2

Fossil Fuels and Climate Change

In this chapter and the three that follow, I give a brief overview of the four technologies that pose particularly dire threats to humankind. I won't go into a lot of scientific detail, leaving that to the many excellent specialist books available on each of these fields. Rather, my focus is on the Janus-faced nature of such inventions: the fact that they are all instruments of tremendous potential benefit to humankind, as well as plausible vehicles of great harm.

* * *

When I was in my early teens, I discovered the power of fossil fuels in a very direct way. A group of friends and I were experimenting with ways to make bigger bangs – tying firecrackers together in bundles, breaking them apart to make piles of explosive dust to put into pipe bombs, and so on. Then one of us had a brilliant idea: "Let's blow up some gas!" We siphoned a quart of it from a parent's car into an empty milk carton, then went into the woods and set it up at the base of a redwood tree with a fuse we'd pieced together. We lit the fuse, dove behind a nearby log, and – BRAOOOOM. When we peered over the log's edge, ears ringing from the violence of the blast, a 20-foot mushroom cloud was billowing through the branches above. Everything was singed all around us, and little flames were springing up among the leaves. It's a miracle we didn't start a forest fire. Fossil fuels are powerful stuff.

Humankind made this discovery (more sanely) a couple centuries earlier, when it started moving beyond watermills and windmills, animal power, and the burning of wood, peat, and charcoal, and learned how to tap the energy of coal, petroleum, and natural gas. These are called fossil fuels because they were created millions of years ago by terrestrial plants or oceanic microorganisms that converted the Sun's energy through photosynthesis; as these creatures died, their bodies accumulated in the ground and decomposed anaerobically, gradually forming large beds of fossilized organic matter. When the organic matter is retrieved today and burned

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(oxidized), it unlocks the original chemical processes laid down by that primordial photosynthesis, releasing carbon dioxide, water, and energy.[1]

The global energy transition went through several phases: coal burning surpassed traditional biofuels like wood around 1900, then was in turn surpassed by petroleum and natural gas after World War II. As I noted earlier, the growth in global energy consumption followed a steep upward curve, not only in raw total numbers, but even when calculated on a per capita basis: each of us today is consuming about four times as much energy per year as the individuals of the early nineteenth century (see Figure 2.1).

This accelerating expansion, particularly impressive after World War II, was partly due to rapid economic growth in former developing nations like China, India, and Brazil that have been catching up to the advanced industrial nations. The result is plain to see (Figure 2.2).

It would be churlish to deny the myriad beneficial effects of this economic revolution powered largely by fossil fuels. As the psychologist Steven Pinker has persuasively argued, the improvements in human flourishing throughout the planet over the past couple centuries have been striking: infant mortality rates are down; people are living longer and healthier lives; women have won impressive gains in status; extreme poverty has declined; new technologies for communication and transportation have knitted the

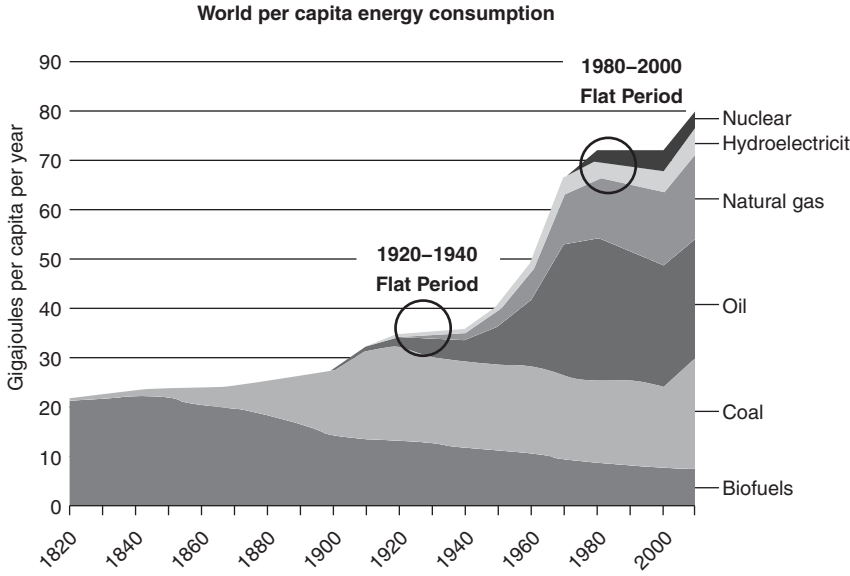

Figure 2.1 World per capita energy consumption, 1820–2010.[2]

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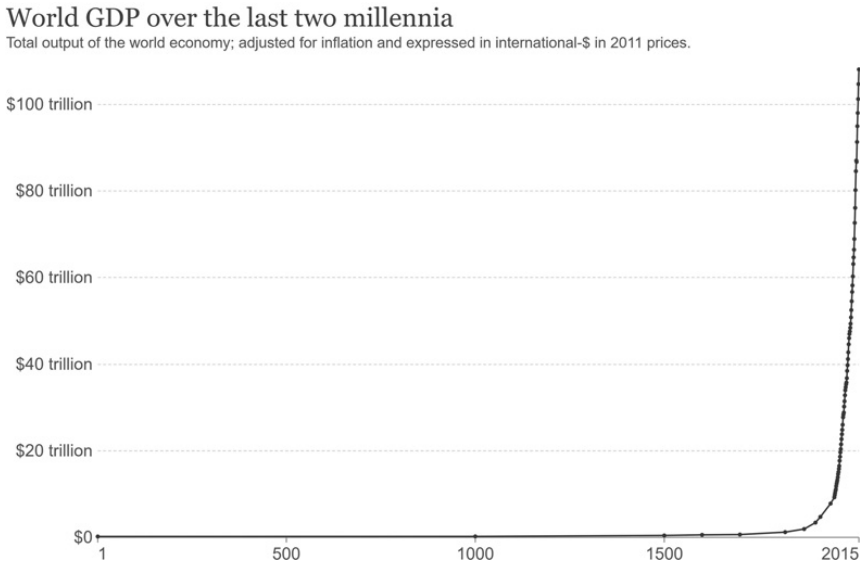

Figure 2.2 World gross domestic product (GDP) over the past 2,000 years.[3]
Sources: World GDP – Our World in Data, based on World Bank & Maddison (2007)

continents more closely together; literacy rates have climbed steadily; and economic opportunities are far more widely available than they were a century ago.[4] On the other hand, many severe and pressing problems continue to afflict human society – for the boons of economic growth have not been equally distributed. Hundreds of millions of people still lack access to basic material necessities like clean water and regular nutrition, and millions more die every year from diseases that are aggravated by poverty. Although education and medicine have spread impressively into new parts of the world, far too many people still languish for lack of them. Much progress remains urgently to be made.

One side-effect of this economic revolution – unrecognized until relatively recently – is the sheer amount of carbon dioxide (CO_2) that it has released into the atmosphere. Fully 85 percent of human energy consumption today derives from fossil fuels, and this means that every single activity you and I engage in every day has a carbon footprint.[5] It's not just when you fly in an airplane or heat your house or drive your car. The food you eat was grown on farms that used vehicles powered by fossil fuels, was processed in facilities powered by fossil fuels, and brought to your table by vehicles powered by fossil fuels – either directly, via gasoline, or indirectly via the electricity that ran the machines. This is known in the expert literature as

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"embodied carbon." The clothes we wear, the cell phone we talk on, the plastics and metals in the gadgets we use, the room we sleep in, the office we work in – carbon consumption is everywhere. Even if you are just sitting on a park bench, eyes closed, meditating quietly, you are still running off energy that your body acquired via the elaborate network of fossil fuels.

This poses a problem. For hundreds of thousands of years, atmospheric CO_2 levels have fluctuated naturally in a range between 180 and 300 parts-per-million (ppm). The periods of higher CO_2 levels and lower CO_2 levels have correlated in lockstep with periods of warmer or colder global average temperatures – the hothouse periods and ice ages. Yet in the past 200 years – a tiny blip in the timescales of geophysics – human use of fossil fuels has abruptly raised the CO_2 to 400 ppm, and the level is projected to continue rising rapidly over the coming decades as CO_2 accumulates in the atmosphere and humans keep pumping out more and more.[6] (See Figure 2.3.)

Once it is out there in the sky, the CO_2 stays in place for hundreds of years, where it acts like a blanket around the planet, trapping the Sun's heat and causing the global temperature to rise. This is known as the greenhouse effect, and CO_2 is the chief culprit among the various gases that produce this warming process. About 25 percent of today's global warming is caused by a different gas, methane (CH_4), which is released in significant quantities by animal farming and by leaks in natural gas pipelines and wells. Although

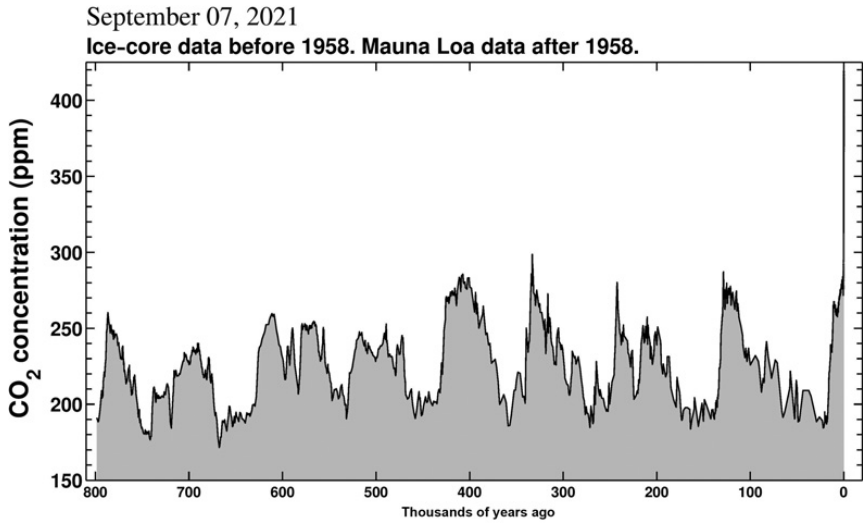

Figure 2.3 Carbon dioxide concentrations over the past 800,000 years.[7]

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methane doesn't linger as long in the atmosphere as CO_2, it traps heat far more efficiently, so reducing emissions of both these gases is a high priority.[8]

One or two degrees may not sound like a lot, since we are accustomed to watching our local weather fluctuate by as much as 10 or 20 degrees every 24 hours, and even more with the changing seasons. But weather (what we experience locally) is not the same thing as climate (the broad patterns of average temperature that characterize the globe as a whole). At the planetary timescale, three or four degrees can make the difference between a temperate period and an ice age (see Figure 2.4).[9]

We humans, with our relatively sudden and dramatic release of greenhouse gases, risk carrying the Earth past a critical threshold at which the planet's own climate dynamics take off on a self-reinforcing cycle of their own.[10] As the planet warms, several key factors come into play: the ice at the polar regions recedes, reflecting less of the Sun's energy back into space; permafrost regions like Siberia, where vast reservoirs of CO_2 and methane lie trapped in frozen bogs, start to thaw and release their gases into the air; water evaporates more readily from the oceans, increasing water vapor in

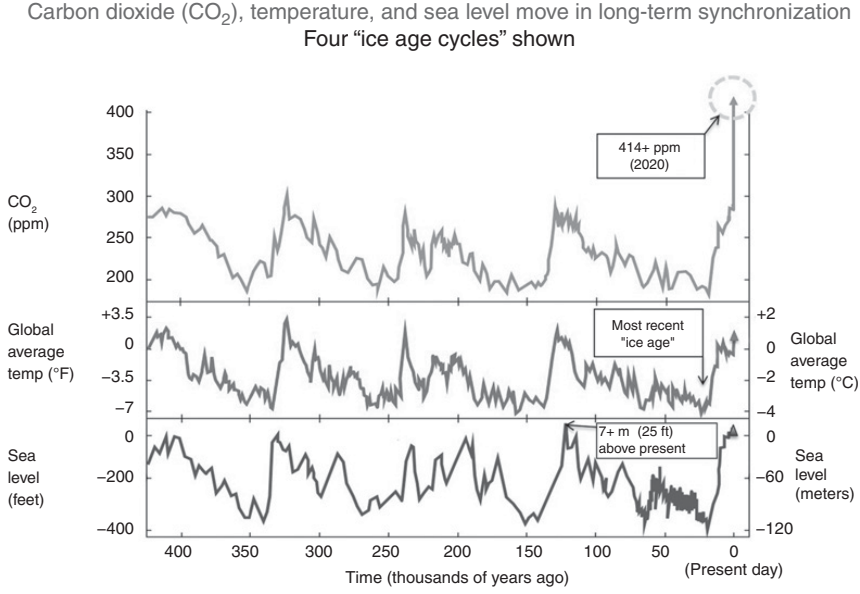

Figure 2.4 Carbon dioxide concentrations, global temperature, and sea levels over the past 400,000 years.[11]

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the atmosphere that adds to the greenhouse effect; and forested areas, which absorb and store CO_2 in the biomass of trees, are depleted by drought and wildfires. All these factors generate a feedback loop in which each degree of additional warmth triggers still more warming factors, and the process accelerates on its own. Once these tipping points are passed, the sheer scale of this runaway process could vastly exceed human technological capabilities and become unstoppable.[12]

I take myself as a prime example of someone who didn't wake up to the full severity of the climate threat until recently. I should have known better, because I spent most of the 1990s researching and writing a book about the impact of green ideas in France, so I was quite familiar with the environmentalists' message.[13] But I made the fateful trio of assumptions that many people make on this subject:

1. *We have time*: the impact of climate change won't be fully felt until a couple centuries from now.
2. *The planet is resilient*: once we rein in greenhouse gas emissions, the climate will respond quickly to our wise restraint and return to its former equilibrium.
3. *We have more pressing problems*: climate change is a lower priority than other dangers like nukes, global poverty, pandemics, or terrorism.

But I was wrong. This is a dire threat that's already showing its first significant effects today, and that will render your daily life, and the lives of your children and grandchildren, increasingly rough over the coming decades. The immense West Coast wildfires of 2020, the increasing frequency and severity of hurricanes, the accelerating retreat of glaciers and polar ice, and the die-offs of coral reefs – these are but harbingers of even worse things to come. By the closing years of this century, many aspects of today's world that we casually take for granted will be gone. Three basic trajectories to the year 2100 have been mapped out by climate scientists, each one depending on how swiftly and effectively humankind mobilizes to mitigate this danger.[14] I think of them as choices between "Not too bad," "Nasty," and "Hell." It's worth underscoring that the scientific consensus on these projections now lies at about 97 percent: in other words, this is what the best scientific minds from the top research universities and government labs around the world are concluding *nearly unanimously* from decades of cutting-edge research.[15] (I'll discuss the politically fraught "debate" over climate science in Chapter 12.)

The best-case scenario presupposes a massive and sustained effort on the part of humankind, starting immediately, to rein in greenhouse gas

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emissions worldwide and also to develop new technologies for removing increasingly large amounts of those gases from the atmosphere. Under this optimistic scenario, the new normal around the year 2100 would be on track to look something like this:[16]

- Greenhouse gas emissions are reduced rapidly and brought to zero by mid-century.
- Global average temperature in 2100 is 1.5 to 2 degrees Celsius higher than preindustrial times (about 0.5 to 1 degree higher than today) and is remaining stable at that level.
- Some accumulated greenhouse gases are being gradually removed from the atmosphere by new technologies deployed in the latter decades of the century.
- Oceans have risen by 10 to 20 inches, forcing many sections of coastal cities to be evacuated and relocated.
- Droughts are more frequent and severe than today, but agriculture is still feasible in most regions where it is currently practiced.
- Extreme weather events such as floods, superstorms, heat waves, and wildfires have become more common.
- Ocean acidification and warmer waters have rendered the world's fisheries far less productive.
- Many forms of wildlife are endangered, with their populations dwindling.
- New diseases are spreading from tropical regions to warming northern and southern regions nearer the poles.
- Forced migrations are increasing, as people are displaced by drought and famine, along with the civil strife that those two factors have aggravated.
- The global economy has been noticeably affected by the costs and burdens imposed by the challenges of work in a hotter climate.

The midrange scenario presupposes a delay of a couple decades from the present day before the serious mitigation efforts described above go into effect. Under this scenario, greenhouse gas emissions would continue to rise until about 2035 or 2040, then gradually stabilize and decline to zero by the 2070s. Global average temperature in 2100 would be about 3 degrees Celsius higher than preindustrial times.[17]

The worst-case scenario assumes that humankind continues over the coming decades to do what it is doing today – political bickering and feckless half-measures – and only begins serious mitigation efforts after the effects of climate change become so grievous that nearly everyone finally acknowledges the danger is real. By that point, unfortunately, the problem may

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already have acquired a momentum of its own and may lie beyond the reach of human countermeasures. Under this scenario, the new normal around the year 2100 would be on track to look something like this:[18]

- Greenhouse gas emissions continue to rise until 2050 or later, then rapidly stabilize and decline toward zero by the 2080s as draconian mitigation measures are desperately adopted.
- Global average temperature in 2100 is 4 to 6 degrees Celsius higher than preindustrial times.
- The climate continues warming rapidly after the 2080s despite emissions at zero, because feedback mechanisms from factors such as melting permafrost, ice loss, water vapor, and wildfires are propelling major new releases of greenhouse gases from natural sources, along with an accelerating rise in temperature that further aggravates the process. The planet has entered a self-reinforcing spiral of warming similar to those that occurred during previous eras of natural warming in prehistoric times.
- Frantic attempts to remove accumulated greenhouse gases from the atmosphere via new technologies deployed in the latter decades of the century fail to keep up with the new greenhouse gases released naturally by a warmer planet.
- Oceans have risen by as much as 6 feet and are still rising by as much as 1 foot per decade after 2100, forcing most coastal regions to be evacuated as people retreat inland.
- Droughts are much more frequent and severe than today, and agriculture has become impossible in a broad swath of land north and south of the equator.
- Extreme weather events such as floods, superstorms, heat waves, and wildfires have become much more common and deadly than today, and regularly kill large numbers of people. Large portions of the planet are uninhabitable for humans and have become searing desert wastelands.
- Ocean acidification and warmer waters have rendered many aquatic species extinct, and large regions of the oceans are dead zones.
- Tropical diseases have become endemic in all regions even near the poles.
- Global human population has declined, as people crowd into the regions near the poles where agriculture remains viable. The massive displacement of humans is marked by wars, disease, floods, droughts, and famines that cumulatively claim billions of lives.

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- Many nations' political institutions have become more authoritarian in nature, as populations respond to the climate crisis with emergency governance measures and martial law.
- It is possible that the Earth is heading into another of the dozen major or minor extinction periods that have marked its long history, when 6-degree cooling or warming caused large percentages of the planet's biological life to perish.

The main point to notice about these three trajectories is that they contain good news as well as bad: there is still time for humankind to wake up to the danger. It's not too late to render the best-case scenario a reality: all we need do is stop dithering and take effective action. I'll describe some of the strategies for this in the coming chapters.

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