will be catastrophic. Even a little warming will cause severe disruptions in the availability of fresh water for large portions of the earth's population. Similarly, food availability will also be severely impacted. Thus, a wait-and-see scenario will not avoid dire consequences.

As the worsening climate makes certain areas either uninhabitable or very difficult to live in, the number of so-called "climate refugees" will increase. International law does not recognize that term, and persons leaving areas because they are forced out by climate-influenced changes are not covered under the *Geneva Convention Relating to the Status of Refugees*, which limits its protection to people leaving an area because of their fear of state-led persecution. Nevertheless, climate refugees will become an increasingly prominent phenomenon in the coming years and decades. Although climate refugees will be escaping many different climate-induced emergencies, Griffin focuses his discussion on sea-level rise, discussing in detail a few areas of particular importance. The Carteret Islands are a small group northeast of Papua New Guinea. The entire population of about 2,600 is being forced to move, because their low-lying homeland is threatened by rising seas. Among other things, their home-grown food sources, such as breadfruit, bananas, and coconuts, can no longer be well-supported. The so-called seasonal "king tides" are becoming more dangerous, and inundation is creating breeding grounds for mosquitos carrying malaria. Griffin notes the especial cruelty of their situation, because they have not contributed at all to the problem—they have no roads, no vehicles, and no airplanes, and they have little use for electricity.

The president of the Maldives, a nation consisting of an archipelago in the Indian Ocean, warned that the nation faced disappearance due to rising seas and moved to support an international coalition to lower the levels of CO_2 in the atmosphere to 350 ppm. He was very much involved in negotiations at the 2009 climate conference in Copenhagen and in subsequent conferences, and did what he could at home to make his nation carbon neutral. Unfortunately, he was removed from office by a coup, which, as Griffin notes, illustrates the tendency of many politicians to take their own political contests more seriously than the threats facing their homelands.

The Sundarbans are in the delta of the Ganges River and constitute the largest mangrove forest in the world and is highly biodiverse. They are situated so as to protect low-lying coastal communities from the effects of large storm surges. However, over 185,000 acres, including some entire islands, have been submerged in the last 30 years. Under the current trajectory, 75% of the area will be destroyed in the next 40–50 years, giving rise to the migration of large numbers of people—the population of the delta area is about 4 million. Already, more than 200 people leave the area each day, mostly moving to Calcutta, which is already overcrowded.

The nearby nation of Bangladesh is one of the countries most threated by sea-level rise, which will require the relocation of as much as 25–35 million people, which, in turn, will greatly increase the level of poverty. Since the remainder of Bangladesh is already very densely populated, this will create pressure on other countries to accept refugees. This pattern will be repeated in many places throughout the world. It will also underscore the need for further development of international law and organizations to expand the formal definition of refugee to include those escaping devastating effects climate deterioration.

There are national security consequences to climate change. Among these is the creation of climate refugees. Another is war, which may arise from conflicts over arable or habitable land, or a breakdown in food systems, or from other impacts, and may affect vast populations. Even if the rest of government has paid too little attention to climate change, the military and the intelligence community has been acutely aware of security threats occasioned by climate change. In fact, in the US, the Pentagon has long considered these threats as sitting at the forefront of its concerns and has sponsored numerous studies. It applies the concept of "threat multiplier" to climate change effects. That is, even if many wars are not initially, or even primarily, about climate, climate change does factor into them and exacerbates the conflict. The perspective of the military on climate change has been treated in much detail by Klare (2019).

Though small or local ecosystems may collapse from time to time from a variety of causes, scientists are becoming aware of the possibility of large-scale, or even global, ecosystem collapse as a consequence of global warming, particularly under a Plan A scenario. Perhaps the most obvious such event would be the collapse of the oceanic ecosystem resulting from ocean acidification, which would destroy coral reefs and prevent the formation of the calcium skeletons or exoskeletons of many marine animals, but most pertinently of foraminifera, which are the base of many oceanic food chains. Attention has also focused on the possibility of more extensive collapse on land. A 2004 study (Thomas et al. 2004) found that under a business as usual scenario, 15–37 percent of land animal and plant species would be committed to extinction by 2050. Griffin notes that a 2007 study concluded that the plankton, edible fish, bees, and topsoil, all of them essential to human survival, are in severe danger and their loss must be averted. A comparative study of historical extinction rates with those of today concluded that species are now disappearing at a rate 1,000 times that of the past and that we are facing a major extinction crisis comparable to the end of Cretaceous extinction event that spelled the end of the dinosaurs and large numbers of other species (Pimm et al. 2014).

An important study discussed by Griffin attempts to recognize planetary boundaries that must be observed to prevent global ecosystem collapse (Rockström et al. 2009). The idea is that as the earth transitions from the Holocene (the geological epoch that began following the latest glacial era, about 10,000 years ago) to the Anthropocene (a proposed geological epoch that began at the dawn of the industrial revolution or later in recognition of the substantial human impact on the earth's geology and biosphere, including climate change), many of the conditions that permit the maintenance of the global ecosystem are being altered beyond the bounds that held sway during the Holocene. The authors ask what the non-negotiable global preconditions are that we need to respect in order to avoid catastrophic environmental change on a planetary scale. They refer to the preconditions as thresholds—a concept that is similar to the tipping points we have already discussed with respect to irreversible changes brought on by climate change. Transgressing one or more of these thresholds could lead to an abrupt change in the global ecosystem. Since we have no precise knowledge of these thresholds, in particular when, or under what conditions, they would be triggered, the authors call for study of the dynamics of these thresholds and the associated feedbacks on a continental and global scale. They suggest that we agree on a set of boundaries within which we can expect to operate safely. At one point it was assumed that a 4°C rise in global temperatures would provide safety for global ecosystems, but most scientists later came to believe that no more than a 2°C rise will guarantee safety. However, Rockström et al. (2009) proposed that a safe boundary would be an increase of no more than 1.5°C. They recognize nine planetary boundaries, of which three have already been passed. These include atmospheric CO_2 concentration and loss of biodiversity. They urge that we do what can be done to repair or mitigate the boundaries that have been passed and also to ensure that no further boundaries are passed.

Griffin agrees with numerous scientists that the release of methane from permafrost in the Arctic poses the greatest threat of collapse of the global ecosystem. Permafrost is the expanse of soils in the Arctic that has been frozen since the most recent glacial period. It contains vast amounts of carbon from dead animals and plants, primarily in the form of methane. It is estimated that the carbon in the permafrost constitutes half of all the carbon stored in the earth's soils. If it were all to be released, it would constitute four or five times all the carbon that has been released by human activity since 1850. The concern is heightened because the Arctic is warming twice as fast as the rest of the planet, which makes thawing of the permafrost, and the consequent release of methane, even more likely. This is particularly so, since most of the carbon is in the top three meters of the permafrost. If the permafrost is on dry land, the carbon will be broken down by oxygen-breathing bacteria and released as CO_2, whereas if it is below a wetland, it will be released as methane, which is a far more potent greenhouse gas than CO_2. It was once thought that the release of methane from permafrost was a minor problem that would take place only in the distant future. But there is now strong evidence that the release is happening now. In recent years, the shallow waters off the Arctic coast of eastern Siberia on what is known as the Arctic shelf is saturated with methane, which was later shown to be arising from underwater permafrost. If business as usual continues, the release of even a portion of the methane stored in the shelf is released, that could trigger substantial abrupt warming. Because of the increased warming, the methane release will become self-sustaining as a positive feedback loop, leading to runaway warming and ecological collapse. In 2013, it was discovered that permafrost in the Antarctic region is also subject to warming and release of carbon.

Efforts to deal with the reality of climate change have been hampered by a vigorous denial movement. Therefore, in order to understand and act on climate change, it is necessary to understand and engage with the denialism. The book *Climate Change* by Joseph Romm briefly refers to denialism, whereas Griffin devotes an entire chapter to this topic. Since I am planning a full review on this topic in a later issue, I will not go into much detail here, but suffice it to say that any understanding of denialism must begin with a perusal of *Merchants of Doubt* by Naomi Oreskes and Eric Conway (2010), which is also discussed at some length by Griffin. Very briefly, Oreskes and Conway point out that climate change denial is nothing new, and they describe how the denialist campaign is not only very similar to previous anti-science denial campaigns over the past 60 some years, but have involved the very same individuals and the institutions they created to foster those campaigns. These include the denial by the tobacco industry and its supporters against the strongly supported evidence that nicotine causes cancer, and shortly afterwards that secondhand smoke is also dangerous; the denial by polluting industries that certain sulfur-based pollutants cause acid rain, which caused devastating losses among trees, fish, and other organisms; the denial by the chemical industry that chlorofluorocarbons released by spray cans, refrigerators, and air conditioners were damaging the ozone in the stratosphere, which protects us from damaging ultraviolet light from the sun; the denial by pesticide manufacturers about the danger caused by DDT, as was thoroughly exposed by Rachel Carson in her book *Silent Spring*. Beginning several decades ago, the fossil fuel industry, despite the knowledge that they had developed internally about the reality of anthropogenic climate change and its cause, employed the same people and institutions to carry out a pervasive program of disinformation and denial and of influencing politicians. These methods include using front organizations, hiring a handful of scientists whose conclusions are not in line with those of the vast majority of the scientific community to make authoritative-sounding pronouncements, and placing denialist articles in various publications, while at the same time concealing the source of support for these individuals and organizations from within the fossil fuel industry.

Concomitant with the denial campaign, the efforts to deal with climate change have also been hampered by the failure of the media, especially in the US, to report vigorously and accurately on this issue, and Griffin devotes another chapter to this topic. The principal reason this is a problem is that, as the prominent climate scientist James Hansen has indicated, getting government to act boldly requires public pressure, which, in turn, requires a fully informed populace. But, as a result of this failure by the media, there is not only a large gap between the understanding of climate change by scientists on the one hand and by the public at large on the other, but there is also a remarkable inconsistency in their respective views. To put this in perspective, Griffin cites a parable devised by the journalist Eric Pooley, in which we suppose that scientists had discovered a meteor rapidly moving toward the earth that would strike later this century with dire consequences and that we had only ten years to divert or destroy the meteor. The news media would be completely on top of the story and would cover it exhaustively so that it became the story of the century. Of course, unlike the case with climate change, there is no powerful industry or other interest that would benefit from obscuring the truth about the meteor. Climate change is the meteor that threatens civilization, but in this real-world case the media coverage is tepid at best.

Griffin posits several aspects of the failure of the media to report fully in climate change. One is the practice of false balance. To be sure, balanced reporting is a hallmark of good reporting. But that requires that two or more sides have at least arguably equally valid arguments, or, if not equal, at least of sufficient significance to be recognized. However, when there really is only one well-supported and valid side to a story, it is a disservice to the consumers of the news to act as if opposing viewpoints have equally valid reasons to be heard, and more of a disservice if the two sides are reported without any commentary distinguishing between the validity of the one and the lack of support for the other. Another aspect is the felt need by the media to report on conflicts, even when there is none. By holding up both sides of the so-called climate "debate" (a misnomer if there ever was one), the media feeds the hunger for provocative stories and controversy. The third aspect is the powerful presence of fossil fuel advertisers who would threaten to withdraw their lucrative business if the media reported fairly and accurately on a topic that they would rather not see treated in that fashion. Griffin notes that news coverage of climate topics has actually been decreasing over the last several years, and that it is more likely to cover supposed scandals, such as the "climategate" stories than the substance of international conferences. Weather reports on television often cover extreme weather events without any mention of climate change. Finally, there are the explicit denialist outlets, among which Griffin mentions *Fox News*, the *Wall Street Journal*, the cable channel CNBC, and certain opinion columnists in the *Washington Post* and other newspapers.

A third obstacle to effective and aggressive action to protect us against climate change that Griffin explores in some depth is political failure. Along with many others, Griffin recognizes climate change as "the defining challenge of our time." "However," he further notes, "the political world has not risen to this challenge." Scientists have been sounding the alarm publicly and in many ways to alert governments to the catastrophe that will follow upon continued business as usual, but this has had little effect. This is not because political leaders have been misinformed. Griffin recounts the numerous reports made for and at the behest of government, international conferences, international agreements, and many other forms of communication, in which the facts have been clearly presented. So, why has the political world failed to take meaningful action? One reason, perhaps, is simply that humans, including politicians, are often foolish, in this area as in so many others. More importantly, however, Griffin believes that politicians do not fully appreciate the difference between science and politics. The latter is often seen as the "art of the possible," doing what can be done in an environment where compromise and negotiation are the main tools, unlike science, which does not compromise to reach its conclusions. It is too easy to see action, even on this "defining challenge," as politics as usual. It is all too easy to fail to grasp the stakes. Another important factor can be laid to the common human weaknesses of fear, greed, and self-interest. There is no lack of knowledge about the problem, nor are cost-effective solutions lacking. What is lacking is the necessary political will. The short-sightedness can be exemplified by an

Asian foreign minister attending the Copenhagen Conference on climate change in 2009 who averred that he was not there to save the world, but to protect his country's national interest. This attitude has surely been repeated many times. Self-interest also applies to large fossil fuel corporations that have known of the danger for decades, but nevertheless act in their own financial interest. Governments, including legislative bodies, are populated by many who are friendly to the fossil fuel industry, whether because of their receipt of massive donations or because their own districts are home to these facilities.

Given these failures, it is important to examine the moral challenge facing us as a society, which Griffin characterizes as "unprecedented." He quotes Bill McKibben (2012) as also recognizing this as "the greatest challenge humans have ever faced." Griffin notes that, despite the variety of religious and philosophical traditions in the world, a basic ethic is recognized by virtually all traditions, which is some version of the Golden Rule: Do not do to others what you would not have done to you. There exist also nearly universal sets of negative injunctions against such basic acts as murder, lying, stealing, and so forth. In this spirit, Griffin has fashioned what he calls the ten climate commandments, which forbid such actions as depriving people of clean air or clean water, destroying their soil, ruining their seas, forcing them to migrate, and so forth. He notes that fossil fuel corporations have violated all of these, and that governments have failed to protect people from these violations. There is also a strong tradition of basic human rights, an important example being the *Universal Declaration of Human Rights* that was approved by the UN General Assembly in 1948. The ideas, however, go back at least to classical times, and more recently to the French *Declaration of the Rights of Man*. These basic rights should form the bedrock principles on which climate action must rest. An ancillary principle is that of intergenerational justice, whereby we owe duties not only to our contemporaries, but also to generations that will follow us. The principle has been enunciated by many sources, including the *Constitution of the Iroquois Nations*, Thomas Jefferson, and many climate scientists and activists. In the context of climate change, an important consideration is the duty owed by rich nations, which have been most responsible for creating the problem, to the poorer nations of the world.

Because solving the problems created by climate change involves much more than just scientific or technological expertise, economics is necessarily involved. Griffin gives a substantially more detailed discussion than the brief sections of Joseph Romm's book, but, since this topic will be covered in a future review, I will not go further into it here.

The final section of *Unprecedented* discusses alternative sources of energy and the abolition of fossil fuels, as well as the means of achieving these goals. This is not materially different from Romm's discussion of these topics, albeit presented in greater depth, and so there is no need to cover that section here.

Climate Change by Mark Maslin is one of over 700 titles in the *Very Short Introduction* series published by Oxford University Press. Each volume presents, usually in less than 200 pages, a concise, but authoritative, treatment of a topic for the general reader by an expert in the field. They are meant to be balanced and complete (at least within their small compass). The author is a professor of

Earth System Science at University College London in the UK. It covers much the same ground as do Romm and Griffin, but more concisely. But it has some features of its own that make it a useful complement to the books by Romm and Griffin. Unlike either of the other volumes, Maslin's book is liberally supplied with charts and graphs that help make the facts of the science and their impacts more palpable. The basic science is treated somewhat more fully than in either Romm or Griffin. After a brief explanation of the greenhouse effect, Maslin describes the variations in atmospheric CO_2 over the past 800,000 years, which covers eight cycles of advances and retreats of glaciation. By drilling deeply into the Greenland and Antarctic ice sheets, scientists are able to recover air bubbles that became trapped when the ice was first laid down. By analyzing the air in these bubbles, the composition of the air and the average temperature can be determined. Paired graphs show how the temperature tracks the variation in CO_2 concentration. This varies between ca. 180 ppm and ca. 280 ppm throughout this entire period until the very end, where it suddenly increases to more than 400 ppm at the present day. The concentration of atmospheric CO_2 has been measured daily since 1958 at an observatory at the top of Mauna Loa in Hawaii, which is at an elevation of about 4,000 feet. Maslin reproduces a graph showing the results of these measurements. There is an annual variation of a few parts per million that reflects the uptake of CO_2 by plants, which is highest in the northern hemisphere spring, which includes the greatest expanse of land on the globe. This then increases in the fall. But this minor annual variation is a mere blip in the overall virtually monotonic increase in concentration from ca. 316 ppm in 1958 to over 420 ppm today.

Another chart shows the amount of CO_2 emissions annually by nation or region—China, India, the European Union, the US, and the rest of the world—since 1960. Although currently the largest emitter among nations is China, the US has emitted the most in the aggregate since 1960. These results are provided by the IPCC, which was created in 1988 by the United National Environmental Panel and the World Meteorological Organization. The purpose of the IPCC is to make periodic assessments of the state of knowledge about the science of climate change, its physical, biological and social impacts, and strategies to alleviate climate change and its impacts. The assessments are prepared by some 500 experts from 120 countries and are reviewed by thousands of others before they are released. Among other things, these assessments provide governments with information that is useful in evaluating risks and in formulating responses to the climate crisis. The experts involved in drafting the reports are nominated by governments, international organizations, and relevant non-governmental organizations (NGOs).

The IPCC reports reveal that the principal source of atmospheric CO_2 is the burning of fossil fuels. Emissions are not evenly distributed among nations. The vast majority has historically been produced by the developed nations of the world. The next largest source is from land-use changes, mainly deforestation for agriculture, urbanization, or other uses. Humans have contributed about half a trillion tons of carbon to the atmosphere since the beginning of the industrial revolution. About half has stayed there, a quarter has gone into the oceans, and another quarter into the terrestrial biosphere. But the concern is that as the ocean warms, it will be able to absorb less carbon, and as deforestation and agriculture both grow, the land will also absorb less carbon. The result of both of these processes is that atmospheric concentrations will grow even more quickly than they otherwise would for a given level of emissions.

Maslin also covers a couple other topics in greater detail than either Romm or Griffin. One of these is the history of scientific knowledge about climate change and the response by the emerging environmental movement. Several scientists in the mid-1800s, such as Eunice Newton Foote, John Tyndall, and Joseph Fourier, made the first investigations into the greenhouse gas nature of CO_2. These early investigations were followed up by the Swedish chemist, Svante Arrhenius, who made the first calculations of how much the earth's temperature would vary depending with changes in atmospheric CO_2 concentration. He correctly predicted that the burning of fossil fuels would be sufficient to cause warming. In 1938, the engineer Guy Stewart Callendar gathered temperature records from the previous 50 years from stations around the world and was able to demonstrate that warming was indeed occurring. His continued investigations and publications over the next couple of decades encouraged other scientists to expand those studies. Substantial improvements in technology during World War II allowed Charles Keeling to make more accurate measurements of atmospheric CO_2, and he instituted the daily measurements that have been made ever since 1958 atop Mauna Loa in Hawaii. The nearly monotonic increases are presented in a graph popularly known as the Keeling curve. Despite these scientific advances, acceptance of the reality of global warming was slow to be recognized. One reason for this was a slight decrease in global mean temperatures between the 1940s and 1970s, leading some to predict a new ice age. However, increasing knowledge, both of current conditions and of past climates, indicated that this was extremely unlikely. By the 1980s, sufficient evidence had accrued to demonstrate to a substantial degree of certitude that the climate was indeed warming and that the rate of warming was increasing. An additional factor was the lack of environmental awareness. The establishment of a global environmental movement, at least partially in response to the work of Rachel Carson in the 1960s, began to bring an awareness of global warming to a wider public.

Along with the scientific advances and the growing social awareness has been attention to climate change by some economists. A particularly significant contribution was made by the British economist, Nicholas Stern, who was commissioned by the British government to prepare a report that has become known as the *Stern Review*. This 700-page report recognized the serious danger imposed by climate change and advocated aggressive and immediate action. It concluded that the cost of taking such action now is affordable and would be substantially less than waiting or going slow. Prominent among other economists is William Nordhaus, who was awarded the 2018 Nobel Memorial Prize in Economic Sciences for his work on the economics of climate change. While he recognizing the necessity of action, he thought, at least at first, that 4°C of warming would be acceptable and counseled less aggressive action. Many economists felt that aggressive action now would be too costly. Among the major differences among economists is establishing a proper price to be placed on carbon that would sufficiently discourage its use. A future review will look into these issues in more detail.

Another useful aspect of Maslin's book is his discussion of climate modelling to estimate future changes in the climate and their impacts. To predict future climates, it is necessary to use comprehensive three-dimensional models that include all parts of the climate system and subject them to mathematical analysis based on physical laws. The substantial improvement in models and their accuracy over the last four decades is based on our increased knowledge of the climate system and gigantic leaps in available computer power. The major uncertainty in modelling is not from the science—that is, the physics, biology, and chemistry—but from the difficulty in estimating future emissions of greenhouse gases, which depends on so many things, such as the economy, personal lifestyles, political changes, technological changes, and much more. Nevertheless, computer models have been invaluable in predicting varying outcomes based on different scenarios of future actions by government and industry with respect to climate change. These are presented in some detail in Maslin's discussion.

For those wishing a reasonably quick, but still comprehensive, overview of the subject, Maslin will do admirably. It is very clearly written and provides an excellent overview that may be sufficient in itself for some, and for others it will serve well as an introduction before going into greater depth in other books. Joseph Romm provides a more comprehensive, but still easily digestible, overview that is factual and that covers the major topics in an objective manner. Griffin presents an even fuller treatment of many of the topics, and considers others that are barely touched on by Romm and Maslin. As befits a specialist in the philosophy of religion and theology, he provides a much more thorough moral perspective than either of the other authors. This is underscored by his repetition after each discussion of the differing consequences of following the three plans, Plan A, Plan B, or Plan C, with the phrase: "The only moral choice is Plan B"—that is, immediate aggressive action.

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