4 IT'S ABOUT FOSSIL FUELS

One of Monty Python's best loved skits has Greek and German philosophers facing off in a football (soccer) match. The Greeks, with stars like Aristotle, Plato, Socrates and Archimedes, are dressed in togas; the Germans feature the likes of Kant, Hegel, Nietzsche and Wittgenstein dressed according to their era. The players practice; the referee, Confucius, blows his whistle; and then – nothing. The great thinkers amble about lost in thought while the ball sits abandoned at midfield. And so it goes, on and on and on – all thought and no play. Shortly before the end of regulation the Germans make a substitution to get their offense going: Karl Marx takes the place of Wittgenstein. At first it looks like he's a bundle of energy, but as soon as he takes to the field he starts wandering around immersed in thought like everyone else. Then, with seconds to go, Archimedes shouts, "Eureka!" He just came to the realization that this is a football match, not a philosophical academy. He launches an attack, and while the Germans look on in confusion the Greeks score with a cross and a header; the match is theirs.

You can find this bit on the internet, and if you haven't seen it you really should. What makes it funny, of course, is the absurdity of philosophical immersion when the task at hand is to score a goal. Substitute "ending carbon emissions" for putting the ball in the net, and you have the gist of much of the chapter that follows.

As we've seen, the central task in forestalling catastrophic climate change is very simple: barring the very rapid adoption of transformative technologies that don't exist yet, we need to leave most of the known coal, oil and gas reserves in the ground. How to do that without causing an economic – and social and political – cataclysm is complicated, but the climate objective isn't.

But many of our present-day thinkers resist this simplicity. Having long dedicated themselves to abstruse speculation about the nature of our economic and cultural systems, they insist that the climate crisis is not *really* about carbon emissions but a deeper, more far-reaching flaw in our civilization. Like Monty Python's philosophers, they may indeed be profound, but not in the game they, and all of us, are actually playing.

A much-advertised claim, for instance, is that the true cause of the climate crisis is economic growth, and unless it is ended and even put into reverse ("degrowth") we are all doomed. Or perhaps the "real" cause is population growth, or capitalism, or global inequality. Others point to the global flows of the carbon cycle and argue that planting trees or bulking up other terrestrial carbon sinks will allow us to burn fossil fuels a little longer. And there is widespread misunderstanding of the relationship between carbon and renewable energy, that the latter somehow makes the former disappear. To be very clear, I am not saying that economic growth is unrelated to carbon emissions, nor that inequality and economic dysfunction can be ignored, nor that forests aren't an important part of the story, nor that a crash program to expand the supply of renewable energy isn't necessary. Climate change touches everything. But it's crucial to keep cause and effect clearly in mind and not get distracted from the primary mission of curtailing the use of fossil fuels. This chapter is about keeping our eye, and our foot, on the ball.

Recall the graphic depiction of the carbon cycle(s) from Chapter 1. Carbon serves two crucial roles simultaneously, the key component of the atmosphere that traps solar radiation and allows the Earth to maintain a toasty temperature suitable for life (unlike our moon, which reflects all the radiation back into space), and the building block of life – the stuff all animals and plants are made of. These functions operate in tandem and support each other. By warming and stabilizing the earth's temperature, atmospheric carbon has created the conditions under which life could flourish. And life recirculates carbon, absorbing it from the atmosphere, fixing it on land and in the oceans as living tissue and releasing it again to make its way back to the

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atmosphere. These flows were approximately in balance and kept the system in a rough equilibrium for eons.

But there is a slower carbon cycle at work as well. Some of the terrestrial and marine carbon leaves the surface cycle as mineral deposits or organic matter that gets pulled down into places, like ocean and lake beds, that are outside the regular flows, and some of this trickle is drawn further into the Earth's mantle by the activity of tectonic plates. In any given year these amounts are minuscule, but over geologic time they add up to very large withdrawals. Meanwhile, some of this carbon leaves long-term subterranean storage and reenters the circulation of atmosphere and life through venting, as with volcanoes. This slow carbon cycle is also roughly balanced over long time periods. The instigator of climate fluctuations over the past several hundred thousand years, the ice ages and interglacial periods, has been variation in the amount of solar radiation received by Earth (due to orbital wobbles), not autonomous changes in carbon flows. The last big climate event caused by imbalances in the deep, slow carbon cycle – unusually large releases of carbon from beneath the earth that vastly exceeded carbon deposition and withdrawal – was probably the Paleocene–Eocene Thermal Maximum that gave us alligators in the Arctic.[1]

The reason we are facing a climate crisis today is that human beings are mimicking this giant uptick in volcanic carbon releases, only at a pace much faster than the one 56 million years ago. The carbon in fossil fuels is, like the name suggests, the residue of ancient life, concentrated under pressure and buried in the Earth. If we had just left it there, the surface and deep carbon cycles would have continued to remain in approximate balance, and climate change would not be an issue. But drawn to the extraordinary energy density of these fuels, humans, with great ingenuity, have been finding them, bringing them back to the Earth's surface and sending their carbon up into the atmosphere through combustion. The withdrawal phase of the deep carbon cycle is still as slow as it always was, but the release phase is in hyper-acceleration. Whatever else it entails, the solution requires us to stop using fossil fuels as soon as possible, leaving them in the Earth where they can bide their time for millions of years to come.

How could we not understand this basic point? The rest of this chapter shows that human ingenuity is at work on this front too.

The Crusade against Economic Growth

On the political left it is now common to hear that the root cause of climate change is an economy addicted to growth. Burning fossil fuels is just a symptom, they say, and we won't exit our predicament until we dig beneath this superficial approach and tackle economic growth directly. Perhaps the origins of this antagonism can be found in the writings of Nicholas Georgescu-Roegen, the author of *The Entropy Law and the Economic Process*, and Herman Daly, whose breakthrough was the book *Toward a Steady-State Economy*.[2] The "degrowth" philosophy was a minor current until recently, but the urgency of action on climate change has elevated it to a litmus test in some circles of whether you are a "corporate" or "radical" proponent of carbon policy.[3]

Actually, there are two versions of anti-growth ideology. One upholds actual degrowth as a matter of urgent necessity; its bumper sticker version is "You can't have unlimited growth on a finite planet," which, of course, is quite true. And even if future advances in space travel allow us to inhabit other planets and even galaxies, it is also true that unlimited growth must some day come to an end in a finite universe. A relevant question is, Is this relevant? That is, are we so close to hitting this wall that we have to start backing up right now? The degrowth rejoinder is that we are, and that the peril of climate change is the proof.

The second version is not about the actual rate of growth, positive or negative, but our thinking about it. Its proponents oppose what they regard as the modern obsession with economic growth, which, depending on the source, is itself rooted in the fundamental nature of capitalism, or neoliberal ideology, or Keynesian macroeconomic policy or the use of gross domestic product (GDP) as a tool of economic measurement. It is this intellectual commitment, they say, that has prevented us from acting to limit carbon emissions because doing so would limit growth. According to them, our survival depends on dethroning economic growth from the all-powerful place it occupies in our culture.

I think both are mostly wrong and serve only to distract us from what needs to be done. In fact, their errors and omissions are so glaring I have to wonder how such ideas can be taken seriously.[4] Why are we even having this debate? Let's consider them one at a time,

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beginning with that apparent truism, "You can't have unlimited growth on a finite planet."

The first problem lies in misunderstanding what "economic growth" means. You certainly can't have unlimited increases in the use of resources on a finite planet, but the size of the economy isn't the same as the amount of "stuff" it uses. The standard measure of economic growth is growth in GDP, and GDP measures the number of goods and services we produce, each multiplied by its value.[5] And what is value? It's what people are willing to pay for, and "stuff" is not the only or even necessarily the most important aspect. A $30 restaurant meal is "bigger" than two $10 meals in economic terms, and a $500 music system is bigger than two $100 systems, with resource use often smaller for the higher-priced item. When you pay for the more expensive meal, ideally you are compensating the services of more skillful kitchen staff, and the more costly music system rewards engineers for their knowledge and skill.

The rejoinder is that, while my objection is correct, in practice economic growth has not "decoupled" from carbon emissions anywhere. From this it is deduced that such decoupling is impossible, but that logical leap overlooks a critical fact: no country has yet begun to take the measures required for decarbonization. Without such policies in place and implemented, we shouldn't be surprised that business as usual is eating up our carbon budget year after year. As we will see in a moment, *any* size of our economy, even one much smaller than what we currently have, is incompatible with meeting the climate challenge unless we make fundamental changes in what and how we produce. Those changes are the objective of climate policy.[6]

To illustrate how public policies can foster growth in the skill component of value without spewing out more carbon emissions, consider the example of Finland. This tiny country of somewhat more than five million people decided many years ago to make music a central part of its public life. Its music policies include programs in the schools and support for live concerts and broadcasts, but also a network of specialized music academies in every region. As of 2007, Finland had ninety-nine such academies, one for approximately every 53,000 citizens. There students of all ages can get heavily subsidized instruction in every type of musical performance – rock, folk, jazz and classical. That year about 60,000 students were enrolled, instructed by 3,500 teachers.[7] To visualize what this means, suppose the United States in this same year

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had proportional numbers in its own system of music academies; that would mean almost three and a half million students and about 200,000 teachers. By comparison, employment in all aspects of the US coal industry, white and blue collar alike, was somewhat less than 70,000 in 2015.[8] Not surprisingly, Finland, despite its small size, is a major force in many varieties of music, especially classical where it accounts for a disproportionate share of the leading conductors and composers – names like Esa-Pekka Salonen and Kaija Saariaho. But beneath the headlines you can find plenty of interesting live music in every Finnish town.

The point is not to promote Finnish music, but to see why it's important that economic growth doesn't have to mean growth in "stuff." Finland's music sector is every bit as much a part of its economy as Nokia or its pulp and paper mills – a more stable, reliable sector in recent years. The money paid to music teachers is real money, just as real as money paid to other workers for the goods and services they provide. Music is a component of the GDP of Finland, as it is anywhere else people pay for it. By collecting taxes to support music instruction, Finland is redirecting consumption from other uses to the spread of culture, while at the same time reducing carbon emissions. Of course, people can't live on music alone – they still need food and heat and produced goods of many types – but societies can enlarge their economies by choosing to promote knowledge, culture, and discovery and not just more "stuff." The first problem with the degrowthers is that they greatly underestimate the potential for economies to grow in ways that have nothing to do with burning fossil fuels.

The second problem is that arithmetic is against them; no reasonable amount of economic shrinkage will make more than a tiny dent in our carbon dilemma. We have evidence for this. As the second millennium CE gave way to the third, global carbon emissions continued their upward trend, growing by more than 2% per year. There was a hiccup in 2009, however, when carbon dioxide emissions actually declined, falling by 0.45% relative to their 2008 level.[9] Why was this? The cause was the financial crisis of 2008, which struck economies all across the world. While the biggest impacts were in the developed countries with the largest financial sectors, the global economy as a whole slipped by about 0.3% in 2009 – the so-called Great Recession.[10] With the resumption in economic growth the following year, emissions resumed growth as well.

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Here is where the arithmetic comes in. As we saw in the previous chapter, a benchmark global carbon dioxide emissions pathway that gives us a reasonable chance to hold warming to 2°C requires a 3.9% reduction every year for generations. Now combine this with the 2009 experience, where a 0.3% decline in the global economy gave us a 0.45% decline in emissions. That yields an economic-degrowth-to-emissions-reduction ratio of 0.64, just under two-thirds. So to get a 3.9% reduction in CO_2 emissions in a given year, we'd have to have an economic contraction of 0.64 × 3.9%, or about 2.5%. Now for some common sense. A 2.5% hit to the global economy is over *eight times* what the world went through in the financial crisis of 2009. And to stay within our carbon budget according to our benchmark we would have to do this *every year* for decades. It's absurd. *A full-on policy of economic shrinkage, if we chose to implement it, would have an insignificant effect on meeting our carbon goals*. Obviously, carbon policy will have to be about what's in our economic pie and how we bake it, not the size of the pie per se.

And yet degrowth proponents are not altogether wrong. There is one way in which our economy could shrink to some extent while leaving most of us better off, and this shrinkage could play a supportive role in climate policy if the other, more important measures (to be discussed in Chapter 6) are also in effect. The issue is hours of work.

Over time economies generally become more productive, measured in economic output (GDP again) divided by the amount of labor it takes to produce it. The benefit of this process can be captured either by continuing to work as much as before and increasing consumption or by working less (or some combination of the two). There is plenty of scope in some countries, particularly the United States, to shift from the first approach to the second, from the rat race to something like a squirrel lifestyle: working hard for a while and then enjoying fourteen hours per day of refreshing sleep.[11] (This is how squirrels do it; people could sleep less and play more.)

As an example, consider work hours in the United States compared with Germany. On average, in 2015 Germans worked 23% fewer hours per year.[12] The reasons are many: the United States has a lower rate of part-time work and no laws mandating paid vacation time; in Germany all workers are guaranteed a minimum of four weeks of paid leave per year, and those covered under nationwide union bargaining get six weeks.[13] The statutory work week is also shorter for full-time workers in Germany, although standards there as elsewhere in Europe are set by a complicated combination of general legislation, sectoral norms and collective bargaining agreements.[14]

Let's return to the arithmetic about economic shrinkage and carbon dioxide emissions in the Great Recession. Suppose the United States were to reduce its labor hours to the German standard with a proportional effect on the size of its economy, and that the same ratio, 0.64, we saw between economic degrowth and reduced emissions in 2009 is applied to this new effort at planned shrinkage. This would give the United States 36% fewer carbon emissions, a meaningful contribution to needed decarbonization, the equivalent of nearly seven years of 6% cuts. I regard this as a substantial overestimate, however, since modern experience around the world with planned reduction in work hours indicates the consequences for economic growth are far less than commensurate.[15] But it's still worth doing.

Now let's move to the second version of the critique of growth. Since actual economic shrinkage runs up against an arithmetic problem – not to mention its political toxicity – more sophisticated degrowthers tell us that what they meant all along was to attack not economic growth as such but the ideology centered on it. By prioritizing growth above all else, they say, "growthism" has frustrated climate action. As for who holds these pernicious ideas, some versions of this story pin the blame on ruling elites, while others denounce economics professors in thrall to neoliberalism.

In reality, this argument is easily punctured. First, political elites are hardly wedded to a philosophy of maximizing economic growth, whatever they may say to justify their actions. All too often they opt for austerity instead, despite its destructive effects on economies and living standards.[16] Arguably, China is the only country that has consistently organized its policies around economic growth since the advent of the twenty-first century.[17]

Second, mainstream political and intellectual figures regularly invoke the desirability of economic growth as the motive for demanding action to *forestall* climate change. They rightly recognize that overheating the planet with all its attendant impacts will cause immense economic harm; in fact, the harm is already being felt. The opening fusillade of high-level climate concern was the Stern Review of 2006, a massive study of the economics of climate change commissioned by

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the British government and led by Nicholas Stern, former chief economist of the World Bank. Stern's group concluded that the economic costs of business as usual far exceeded those of curtailing carbon emissions, and it was a turning point for public debate in the English-speaking world.[18] Since then, each year has seen several further studies by intergovernmental bodies, most of them concurring with Stern.[19] In straightforward language they explain why uncontrolled climate change would be economically disastrous. In the previous chapter, I argued that the conventional economic argument is flawed, but not because I think it conceptualizes economic growth in a manner that erases the effects of global warming on it.

Third, the claim one sometimes hears that economic growth is without value is indefensible in a world of massive poverty and deprivation. Yes, we surely need redistribution when the gap between the richest and billions of the worst off is so immense, but even if we confiscated every "unnecessary" possession of the haves, we wouldn't have enough to give the have-nots the necessities and comforts they rightfully demand. The world may need less of some things, but it needs a lot more of others. Even within the wealthier societies and the wealthier regions and populations within them, we will need massive investments for decarbonization, and investment is a component of the economy and its growth. It is entirely reasonable to search for solutions to the climate challenge that minimize impacts on economic growth and poverty alleviation.

Finally, there is a more general point to be made about the role of political and economic values. When degrowthers say economic growth should not be given a priority over all other objectives, they are on solid ground, but this is true of *any* value and not just economic ones. Consider freedom. Freedom is a value all of us would surely endorse, but not to the exclusion of all else. Sometimes it is necessary to restrict it for purposes of public health, fairness, preservation of the environment, animal welfare or other goals. Similarly, I would count myself an egalitarian; I would like to live in a world that is far more equal than this one, but I would hardly set aside all other values in order to eliminate every last vestige of inequality. The same applies to protecting the environment, advancing cultural and intellectual progress, and every other conceivable ideal; no value is so all-encompassing that it can be sensibly pursued without regard to all the others. This is why it doesn't break new ground to acknowledge that economic growth is generally desirable, but not at the expense of a livable planet. If recognizing the need to balance competing objectives is what is meant by degrowth, we can also embrace de-freedom, de-equality, de-culture and de-every-other-single-value.

To set this topic to rest, I want to emphasize that causation runs from climate action to diminished growth, not the other way around. As we will see at length in the following chapter, making the transition to an economy devoid of fossil fuels within the span of a few decades will be a daunting challenge. It is difficult to foresee how much disruption it will entail, but there will almost certainly be periods in which adherence to climate policy interferes with economic growth. With well-designed policies we can keep those periods to a minimum. To think, on the other hand, that stopping growth or even devaluing it will fix the climate crisis, however, is like thinking that living on the street solves the problem of not being able to pay the rent.

A Choice of Crusades

Long before climate change emerged as a critical issue humanity needed to address, groups had arisen to combat a wide range of other ills. For those campaigning on some other front, it seemed natural to enlist the climate crisis as one more reason why their issue was the "true" challenge facing society. Carbon emissions, we are often told, are only a symptom, and unless we join some additional crusade we are doomed – third in the parade of misconceptions previewed in the Introduction to this book. In reality, while many of the causes promoted in this way merit our support, it is not because they have much to do with the climate, and claiming they do distracts us from the measures we actually need to take. While the list of these purported "deeper" causes is long, here we will consider just a few of them to see how little basis there is for such claims.

Let's begin with the original Malthusianism, the claim that "unchecked" population growth is the true source of our carbon problems.[20] There is a long history to debates over this issue which I will avoid entirely.[21] As far as climate change in particular is concerned, it is obviously true that both carbon emissions and global population have risen during recent decades, but this doesn't mean that the first trend has caused the second. Indeed, if human population were to suddenly level

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off at its current level, our carbon predicament would be essentially unchanged.

The arithmetic is, if anything, even more unfavorable to the population argument than it was to economic degrowth. While population has continued to grow, its rate has gradually declined from 1.31% in 2000 to 1.05% in 2020, to take the most recent decades.[22] For population to actually decline, this rate has to be brought below zero, and even if this were to happen (it has already happened for some upper-income countries) it would be a long time before the number of people would be significantly less than it is at present. For example, suppose our approximate 1% growth rate were to instantly become −1% – impossible, of course, especially considering the inertia caused by past growth's effect on the age distribution, but this is just an illustration. Global population in 2020 was about 7.8 billion. This immediate and continuing 2% change would, after forty years, still leave us with about 5.2 billion fellow humans, or two-thirds of our current number. To repeat, this scenario is inconceivable without some sort of catastrophe in the background, and even so it yields a human population whose demands on the planet's resources would be only moderately less. If we are still emitting two-thirds of today's carbon emissions per year after four decades, the alligators will be firmly on top.

Simple arithmetic demonstrates that, to be environmentally meaningful within the time frame the climate crisis has bequeathed to us, any reduction in human population must entail a mortality apocalypse of Black Death proportions, and even then our carbon budget will still be on a path to rapid exhaustion. This should not be taken as complacency on my part with humanity's abundance or claim on the planet's living space. I would be happier with fewer of us, and any environmental problem will be easier to solve if people are taking up less room. Nevertheless, the pace and scale of any plausible population reduction is nearly irrelevant to preventing a climate catastrophe.

While concern over rising population has a long history, other putative "true" causes of the climate crisis are more recent. Among them is the belief that globalization is the true enemy, and the solution is to greatly cut back on international trade, producing as locally as possible. Examined closely, this turns out to be a mood, not an argument. First, "international" is not the same as "far away." A large portion of international trade is between countries that border each other, like the United States and Canada or Mexico, or the member nations of the European Union.[23] For geographically large countries like the United States and Russia, trade within their borders can often cover longer distances than trade with neighbors. Moreover, from a carbon point of view, the issue is not how far a good travels but how much carbon it uses to get there. Consider an item, like a carton of consumer electronics, that first travels by container ship from China to a US port in Seattle or Long Beach and then goes by truck to a warehouse in St. Louis. It will certainly be responsible for far more carbon emissions in the second leg of its journey than the first. In fact, if it goes by train to St. Louis and then by truck to its final destination a few miles away, that last truck ride may still be the largest contributor. Carbon distance is not spatial distance. Finally, all maritime shipping combined was responsible for about 2.2% of global CO_2 emissions in 2014. This is not trivial, but it is not a major factor either. Improved methods have the potential to reduce this amount further, even without a reduction in the volume of trade.[24] The bottom line is that you may have a preference for locally produced goods for some other reason, but this does not translate into any particular position on international trade, nor is it likely to make much of a difference in global carbon emissions.[25]

Another recent trope has it that the underlying cause of our predicament is psychological, the separation of people from nature and the awareness they would then have of their carbon-burning lifestyle. Cities are mental dead zones; we should flee them for the fields and forests that nurtured societies wiser than ours; only then will we be able to pull back from the apocalypse.[26] I suppose it makes intuitive sense to those who expound this view, but there is no evidence that living closer to nature leads to a less exploitive relationship to it. On the contrary, consider a fascinating graphic essay, "The True Colors of America's Political Spectrum Are Gray and Green," which appeared in the *New York Times* prior to the national election of 2020.[27] Seen from the air, precincts can be placed on a color spectrum from gray (asphalt and buildings) to green (vegetation). As they show, the greener a neighborhood, the more likely its inhabitants were to vote for Donald Trump rather than Hillary Clinton in 2016. While Clinton was hardly a hawk on climate matters, she was certainly more supportive of curtailing carbon emissions than Trump, who campaigned in favor of rescuing the coal industry. It's as if trees, food crops and other green things were transmitting chemical signals urging nearby humans to maximize their pollution.

The irony in the back-to-nature argument is that one of the greatest successes enjoyed by environmentalists is in the field of education. It is now common for children to be exposed to ecological knowledge and principles from an early age, and this has likely played a role in sensitizing them to the need for protecting natural systems; presumably, the Clinton supporters have internalized this learning better than the followers of Trump. But environmental education, even though it may entail occasional field trips to greener places, is a product of our industrialized, urbanized world – scientific research, expertly produced books and films, and skilled, professionally trained schoolteachers. Good programs can be found in schools everywhere, and they prosper in communities that support education in general. The lesson is that climate activism and acumen are, above all, products of knowledge and understanding, and not so much the epiphanies that arise spontaneously from leaning against a tree or fishing a trout stream. It's good to get out into nature, of course, but voting patterns show it's even more important to get into schools and libraries. In any case, to the extent that nature deprivation is a factor in humanity's poor response to the climate challenge, remedying it matters for this issue only insofar as it leads us to adopt the policies required to keep fossil fuels in the ground.

It's understandable that people should care about things other than limiting planetary warming, and it is not the message of this book that we should drop everything and devote ourselves only to adhering to a carbon budget. When it comes to mitigating climate change, however, our success will depend on whether we can bring about the rapid curtailment of fossil fuel use; it doesn't help to overload this difficult task with unrelated demands. Other crusades are worthwhile only if they are recognized as additional goals we should strive for while we struggle to decarbonize.

Salvation through Silviculture?

Deforestation was not the instigator of modern climate change, but many look to reforestation as an essential part of the solution. Models of future anthropogenic impacts usually identify a major role for changing land use, particularly the conversion of marginal agricultural areas and pasturage to forest cover, making possible "negative emissions." Tree planting, or simply pledges to leave trees in place, are often the basis for carbon offsets, allowing their purchasers to burn

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fossil fuels while declaring themselves carbon neutral. The claim at the outset of this chapter that the basis of the climate problem is extraction and combustion of fossil fuels and the solution is to end this practice as soon as possible is apparently contradicted, or at least modified, by all this preoccupation with forests.

It's important to recognize, however, that 1870 is not an often-used baseline year for measurement of human-caused alterations of the greenhouse effect because tree-cutting began in earnest after that date. On the contrary, there had been steady reductions in forest cover throughout the world beginning thousands of years ago with the development and spread of settled agriculture.[28] The best evidence is in Europe, where the development of the saw and rapid population increases after 1000 CE accelerated forest clearing, but similar trends were under way in China and North America. Very rapid acceleration of clearing took place in the nineteenth century and continued into the twentieth (and today). While it is probable that this long history of pushing back the forest has had an impact on the atmosphere, if our carbon problem were due mainly to this factor it would have been apparent long before 1870.

Nevertheless, it is possible that, while land use changes have played a minimal role up to this point, they might help rescue us going forward. The millennia of forest clearing by our ancestors has potentially given us the opportunity to buy time by rebalancing the carbon cycle away from higher atmospheric concentrations. At least it's worth considering.

For many who are closely involved with climate change on a scientific or policy basis, moreover, the benefits of reforestation are obvious and taken for granted. All climate models currently used to predict future greenhouse gas accumulations and assess policy alternatives incorporate a significant role for land use. Public discussions about what needs to be done almost always include it. Large sums of money, as we will see, already stand behind reforestation programs. Even Donald Trump, who called the subject matter of this book a "hoax," advocated planting a trillion trees.[29] Isn't this a settled matter?

There can be no dispute about the need to include changes in terrestrial (and other) carbon sinks in quantitative climate models. These are systems of simultaneous equations, many of which represent fluxes within the carbon cycle. Atmospheric carbon exchange with the oceans has to be in the model, and so do the flows of carbon into and

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out of the world's soils. In each time period modelers must account for the carbon taken up by plants, including trees, as well as the carbon they release through transpiration or when they decompose or burn. By tracing all these flows and the ongoing change in the factors that influence them continuously through time, such models allow the future evolution of the climate system to be estimated with increasing precision. It would make no sense to leave any of it out, including carbon fluxes associated with changes in forest cover.

This is the basis for saying that planting a certain number of trees in a particular location – say, Madagascar – in a given year will effectively reduce the human contribution to greenhouse gas concentrations in that year and in subsequent years as the trees grow. And so an airline traveler is offered the option to offset the carbon emissions resulting from a trip by paying for some of these faraway trees. (They're far away if you're not in Madagascar.) This offset treats the carbon introduced into the surface carbon cycle by the extraction of formerly buried fossil fuels as equal and opposite to the carbon pulled from the atmosphere by photosynthesis as a new tree begins to make its way upward. And for the years in which that growth occurs that's correct.

Those offsets are adding up. The global program that consolidates the largest portion of them is called REDD+ for "Reducing Emissions from Deforestation and Forest Degradation"; the "+" was added to signify that the program was concerned with positive enhancements to forests and not just reversing their deterioration.[30] REDD+ doesn't sell the offsets itself; rather, it inventories forests, provides carbon measurements and facilitates certification to support forest offsets sold to buyers eager to acquire carbon credits. Suppose, for instance, you are an air traveler who decides to offset the emissions from your trip by donating a few dollars to a special "carbon neutrality" fund. This fund will pool your money with that of other contributors to finance a forestry project somewhere on the planet. The fund's managers will look for a certified project so they can advertise its legitimacy; otherwise, you might distrust it and not participate. So what does everyone get from this?

- You: Your guilt about contributing to greenhouse gas accumulation through air travel will be assuaged.
- The airline company: They will not worry that you might choose to travel less in order to protect the climate.

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- The offset fund: They assess a portion of the proceeds for staff and expenses. These funds are nonprofits, but they provide livelihoods and prestige for their employees.
- The organization implementing the forestry project: Their enterprise, which might be public or private, for-profit or nonprofit, is successfully financed. Often these projects are in low-income countries where the revenues derived from selling offsets are some of the best economic opportunities available.

But we have left out certification. This is very expensive, since carbon assessments of forests require hands-on data collection; individual projects have to fit to an overall forest development plan; and plans require forestry expertise and still more data collection. If the offsets had to cover these additional costs they would need to be much more expensive per tonne of carbon, and the entire industry would have difficulty getting off the ground. This is why REDD+ was created: it assumes these costs itself and lets the rest of the industry profit.

So who pays for REDD+? Interesting question. All financing comes from governments; Table 4.1, taken from a recent REDD+ annual report, shows the cumulative funding through the end of 2015.

Nearly the entire funding was from Europe and more specifically Norway, which alone accounted for almost 88% of the total. In fact, it wouldn't be too far off the mark to say the worldwide forest offset business supported by REDD+ is a creation of the Norwegian government. Normally, I would be hesitant to speculate about motives,

Table 4.1. Cumulative funding of REDD+ through December 31, 2015, in millions of US dollars

Denmark	8.9
European Union	11.8
Japan	3.0
Luxembourg	2.7
Norway	234.1
Spain	5.5
Total	267.0

Source: UN-REDD (2016).

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but in this case they are rather clear: Norway is one of the world's wealthiest countries, with large deposits of oil and gas on a per capita basis, and it also prides itself in its progressive values. In other words, it is a major contributor to climate change and profits from it, but also wants to demonstrate it is taking the lead in fighting climate change. Taking a portion of its hydrocarbon proceeds and financing a global program to support reforestation in other countries is just the ticket. Indeed, through its sponsorship of REDD+ Norway might claim that all its production and export of fossil fuels is offset by the forest programs it facilitates.

So, if we consider the internal and external political benefits for Norway, the global forest offset industry looks like a win-win-win-win-win. Buyers are happy. Companies like airlines that promote offsets are happy. Offset fund administrators are happy. Forest investors are happy. Norway is happy. What's not to like?[31]

The one lingering question is whether forestation projects actually withdraw carbon from the atmosphere the same way burning fossil fuels adds to it – whether they constitute measurable negative emissions. After all, placebos make us happy too.

Forests: A Stopover, Not a Final Destination, for Carbon

To sort out the legitimate from the fictitious effects of forestation, we have to go back to the basics, the surface carbon cycle described in Chapter 1. In a nutshell, if we suppose for the moment that introductions of new carbon from long-term storage – under the earth, in undersea methane deposits and in stable peat and permafrost – equal the transport of carbon back to long-term storage, the surface cycle is in equilibrium, with a constant amount of carbon that circulates through it. This is roughly the situation we would be in if human beings had never discovered fossil fuels.

In that case, the various sinks and fluxes depicted in the carbon cycle graphic would remain unchanged year after year. Their sizes, incorporating only "natural" flows and not anthropogenic ones post-1870, are given in that diagram and summarized in Table 4.2. Of the four major temporary storage locations for carbon, the atmosphere might actually be the smallest, while the ocean is by far the largest – logical in view of the size of the ocean relative to land, horizontally but also vertically. In the absence of human intervention, approximately the

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same amount of carbon would reside in terrestrial vegetation at any point in time as in the atmosphere. Soils play a larger role but exchange only very slowly with the rest of the system.

A useful way to summarize the relationship between stock (the size of the sink) and flow is average turnover time, defined as the sink divided by the flux. This can be interpreted as the average time a carbon-bearing molecule, like carbon dioxide, spends in a given location before moving somewhere else. Performing this calculation produces the turnover times in the table. Here the atmosphere is clearly the winner, with carbon entering and leaving rapidly compared with the size of the sink, while soils and the ocean see little annual turnover. Carbon in vegetation turns over almost as fast as that in the atmosphere.

Table 4.2 is reasonably accurate for the preindustrial carbon cycle, but human beings have altered it in various ways, especially by extracting and burning fossil fuels. The surface carbon cycle is no longer in equilibrium, and fluxes in and out of the various sinks are no longer equal; this has to be taken into consideration when we think about how this cycle operates today.

Since our topic of the moment is forestation, let's take a closer look at "vegetation." This category is an average of vastly different biomes, including not only forests but also grasslands and even desert. What about forests in particular? A recent study estimated average turnover time in tropical forests at 4.2 years and temperate forests at 23.5 years – interesting in that most forestation projects qualifying for offsets are in tropical regions.[32] Short turnover times do not in

Table 4.2. Natural carbon sinks and fluxes and average turnover times, in gigatonnes carbon per year or average number of years

Location	Sink	Flux	Turnover
Atmosphere	589	170	3.5
Ocean	38,000	61	623.0
Vegetation	450–650	107	4.2–6.1
Soils	1,500–2,400	2	750–1,200

Source: IPCC (2014). This table is derived from the sink and flow data provided in the graphic representation of the carbon cycle in Chapter 1.

themselves mean that carbon sinks are any less sink-y, since, in equilibrium, inflows equal outflows. At a superficial level, it's like the difference between a fast food restaurant and a more upscale dining establishment. Both may have fifty patrons at any point in time, but there's more coming and going in fast food. One might ask whether it makes a difference if the goal is simply to keep a certain number of people off the street, and in equilibrium the answer is no.

But we are not in equilibrium, and not even in a steady, predictable disequilibrium. Carbon fluxes are changing for a variety of reasons, some under human control, and others, as the elements of the carbon cycle adjust to new conditions, not. Faster turnover means greater susceptibility to disruption – to relatively abrupt changes in the size of the sink. This in fact is exactly the core problem of carbon accumulation in the atmosphere: we are emitting enough greenhouse gases to fundamentally alter the size of the atmospheric sink in just a few human generations. This would not be possible, at least not without a massive effort, in the ocean, where the sink is immense relative to the size of the flows.[33] And this brings us to forests, especially in the tropics, where a situation similar to the atmosphere obtains. Humans can try to rapidly increase forest sinks through accelerating inflows by planting trees (good), but the sinks are also vulnerable to sudden changes in outflows (bad). Looking only at the first and not at the second is seriously misleading.

With this context in mind, we're ready to face the central problem with forest carbon accounting. Recall that climate models record, as they must, the annual fluxes of carbon to and from forest sinks. It's the job of these models to produce quantitative estimates of annual changes in the amount of carbon in the atmosphere, so the effects of forests are measured in those terms. The reliable prediction horizon of these models is a few decades, and they produce the best forecasts they can under the circumstances.

But the real question we would want to answer in evaluating the climate impact of a forestation project is not just its effect in any given year or even over thirty to forty years, but the net effect over the full life span of the project, or at least over a century or so. We want a life-cycle analysis, even if more distant outcomes are somewhat speculative.

To make things simple, suppose again the carbon cycle is in equilibrium, where inflows to each sink exactly equal outflows from it,

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and then a new forest project is undertaken. At first inflows of carbon from the atmosphere to the forest will exceed the outflows, which is what conventional measurements capture, but after many years a new equilibrium will be established as biomass growth declines and decomposition increases. In this example we are ignoring all the impacts on the carbon cycle that are unrelated to this particular project. With a little reflection it should be clear that its effect on the equilibrium level of atmospheric carbon is roughly equal to the change in the steady-state size of the forest sink, the amount of carbon residing in the forest prior to the project compared with the amount after the new equilibrium is established. This is the net carbon buildup in forest biomass, and that's what could potentially offset carbon emissions from other sources.[34]

So what can we say about this change in equilibrium carbon sequestration? Alas, not very much. It will most likely be greater than zero: plant a new forest, and you are likely to have more carbon storage in that forest in perpetuity. What the *steady-state* amount will be, however, is much more difficult to predict.

The first point, obvious to anyone who knows about forest ecology, is that "steady state," while it may have a statistical meaning at very large geographic and temporal scales, is a poor descriptor of a mature forest. For any given patch of forest, disturbance is part of the story. Fires, storm damage and the periodic eruption and containment of biological threats are never-ending.[35] The forest project that earned its proud investors many tonnes of carbon offsets may well fall prey to one of these forces, and its carbon value should be discounted by the degree of that risk, but we will see that challenge is largely unmet.

And the situation is worse because we are not in equilibrium, nor will we arrive at equilibrium over calculable time frames. Because of this fact, simple extrapolation from the past is a poor guide to the future of forests planted or protected today.

Thus one important factor is climate change itself. It is virtually certain that temperature and precipitation will change dramatically in many locations, and this will change what types of forests can survive in which regions. Fire risk for forests in the United States has doubled in recent decades, clearly due to climate change. Drought is an increasing hazard worldwide. Warming has exacerbated the toll taken by pests and pathogens. Even more disturbing, these risks to forests are synergistic: each threat increases the impact of the others. Research at the

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intersection of climate science and forest ecology has begun to shed light on the rising vulnerability of forest sinks, but this awareness has not yet made its way into the realm of offset promotion, like REDD+.[36]

A secondary confounding factor is how future societies will respond to the pressures of a changing world. As we saw in Chapter 2, most analysts now expect climate change to lead to crop losses, with the impacts becoming more severe as global temperatures continue to rise and climate systems are altered. How will people react? It is more than possible they will convert additional land to agricultural uses to make up for losses in productivity, but this would probably entail forest clearing, as it has in the past. It is especially in tropical regions that agricultural impacts will be the biggest, and where most forestation projects are located.

The only reasonable conclusion is that negative emissions through forestation are uncertain in size and all too reversible. We have good estimates of their carbon sequestering effects on a year-to-year basis over the next few decades, but not over the long run. If a tree is planted and absorbs carbon for fifty years, only to release all of it through fire or cutting in the fifty-first year, it has no net effect on atmospheric accumulation over the entire period. In this respect there is no symmetry at all between the negative emissions of planting a forest and the positive emissions of burning fossil fuels. Introducing new carbon into the surface carbon cycle by bringing it up from subterranean deposits is irreversible, given the technologies we possess today and are likely to possess in the future.[37]

Meanwhile, even if we had precise estimates of the long term, steady-state carbon storage potential of forest protection and enhancement, we would still face practical uncertainties about how much of it can be attributed to offsets. Above all, a major reason trees are cut down is that there is demand for them or the land they occupy. Safeguarding a forest stand in one location may lead to increased clearing in another in order to satisfy this demand; indeed, economics predicts exactly this outcome.[38] While it might be possible to estimate this effect over a large scale, like a major region or a country, it is virtually untraceable at the level of single projects – but this is the level at which forest offset programs supported by REDD+ operate. In reality, as Norway's own Auditor General reported in 2017–2018, the large potential for displacement of deforestation, combined with a lack of follow-up on REDD+ projects, and even outright fraud, leave "considerable uncertainty" over the contribution of forest offsets to climate mitigation.[39]

And there is another problem with offsets based on storing forest carbon: it is difficult to know whether the trees planted or preserved under an offset program would have had the same fate if the program hadn't existed. This complication, which we will examine more systematically in Chapter 6, is about the "additionality" of the offset – whether the carbon sequestration it ostensibly finances is truly greater than what would occur otherwise.

Consider, for instance, Pennsylvania Ridges, a 3,800-acre forest in the middle of that state. According to the seller of carbon credits for protecting this property, without a large infusion of extra revenue, almost three-fourths of the trees will be cut down within five years. It sounds like a valid proposition; by purchasing forest credits you can keep this carbon secure far into the future. There is just one problem: the entity selling these credits is the Nature Conservancy, which purchased Pennsylvania Ridges twenty years ago precisely to forestall timber harvests by its previous owner. The offsets provide additional income to the Conservancy but not additional forest protection, unless their earlier campaign to raise money for saving this property was just a ruse. But the Pennsylvania credits are on the market, and the Walt Disney Company has bought 180,000 of them.[40]

Another example was recently provided by the reputable online news organization ProPublica in conjunction with the *MIT Technology Review*. It found rampant abuse of the forest offset component of the California cap-and-trade program, which we will consider in greater detail in Chapter 6. The centerpiece was a case study of a forest owned by the Massachusetts Audubon Society. This nonprofit, which manages its holdings for habitat and conservation, and not timber, nevertheless earned $6 million by selling pledges not to log a parcel of 9,700 acres. This allowed the buyers, mostly oil and gas companies, the right to emit an extra 600,000 tons of carbon dioxide. This further illustrates the perverse incentives that pervade the world of offsets, forest-based and otherwise. Incidentally, it also shows how cheaply emitters can escape California's carbon cap: just $10 buys you a ton.[41]

The verdict on forestry projects is similar to the one we will come to later with other so-called carbon removal technologies: planting new forests and maintaining and enhancing the ones we already have is highly desirable. *Some* increased carbon sequestration is likely to result from all this effort, and it may even turn out to be quantitatively important. *But investments in forests should never be used to avoid reductions in other sources of carbon emissions, particularly the extraction and combustion of fossil fuels*. We simply don't know what the long-term carbon impact of any particular forestry project will be, so we can't legitimately use it to offset a known and irreversible impact from the use of fossil fuels. A better approach is to use policies to curtail the use of fossil fuels to ensure, as far as possible, that we avoid warming in excess of 2°C, and then use forestation and similar interventions into the global network of carbon fluxes and sinks to bring warming down even further.

This is our first intimation that all is not well in the land of offsets. We will see more evidence for this judgment in Chapter 6.

Conservation and Renewables: The Danger of Positive Thinking

Public opinion specialists tell us the negativity surrounding climate change needs to be expunged.[42] Scaring people doesn't work, and anything that sounds like sacrifice – especially if it can be construed as a tax – is a big turnoff. Instead, we should lead with the positive. Replace the grim talk of climate catastrophe with a glowing picture of our green future, with a solar array on every rooftop and heirloom beans in every pot. Forget about taxes or controls on fossil fuels and point to all the green jobs that will be created in the ecotopia to come.[43] Alas, this exemplifies the wishful thinking the Introduction to this book warned us against.

This thinking is at the heart of the current strategy of centering climate policy on a Green New Deal (GND). The origin of this approach is a 2004 position paper written by Michael Shellenberger and Ted Nordhaus, two marketing consultants whose clients included major environmental organizations.[44] Surveying the failure – already at this time one could use the word "failure" – of environmental activists to get government action to reduce carbon emissions, they argued that the entire mental framework of activism had to change. Rather than defining environmental problems scientifically and proposing actions to achieve technical goals, greens should recast these problems as political in the traditional sense: about values, material benefits and, above all, constituencies. Talk about cutting emissions does none of this; it does

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not engage established narratives about progress, nor does it promise to put any money in your pocket, and what constituencies have a particular interest in whether invisible plumes of carbon dioxide ascend or don't ascend into the atmosphere?

Their solution was to propose that the climate problem be recast as one of investment in new technology and infrastructure. Invoke the can-do spirit of inventing new and better ways to do things, and emphasize the economic benefits of a green jobs program. Tailor the proposal to appeal to constituencies like labor unions, minority communities and regions impacted by economic decline. The goal, they argue, is to solve not a technical problem about greenhouse gas concentrations in the atmosphere but the political one of assembling a winning coalition.

The timing of the Nordhaus–Shellenberger epistle was somewhat off, and their attempt to get environmentalists to change course fizzled out. In the past few years it has been resurrected by new advocates, however, in the form of a Green New Deal. At this point the GND is still more a slogan than a set of proposals. It takes various forms in activist and political contexts, as well as between the United States and Europe.[45] In some versions it is essentially a wish list, a set of objectives detached from concrete actions to achieve them. When formulations of the GND specify criteria, there is little guidance to balancing the competing goals that might be pursued or how possible costs can be assessed against them.[46] Thus to advocate a GND is to express support for public programs to subsidize the expansion of renewable energy, upgrade the electrical grid, retrofit the housing stock for greater efficiency, improve mass transit and finance new, less-carbon-reliant technology. At the same time, the GND is expected to facilitate full employment, with additional targeted support for workers currently in the fossil fuel sector and racial or ethnic minorities – the "just transition" component.

Before launching a criticism of the GND framing of carbon policy, I want to make it clear that, not only do I not oppose any of these items, I am strongly in favor of all of them. We surely need a rapid increase in green energy production and end-use efficiency, along with new technological options for decarbonization. Promoting a high-employment, high-wage economy is good economics. Opportunities to reverse inequalities inherited from the past should be fully utilized. The GND is excellent economic, environmental and social policy. What it is not, unfortunately, is a sufficient program for avoiding a climate catastrophe. Let's see why.

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Imagine a world ruled by a king whose every word is law. For reasons known only to himself, he has decreed that the amount of energy used in his kingdom, measured in units of oomph (the technical term of choice in that land), must remain at a fixed level, not an oomph more or less. At first, all the energy is produced by burning coal, but the king hates coal mines because of how grimy they are, and he doesn't like his subjects going underground where he can't see them. One possibility is that he could command the mines to shut down and force the populace to search for alternative energy sources. Another is that he could order the building of other energy supply systems. For instance, he could direct his royal engineers to build an array of windmills, and, since the total energy consumption must remain constant, every oomph of wind energy means one less oomph of energy from coal.

And there's a third strategy, too. If his wizard can find ways to produce the goods the kingdom needs with less energy, the king can decree a lower level of energy production, which would translate directly into less coal mining. The story is the same in either case: if total energy production can be fixed, then there is an equal and opposite relationship between one energy source and the others, or a direct relationship between the fixed level and the source that produces it.

Of course, we don't live in this kingdom or any place even approximately similar. The total energy used in our society is not decreed by anyone, but arises from choices made by millions of producers and consumers. Over the long sweep of history since the industrial revolution, energy use has gone up and up, and the struggle of poor countries to improve incomes and living standards guarantees that, if possible, this trend will continue well into the future. More energy from one source does not mean that much less from the other, nor does less demand for one type of use mean that overall demand will go down by the same amount. This is a simple and obvious point, but somehow it gets lost whenever discussion turns to the subject of the green economy.

To get a rough quantitative sense of the tug-of-war between renewable and nonrenewable energy sources in a world of expanding consumption, consider Table 4.3. Energy consumption is measured in this table in units of oil equivalents, or how much oil it would take to produce the same amount of energy from other sources. This doesn't correspond to climate impacts, but it does give us a useful sense of the trade-off between fossil and non-fossil energy supplies. While two years also doesn't begin to tell the full story of the ups and downs (or, more

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Table 4.3. Global primary energy consumption in million tonnes of oil equivalents, 2017–2018

Fuel	2017	2018	Change
Oil	4,607.0	4,662.1	55.1
Natural gas	3,141.9	3,309.4	167.5
Coal	3,718.4	3,772.1	53.7
Fossil fuel total	11,467.3	11,743.6	276.3
Renewables	490.2	561.3	71.1
Nuclear	597.1	611.3	14.2
Hydro	919.9	948.8	28.9
Nonfossil total	2,007.2	2,121.4	114.2
Combined total	**13,474.5**	**13,865**	**390.5**

Source: British Petroleum (2019).

accurately, the ups and more ups) of energy use over recent decades, it's enough to illustrate the extent to which different sources compete with or simply add on to each other. I have lumped all non-fossil sources together for simplicity, although there are important differences in the environmental and other impacts of renewable fuels, nuclear and hydroelectric power. (Renewables constitute about a quarter of non-fossil energy supplies over this brief period but account for 62% of the growth of this sector.)

Non-fossil energy use increased by 5.7% between 2017 and 2018; how good was that? It's much faster than fossil energy growth, 2.9%, but it's adding to a lower base, since non-fossil sources made up only about 15% of total supply in 2017. The result is that, while oil, natural gas and coal grew at a lower rate, their absolute growth (in oil equivalents) was almost two and a half times that of renewables, nuclear and hydro combined. Now imagine for a moment our hypothetical king who keeps energy use constant: if we had the same growth in non-fossil energy under his regime, fossil sources would have declined by nearly 1% instead of increasing by almost 3%. While that would be far too small in relation to what we need to accomplish, at least it would be in the right direction. I suspect this is the effect many people assume when they hear about expansion in renewable and other forms of non-fossil

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energy supply: more of the "good" energy means that much less of the "bad" variety. Of course, in the real world there is no royal fixed-energy mandate, and the interesting question is, How large an increase in non-fossil energy would it take to actually get the same 1% reduction in fossil supplies given overall energy growth? The disturbing answer is 25%: at the current size and composition of global energy supply and at the current growth rate of that supply, to cut fossil fuels by 1% would require a 25% growth rate in all the other energy sources.

But as we have already seen, our benchmark rate of carbon emission reduction, which is approximately the same as the rate of fossil fuel reduction, is 3.9% for the world and 6% (or higher) for the United States and other relatively wealthy countries. If the annual rate of increase in green energy production to achieve just a 1% decline in emissions is out of reach, the higher benchmark targets are that much more unachievable if we rely on just this one strategy. In other words, *in a world of expanding energy demand, no feasible amount of investment in renewable or other noncarbon energy sources can sufficiently reduce the use of fossil fuels unless action is also taken to suppress those fuels directly*.

Note, incidentally, that following through on this conclusion would mean ignoring assertions one sometimes hears that current fossil fuel investments such as mines, power plants and pipelines "lock us in" to further years or decades of these energy sources – there is no such "lock." On the contrary, the logic of rapidly decreasing fossil fuel use year after year is also the logic of scrapping such investments, no matter how costly that may be to their owners. (Technically, as we will see in Chapter 6, this need not take the form of mandates to decommission them, but the effect will be the same as a result of making their fuel sources or products so expensive their demand disappears.)

To see the same logic at a national level, consider the energy transition (*Energiewende*) taking place in Germany. Initiated at the federal level in 2011, the goal is to completely transform the country's energy consumption by 2040, with targets for electrical generation, home heating, transportation and general energy usage.[47] Due to Germany's consensus-based system of economic organization, with powerful industry associations, unions, public financial institutions, and integration of education and research with all of the above, it has an exceptional capacity to reengineer itself. And in fact the increase in renewable energy sources as a proportion of total energy use has risen dramatically, as shown in Table 4.4.

Table 4.4. Renewable energy sources and coal as percentage of total consumption, Germany, 2005–2016

	2005	2006	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
% Coal[a]	24.0	24.5	25.8	23.8	22.8	23.7	24.8	25.3	25.1	25.4	25.3	24.3
% Renewables	5.0	5.9	7.1	6.9	7.7	8.3	9.3	10.1	10.3	11.3	12.2	12.3

[a] Includes both hard and brown coal. In general, Germany uses somewhat more hard coal than brown (lignite), which has higher carbon emissions per energy content.
Source: European Commission (2020).

Renewables have more than doubled their share of total energy use over this period, and their inroads into electrical generation have been even more impressive, accounting for nearly 30% of the total for 2016.[48] Ambitious plans are in the works to build a virtual forest of offshore wind turbines in the coastal region of the North Sea, with massive transmission lines to convey the energy to population centers in the south. The German housing stock, already well insulated by global standards, is being systematically retrofitted for maximum savings in heating requirements. These and similar measures have justifiably attracted worldwide attention.

But greenhouse gas emissions? This part of the story is not as uplifting. As Table 4.4 also demonstrates, coal has stubbornly retained its importance in Germany's energy portfolio, and cutting back will be difficult since the country has committed itself to shutting down its nuclear industry by 2021. (Nuclear provided 6.9% of all energy consumption in 2016.[49]) The upshot is a decidedly mixed record on the overall carbon front, as we can see in Figure 4.1.

To some extent, the rather stable carbon emissions since 2009 reflect the relative strength of the German economy, which has benefited from robust exports due to the weakness of the euro and continuing demand from China; if Germany had stagnated like most other Eurozone countries its people would be a lot less content, but the climate would be somewhat better off. Indeed, Table 4.5, which uses 2005 as a base year to index carbon emissions, tells us that Germany's progress over the past decade on this front substantially trails the entire twenty-eight-member EU taken as a single entity.

The inescapable conclusion, as strange as it seems, is that the Energiewende has hardly had an impact on overall German emissions; to this point Germany has been outperformed by its neighbors. This

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Table 4.5. German and EU-28 carbon emission indexes, 2005 = 100

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EU-28	100	99.9	99.0	96.9	89.9	91.8	89.0	87.8	86.0	82.8	83.3
Germany	100	100.8	98.3	98.5	91.8	95.2	93.2	93.8	95.7	91.5	91.3

Source: European Commission (2020).

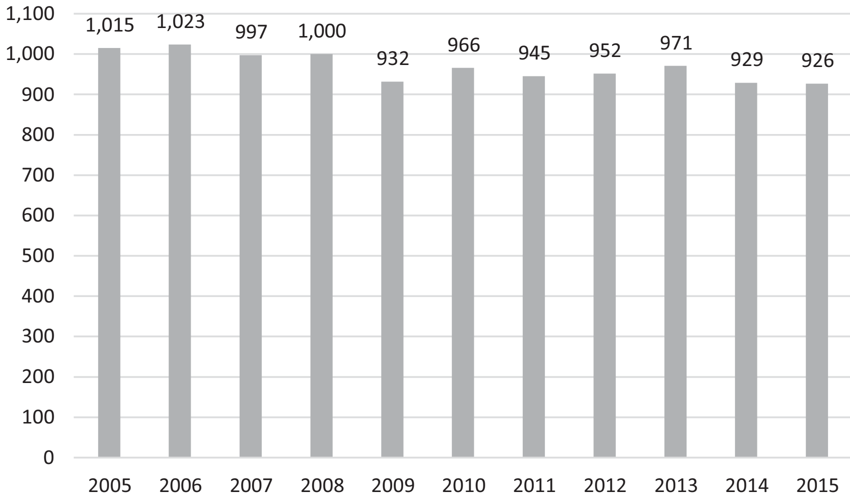

Figure 4.1 German greenhouse gas emissions, 2005–2014, in millions of CO_2 equivalents.
Source: European Commission (2020).

observation is so surprising it has acquired its own name: the *Energiewende* Paradox.[50] Increased renewable capacity has *not* been at the expense of fossil fuels – especially coal – and energy conservation in some sectors, like residential heating, has not automatically translated into corresponding reductions in overall demand. The picture is somewhat complicated by energy imports and exports, since surpluses of electricity at times when wind and solar are abundant are shared with other countries on the same grid, but Germany also draws from the grid at other times; a thorough analysis of Energiewende would have to take this factor into account, but we won't.

The German struggle to rein in emissions while sustaining its economy is fascinating and can easily occupy a book of its own. The reason for bringing it up here is much simpler, however: it vividly

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illustrates the fact that investing in renewable energy is not the same as reducing the use of fossil fuels. There is no monarch decreeing that German energy consumption must remain fixed or that its mix of nonrenewable energy sources is not allowed to change. Germany is entirely capable of making very large investments in wind and solar energy as well as energy efficiency technology *and* maintaining an unacceptably large appetite for fossil fuels, especially coal. Energy is not a zero-sum world.

Nevertheless, it would be unfair to dismiss the value of Energiewende and similar attempts elsewhere to build a decarbonized energy system – a goal of the GND as well. It is indisputable that a climate catastrophe cannot be avoided unless a transformation of this sort takes place. One way to think about it is to redefine what we mean by mitigation and adaptation in climate policy. Normally, mitigation refers to the set of policies that have to do with changing energy use so that atmospheric carbon concentrations can be stabilized, while adaptation has to do with the investments we will need to make to cope with the climate change we can't avoid. From that perspective, installing wind turbines and solar arrays is mitigation, and constructing sea walls or helping farmers switch to new crops is adaptation.

That pair of boxes isn't quite right, however, since it is the amount and type of fossil fuel we use and not how many wind turbines we build that actually determines the extent of mitigation. A better distinction might be one that defines mitigation strictly in terms of carbon emission reduction and recognizes two different kinds of adaptation – adaptation to unavoidable climate change and also to the unavoidable costs of mitigation. Drastic cutbacks in fossil fuel use threaten to reverse decades if not centuries of progress in improving living standards unless we take other steps to soften the blow. That's exactly what investments in renewable energy sources and energy efficiency promise to achieve: they help us adapt to the profound disruption that going on a strict carbon diet would otherwise entail.

In this way, green energy investments, by reducing the human costs of limiting fossil fuel use, also make serious climate measures more politically palatable. It is easier to get the public to support a strenuous tax on gasoline, for instance, if ample mass transit alternatives are in place and if electric vehicles are inexpensive and have access to a thick network of charging stations. (And, as we have seen, also if a large enough portion of the electricity to run these vehicles can be supplied by renewables not subject to a carbon surcharge.) In practical terms, this benefit from green investments may be decisive. On the other hand, it is politically difficult to get support for a truly massive program of green investments without the spur of high fossil fuel prices, an inconvenient chicken-and-egg dilemma.

For the limited purposes of this chapter, however, we don't have to solve this problem. It is enough to recognize that, crucial as they are, programs to expand the supply of renewable sources and reduce the overall amount of energy we need to power our economy have only indirect and unpredictable effects on fossil fuel use. If we take the threat of catastrophic climate change seriously, there is no substitute for actually curtailing the extraction of coal, oil and gas.