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THE SECRET HISTORY OF FOSSIL FUELS

"YOU MUST MAKE A LOT OF MONEY"

"You're an environmentalist, right?" the girl, college age, asked me. It was 2009, in Irvine, California. I had stopped at a farmers' market near my office for lunch, and she was manning a Greenpeace booth right next to it.

"Do you want to help us end our addiction to dirty fossil fuels and use clean, renewable energy instead?"

"Actually," I replied, "I study energy for a living—and I think it's good that we use a lot of fossil fuels. I think the world would be a much better place if people used a lot more."

I was curious to see how she would respond—I doubted she had ever met anyone who believed we should use *more* fossil fuels. I was hoping that she would bring up one of the popular arguments for dramatically reducing fossil fuel use, and I could share with her why I thought the benefits of using fossil fuels far outweighed the risks.

But fossil fuels cause climate change, she might have said. I agree, I would have replied, but I think the evidence shows that climate change, natural or man-made, is more manageable than ever, because human beings are so good at adapting, using ingenuity and technology.

But fossil fuels cause pollution, she might have said. I agree, I would have replied, but I think the evidence shows that ingenuity and technology make pollution a smaller problem every year.

But fossil fuels are nonrenewable, she might have said. I agree, I would have replied, but I think the evidence shows that there are huge amounts of fossil fuels left, and we'll have plenty of time to use ingenuity and technology to find something cheaper—such as some form of advanced nuclear power.

But fossil fuels are replaceable by solar and wind, she might have said. I disagree, I would have replied, because the sun and the wind are intermittent, unreliable fuels that always need backup from a reliable source of energy—usually fossil fuels, which is the only source of energy that has been able to provide cheap, plentiful, reliable energy for the billions of people whose lives depend on it.

But she didn't say any of those things. Instead, when I said I thought that we should use more fossil fuels, she looked at me with wide-eyed disbelief and said, "Wow, you must make a lot of money."

In other words, the only conceivable reason I would say that our use of fossil fuels is a good thing is if I had been paid off by the fossil fuel industry.

Even though this wasn't true, I understood why she thought it. It is conventional wisdom that our use of fossil fuels is an "addiction"—a short-range, unsustainable, destructive habit.

Eighty-seven percent of the energy mankind uses every second, including most of the energy I am using as I write this, comes from burning one of the fossil fuels: coal, oil, or natural gas.[1] Every time someone uses a machine—whether the computer I am using right now, the factory it was produced in, the trucks and ships that transported it, the furnace that forged the aluminum, the farm equipment that fed all the workers who made it, or the electricity that keeps their lights on, their phones charged, and their restaurants and hospitals open—they are using energy that they must be able to rely on and afford. And 87 percent of the time, that energy comes from coal, oil, or natural gas.[2] Without exception, anyone who lives a modern life is directly or indirectly using large amounts of fossil fuel energy—it is that ubiquitous.

But, we are told, this cannot continue.

While it might be convenient to drive gasoline cars and get electricity from coal in the short run, and while we might have needed them in the past, the argument goes, in the long run we are making our climate unlivable, destroying our environment, and depleting our resources. We must and can replace fossil fuels with renewable, green, climate-friendly energy from solar, wind, and biomass (plants).

This is not a liberal view or a conservative view; it's a view that almost everyone holds in one form or another. Even fossil fuel companies make statements like the one the former CEO of Shell made in 2013: "We believe climate change is real and time is running out to take real action to reduce greenhouse gas emissions."[3] President George W. Bush was the person who popularized the expression "addicted to oil."[4] The debate over our addiction to fossil fuels is usually over *how dangerous* the addiction is and *how quickly* we can get rid of it—not whether we have one.

And the most prominent groups say we must get rid of it very quickly.

For years, the Nobel Prize–winning Intergovernmental Panel on Climate Change (IPCC) has demanded that the United States and other industrialized countries cut carbon dioxide emissions to 20 percent of 1990 levels by 2050—and the United States has joined hundreds of other countries in agreeing to this goal.[5]

Every day, we hear of new predictions from prestigious experts reinforcing the calls for massive restrictions on fossil fuel use. As I write this, news about melting ice in West Antarctica is leading to dire predictions of sea level rises: "Scientists Warn of Rising Oceans from Polar Melt," reports the *New York Times*; "Is It Too Late to Save Our Cities from Sea-Level Rise?" asks *Newsweek*, citing new research that "Miami and Manhattan will drown sooner than we thought."[6]

The message is clear: Our use of fossil fuels is going to destroy us in the long run, and we should focus our efforts on dramatically reducing it as soon as humanly possible.

So when the girl at the Greenpeace booth implied that I had sold my soul, I didn't get offended. I simply explained that, no, I wasn't being paid off; I had just concluded, based on my research, that the short- and long-term benefits of using fossil fuels actually far, far outweigh the risks and was happy to explain why. But she wasn't interested. Pointing me to the Greenpeace pamphlets giving all the reasons fossil fuels are bad, she said, "So many experts predict that using fossil fuels is going to lead to catastrophe—why should I listen to you?" She made it clear that this wasn't a real question and that the conversation was over.

But if she had wanted an answer, I would have told her this: I understand that a lot of smart people are predicting catastrophic consequences from using fossil fuels, I take that very seriously, and I have studied their predictions extensively.

And what I have found is this: leading experts and the media have been making the exact same predictions for more than thirty years. As far back as the 1970s they predicted that if we did not dramatically reduce fossil fuel use *then*, and use renewables instead, we would be experiencing catastrophe *today*—catastrophic resource depletion, catastrophic pollution, and catastrophic climate change. Instead, the exact opposite happened. Instead of using a lot less fossil fuel energy, we used a lot more—but instead of long-term catastrophe, we have experienced dramatic, long-term improvement in every aspect of life, including environmental quality. The risks and side effects of using fossil fuels declined while the benefits—cheap, reliable energy and everything it brings—expanded to billions more people.

This is the secret history of fossil fuels. It changed the way I think about fossil fuels and it may change the way you think about them, too.

DÉJÀ VU

When I was twenty years old, I decided I wanted to write about "practical philosophy" for a living. Philosophy is the study of the basic principles of clear thinking and moral action. While college philosophy classes all too often present philosophy as an impractical subject that involves endlessly debating skeptical questions ("How do you know you exist?" "How do you know you're not in The Matrix?"), philosophy is in fact an incredibly practical tool. No matter what we're doing in life, whether we're coming up with a business plan or raising children or deciding what to do about fossil fuels, it is always valuable to be able to think clearly about what is right and what is wrong and why.

One valuable lesson philosophy taught me is that with any idea, such as the idea that we need to get off fossil fuels, we should look at the *track record* of that idea, if it has one.

Now, you might think: this idea does not have a history because it is a *new* idea based on the latest science. This is certainly the impression many of our leading intellectuals give. For example, in 2012 I debated Bill McKibben, the world's leading opponent of fossil fuels, at Duke University, and he presented his view of our addiction to fossil fuels as cutting-edge: "We should be grateful for the role that fossil fuel played in creating our world and equally grateful that scientists now give us ample warning of its new risks, and engineers increasingly provide us with the alternatives that we need."[7] This is the narrative we hear over and over: fossil fuels were once necessary, but the latest science tells us they're causing an imminent catastrophe unless we stop using them and replace them with cutting-edge renewables.

What is rarely mentioned is that thirty years ago, leading experts, including many of today's leading experts, were telling us that fossil fuels were once necessary, but the latest science tells us they're causing an imminent catastrophe unless we stop using them and replace them with cutting-edge renewables.

Take the prediction we hear today that we will soon run out of fossil fuels—particularly oil—because they are nonrenewable. This prediction was made over and over by some of the most prestigious thinkers of the 1970s, who assured us that their predictions were backed by the best science.

In 1972, the international think tank the Club of Rome released a multimillion-copy-selling book, *The Limits to Growth*, which declared that its state-of-the-art computer models had demonstrated that we would run out of oil by 1992 and natural gas by 1993 (and, for good measure, gold, mercury, silver, tin, zinc, and lead by 1993 at the latest).[8] The leading resource theorist of the time was ecologist Paul Ehrlich, who was so popular and prestigious that Johnny Carson invited him onto his show over a dozen times. In 1971 he said, "By the year 2000 the United Kingdom will be simply a small group of impoverished islands, inhabited by some 70 million hungry people,"[9] and in 1974 he wrote, "America's economic joyride is coming to an end: there will be no more cheap, abundant energy, no more cheap abundant food."[10]

Another catastrophic prediction we hear today is that pollution from fossil fuels will make our environment more and more hazardous to our health—hence we need to stop using "dirty" fossil fuels. This prediction was also made many times in the 1970s—with many assurances that these predictions were backed by the best science.

Life magazine reported in January 1970 that, because of particles emitted in the air by burning fossil fuels, "Scientists have solid experimental and theoretical evidence to support . . . the following predictions: In a decade, urban dwellers will have to wear gas masks to survive air pollution . . . by 1985 air pollution will have reduced the amount of sunlight reaching earth by one half . . ."[11] To quote Paul Ehrlich again, as he may have been the most influential public intellectual of the decade (and is still a prestigious professor of ecology at Stanford University): "Air pollution . . . is certainly going to take hundreds of thousands of lives in the next few years alone," he said in 1970.[12]

And then there's the prediction we hear most today: the supposedly scientifically indisputable claim that CO_2 emissions from fossil fuels will cause a true climate catastrophe within a couple of decades.[13] Reading back in time, I saw that many of the leaders who make that prediction now had, decades ago, predicted that we'd be living in catastrophe *today*.

Here's a 1986 news story about a prediction by James Hansen, the most influential climate scientist in the world over the last thirty years:

> Dr. James E. Hansen of the Goddard Space Flight Center's Institute for Space Studies said research by his institute showed that because of the "greenhouse effect" that results when gases prevent heat from escaping the earth's atmosphere, global temperatures would rise early in the next century to "well above any level experienced in the past 100,000 years."
>
> Average global temperatures would rise by one-half a degree to one degree Fahrenheit from 1990 to 2000 if current trends are unchanged, according to Dr. Hansen's findings. Dr. Hansen said the global temperature would rise by another 2 to 4 degrees in the following decade.[14]

Bill McKibben, when he told Duke students in 2012 that we were on the verge of drastic warming, neglected to mention the results of his decades-old claims, such as this one in 1989: "The choice of doing nothing—of continuing to burn ever more oil and coal—is not a choice, in other words. It will lead us, if not straight to hell, then straight to a place with a similar temperature"; and "a few more decades of ungoverned fossil-fuel use and we burn up, to put it bluntly."[15]

John Holdren, a protégé of Paul Ehrlich who serves as science adviser to President Barack Obama, had a particularly dire prediction, according to Ehrlich in 1986: "As University of California physicist John Holdren has said, it is possible that carbon-dioxide climate-induced famines could kill as many as a billion people before the year 2020."[16]

Just as the media today tell us these catastrophic predictions are a matter of scientific consensus, so did the media of the 1980s. For example, on the issue of catastrophic climate change: "By early 1989 the popular media were declaring that 'all scientists' agreed that warming was real and catastrophic in its potential," a 1992 study reported.[17]

If all the predicted catastrophes—depletion, pollution, climate change—had occurred as thought leaders said they would, the world of today would be much, much worse than the world of the 1970s. In the 1970s, Ehrlich went as far as to say, of the overall devastation ahead, "If I were a gambler, I would take even money that England will not exist in the year 2000."[18]

And these were not idle predictions—the coming fossil fuel catastrophe was so bad, these leading experts said, that we needed dramatic restrictions on fossil fuel energy use. Ehrlich wrote: "Except in special circumstances, all construction of power generating facilities should cease immediately, and power companies should be forbidden to encourage people to use more power. Power is much too cheap. It should certainly be made more expensive and perhaps rationed, in order to reduce its frivolous use."[19]

In 1977, Amory Lovins, widely considered the leading energy thinker of the 1970s for his criticisms of fossil fuels and nuclear power and his support of solar power and reduced energy use, explained that we already used too much energy. And in particular, the kind of energy we least needed was . . . *electricity*, the foundation of the digital/information revolution: "[W]e don't need any more big electric generating stations. We already have about twice as much electricity as we can use to advantage."[20]

In 1998, Bill McKibben endorsed a scenario of outlawing 60 percent of present fossil fuel use to slow catastrophic climate change, even though that would mean, in his words, that "each human being would get to produce 1.69 metric tons of carbon dioxide annually—which would allow you to drive an average American car nine miles a day. By the time the population increased to 8.5 billion, in about 2025, you'd be down to six miles a day. If you carpooled, you'd have about three pounds of CO_2 left in your daily ration—enough to run a highly efficient refrigerator. Forget your computer, your TV, your stereo, your stove, your dishwasher, your water heater, your microwave, your water pump, your clock. Forget your light bulbs, compact fluorescent or not."[21]

All of these thinkers still advocate similar policies today—in fact, today Bill McKibben endorses a *95 percent ban on fossil fuel* use, *eight times* as severe as the scenario described above![22] And all of them are extremely prestigious. Since making these predictions, John Holdren has become science adviser to President Obama, Bill McKibben is called "the nation's leading environmentalist"[23] and more than anyone led opposition to the Keystone XL pipeline, and Paul Ehrlich is still arguably the most influential ecological thinker in the world. Energy historian Robert Bradley Jr. chronicles his accolades:

> Ehrlich held an endowed chair as the Bing Professor of Population Studies in the Biology Department at Stanford and was elected president of the American Institute of Biological Sciences. He was elected to the National Academy of Sciences and received many awards and prizes, including the inaugural prize of the American Academy of Arts and Sciences for Science in the Service of Humanity, a MacArthur Genius Award, the Volvo Environmental Prize, the World Ecology Medal from the International Center for Tropical Ecology, and the International Ecology Institute Prize.
>
> He also received what is hyped as the equivalent of the Nobel Prize in a field where it is not awarded—the Crafoord Prize in Population Biology and the Conservation of Biological Diversity.[24]

Thus, today's leading thinkers and leading ideas about fossil fuels have a decades-long track record—and given that they are calling for the abolition of our most popular form of energy, it would be irresponsible not to look at how reality has compared to their predictions.

Of course, predictions on a societal or global level can never be exact, but they need to be somewhere near the truth.

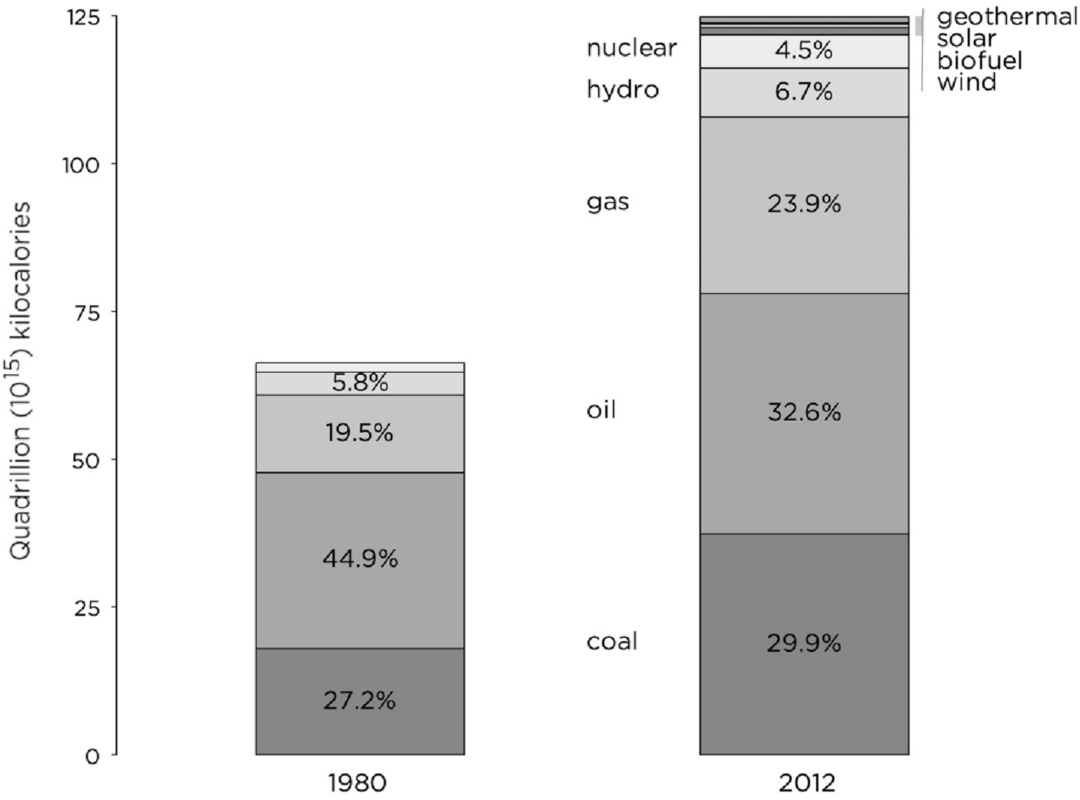
So what happened?

Two things: Instead of following the leading advice and restricting the use of fossil fuels, people around the world nearly doubled their use of fossil fuels—which allegedly should have led to an epic disaster. Rather, it led to an epic improvement in human life across the board.

MORE FOSSIL FUELS, MORE FLOURISHING

Here is a picture summarizing world energy use since 1980.

Figure 1.1: 80 Percent Increase in Worldwide Fossil Fuel Use 1980–2012



Source: BP, Statistical Review of World Energy 2013, Historical data workbook

From the 1970s to the present, fossil fuels have overwhelmingly been the fuel of choice, particularly for developing countries. In the United States between 1980 and 2012, the consumption of oil increased 8.7 percent, the consumption of natural gas increased 28.3 percent, and the consumption of coal increased 12.6 percent.[25] During that time period, the world overall increased fossil fuel usage far more than we did. Today the world uses 39 percent more oil, 107 percent more coal, and 131 percent more natural gas than it did in 1980.[26]

This wasn't supposed to happen.

The anti–fossil fuel experts had predicted that this would be not only deadly, but unnecessary due to the cutting-edge promise of solar and wind (sound familiar?). Then as now, environmental leaders were arguing that renewable energy combined with conservation—using less energy—was a viable replacement for fossil fuels.

Amory Lovins wrote in 1976: "Recent research suggests that a largely or wholly solar economy can be constructed in the United States with straightforward soft technologies that are now demonstrated and now economic or nearly economic."[27] Lovins was a sensation, and around the globe governments gave solar (and wind and ethanol) companies billions of dollars in the hope that they would be able to generate cheap, plentiful, reliable energy.

But as the last graph illustrates, this did not happen. Solar and wind are a minuscule portion of world energy use. And even that is misleading because fossil fuel energy is reliable whereas solar and wind aren't. While energy from, say, coal is available on demand so you can keep a refrigerator—or a respirator—on whenever you need it, solar energy is available only when the sun shines and the clouds cooperate, which means it can work only if it's combined with a reliable source of energy, such as coal, gas, nuclear, or hydro.[28]

Why did fossil fuel energy outcompete renewable energy—not just for existing energy production but for most new energy production? This trend is too consistent across too many countries to be ignored. The answer is simply that renewable energy couldn't meet those countries' energy needs, though fossil fuels could. While many countries wanted solar and wind, and in fact used a lot of their citizens' money to prop up solar and wind companies, no one could figure out a cost-effective, scalable *process* to take sunlight and wind, which are dilute and intermittent forms of energy, and turn them into cheap, plentiful, reliable energy.

So despite the warnings of leading experts, people around the world nearly doubled their use of fossil fuels.

According to the predictions of the most popular experts, who assured us that their conclusions reflected the best science, this should have led to utter catastrophe. But the result was one of the greatest-ever improvements in human life.

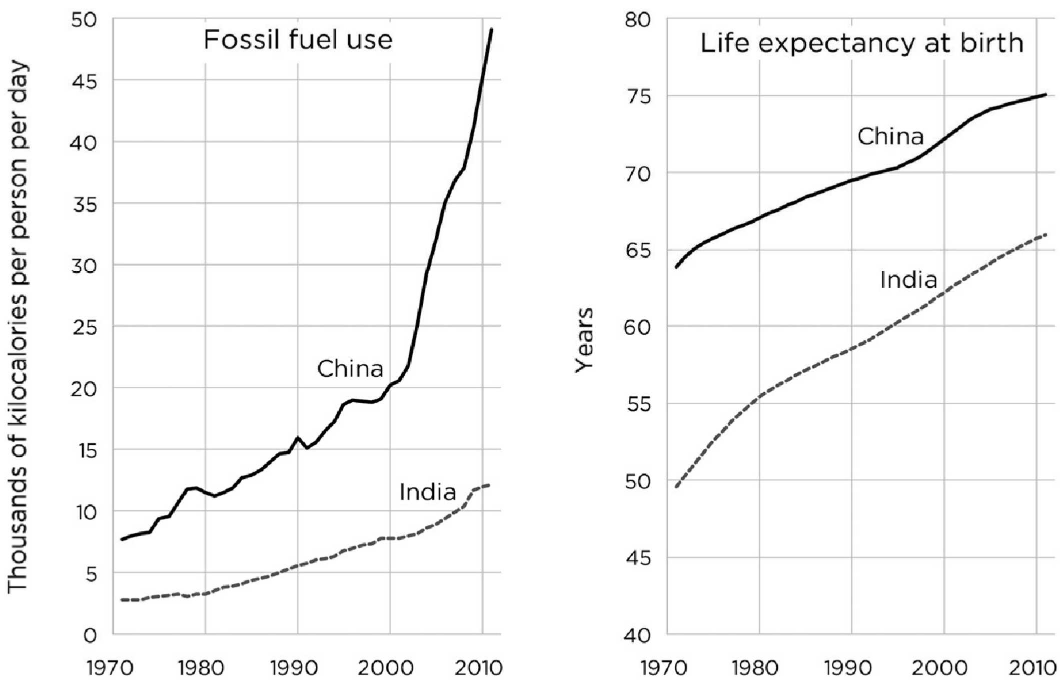
This book is about morality, about right and wrong. To me, the question of what to do about fossil fuels and any other moral issue comes down to: What will promote human life? What will promote human *flourishing*—realizing the full potential of life? Colloquially, how do we maximize the years in our life and the life in our years? When we look at the recent past, the past that was supposed to be so disastrous, we should look at flourishing—and that of course includes the quality (or lack thereof) of our environment.

And there is an incredibly strong correlation between fossil fuel use and life expectancy and between fossil fuel use and income, particularly in the rapidly developing parts of the world. Figures 1.2 and 1.3 show recent trends in China and India of fossil fuel use, life expectancy, and income.

There is no perfect measure of flourishing, but one really good measure is life expectancy—the average number of years in the life of a human being. Another good one, for less obvious reasons, is average income. This is valuable because while in a sense "money can't buy happiness," it gives us *resources* and, therefore, time and opportunity to pursue our happiness. It's hard to be happy when you don't know where your next meal is coming from. The more opportunity you have to do what you want with your time, the more opportunity you have to be happy.

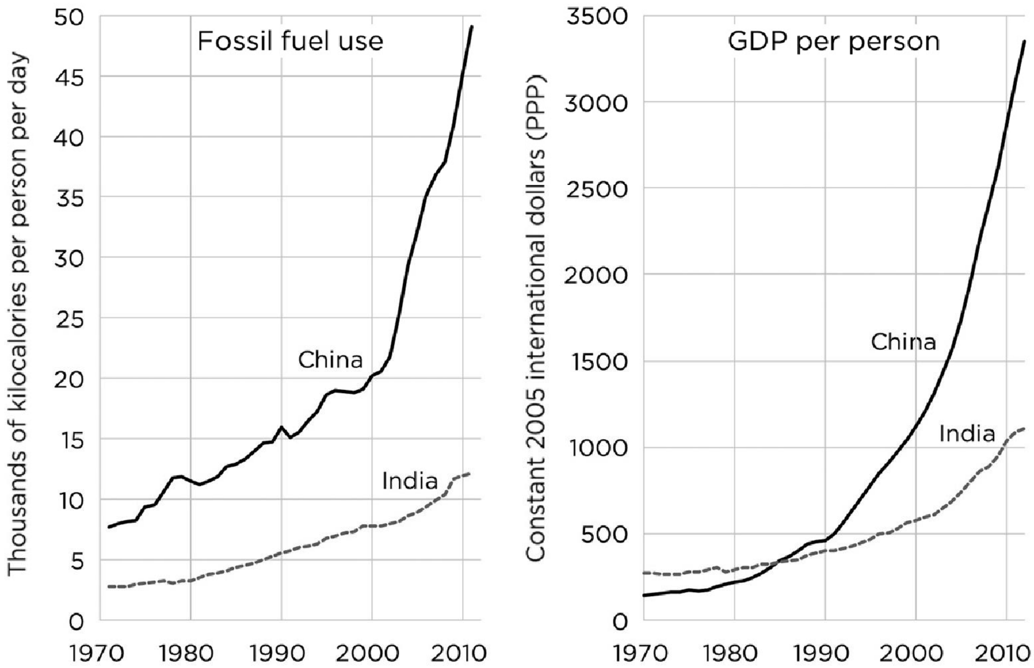
Consider the fate of two countries that have been responsible for a great deal of the increase in fossil fuel use, China and India. In each country, both coal and oil use increased by *at least a factor of 5*, producing nearly all their energy.[29]

Figure 1.2: Fossil Fuel Use and Life Expectancy in China and India



Sources: BP, Statistical Review of World Energy 2013, Historical data workbook; World Bank, World Development Indicators (WDI) Online Data, April 2014

Figure 1.3: Fossil Fuel Use and Income in China and India



Sources: BP, Statistical Review of World Energy 2013, Historical data workbook; World Bank, World Development Indicators (WDI) Online Data, April 2014

The story is clear—both life expectancy and income increased rapidly, meaning that life got better for billions of people in just a few decades. For example, the infant mortality rate has plummeted in both countries—in China by 70 percent, which translates to 66 more children living per 1000 births.[30] India has experienced a similar decrease, of 58 percent.

Not only in China and India, but around the world, hundreds of millions of individuals in industrializing countries have gotten their first lightbulb, their first refrigerator, their first decent-paying job, their first year with clean drinking water or a full stomach. To take one particularly wonderful statistic, global malnutrition and undernourishment have plummeted—by 39 percent and 40 percent, respectively, since 1990.[31] That means, in a world with a growing population, billions of people are better fed than they would have been just a few decades ago. While there is plenty to criticize in how certain governments have handled industrialization, the big-picture effect has been amazingly positive so far.

Ours is a world that was not supposed to be possible.

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Where did the thinkers go wrong? One thing I have noticed in reading most predictions of doom is that the “experts” almost always focus on the *risks* of a technology but never the benefits—and on top of that, those who predict the most risk get the most attention from the media and from politicians who want to “do something.”

But there is little to no focus on the *benefits* of cheap, reliable energy from fossil fuels.

This is a failure to think big picture, to consider *all* the benefits and *all* the risks. And the benefits of cheap, reliable energy to power the machines that civilization runs on are enormous. They are just as fundamental to life as food, clothing, shelter, and medical care—indeed, all of these require cheap, reliable energy. By failing to consider the benefits of fossil fuel energy, the experts didn't anticipate the spectacular benefits that energy brought about in the last thirty years.

At the same time, we do have to consider the risks—including predictions that using fossil fuel energy will lead to catastrophic resource depletion, catastrophic pollution, and catastrophic climate change.

How did those predictions fare? Even if the overall trends are positive, might the anti–fossil fuel experts have been right about catastrophic depletion, catastrophic pollution, and catastrophic climate change, and might those problems still be leading us to long-term catastrophe?

These are important questions to answer.

But when we look at the data, a fascinating fact emerges: As we have used more fossil fuels, our resource situation, our environment situation, and our climate situation have been improving, too.

MORE FOSSIL FUELS, MORE RESOURCES, BETTER ENVIRONMENT, SAFER CLIMATE?

Let's start with the popular prediction that we're running out of resources, especially fossil fuels.

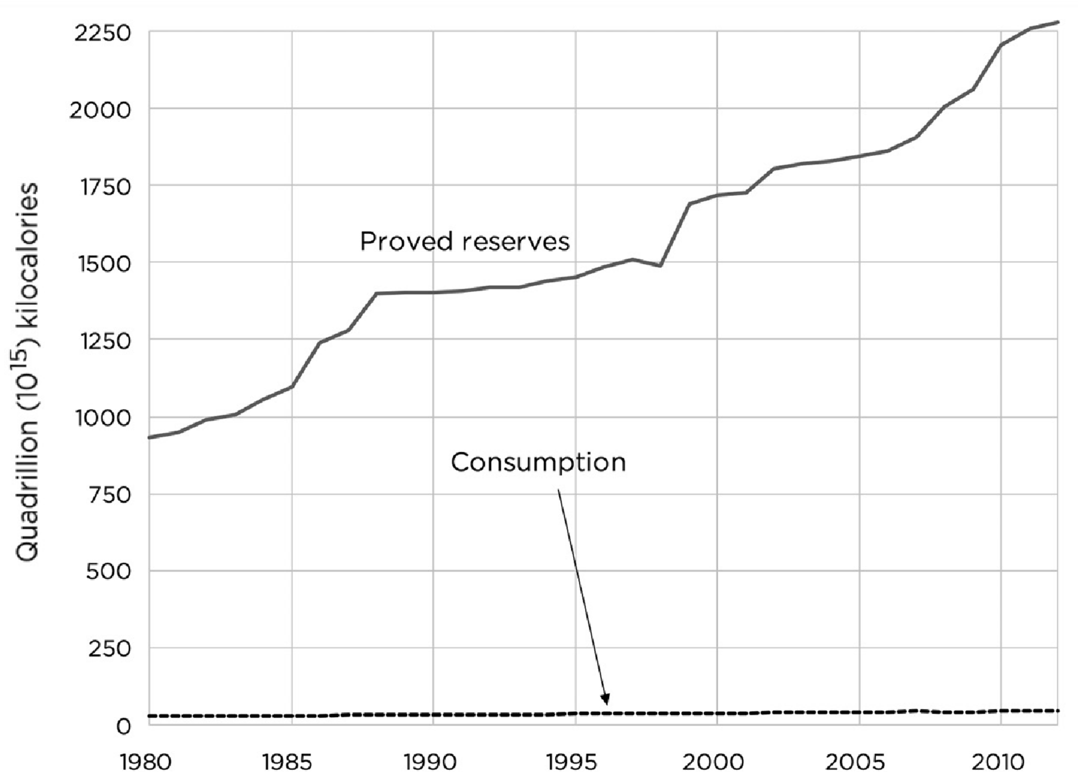
If the predictions were right that we were running out of fossil fuel resources, then nearly doubling fossil fuel use worldwide should have practically depleted us of fossil fuels, even faster than Paul Ehrlich and others predicted. That's certainly what the experts told us in the 1970s. In a 1977 televised address, Jimmy Carter, conveying conventional wisdom at the time, told the nation, "We could use up all of the proven reserves of oil in the entire world by the end of the next decade."[32] A popular Saudi expression at the time captured this idea: "My father rode a camel. I drive a car. My son flies a jet airplane. His son will ride a camel."[33]

Well, no one in the oil business is riding a camel, because as fossil fuel *use* has increased, fossil fuel *resources* have increased. How is that possible?

The measure for fossil fuel resources is "proven reserves," which is the amount of coal, oil, or gas that is available to us affordably, given today's technology. While these statistics are subject to some manipulation—sometimes countries and companies can give misleading data—they are the best information we have and we have historically *underpredicted* availability.

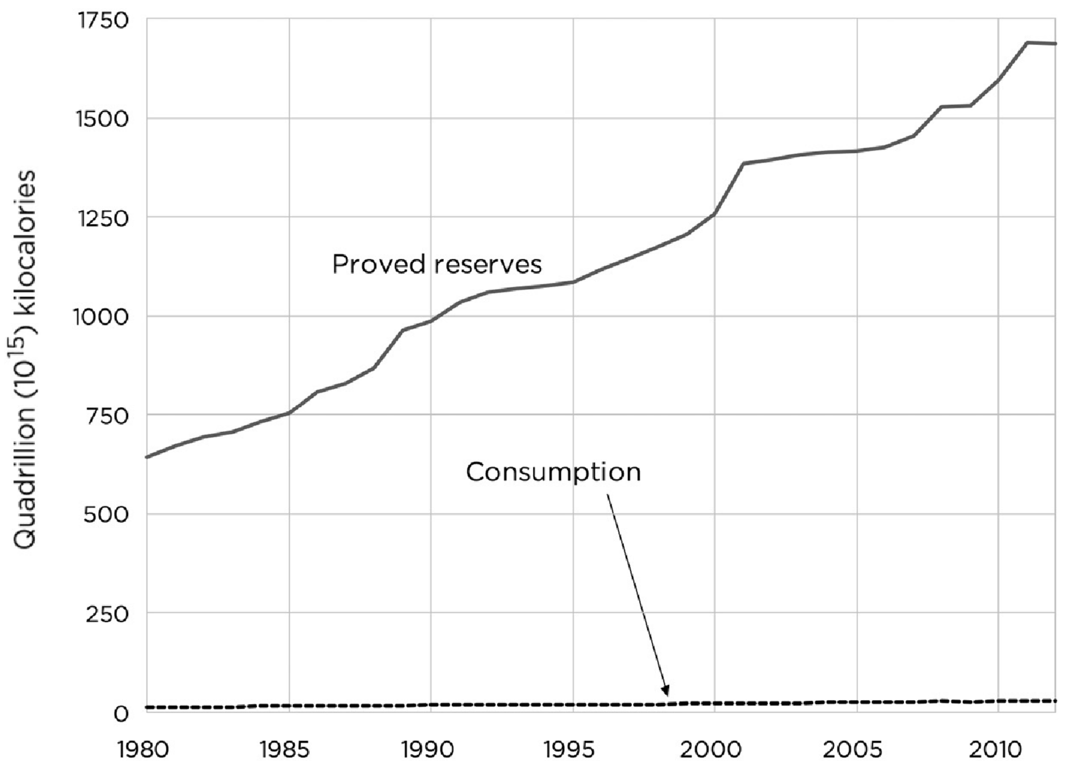
Let's look at reserves from 1980 to the present for oil and gas, the fossil fuels we are traditionally afraid will run out. Coal is much easier to find and extract and is considered to be the fossil fuel that is least likely to run out. Notice how the more we consume, the more reserves increase.

Figure 1.4: More Oil Consumption, More Oil Reserves



Source: BP, Statistical Review of World Energy 2013, Historical data workbook

Figure 1.5: More Natural Gas Consumption, More Natural Gas Reserves



Source: BP, Statistical Review of World Energy 2013, Historical data workbook

This is counterintuitive; the more we use, the more we have.

How did this happen? Stay tuned.

Why did so many expect catastrophic depletion? Again, there was a failure to think big picture. Many experts paid attention only to our consumption of oil and gas resources, but not our ability to create new oil and gas resources.

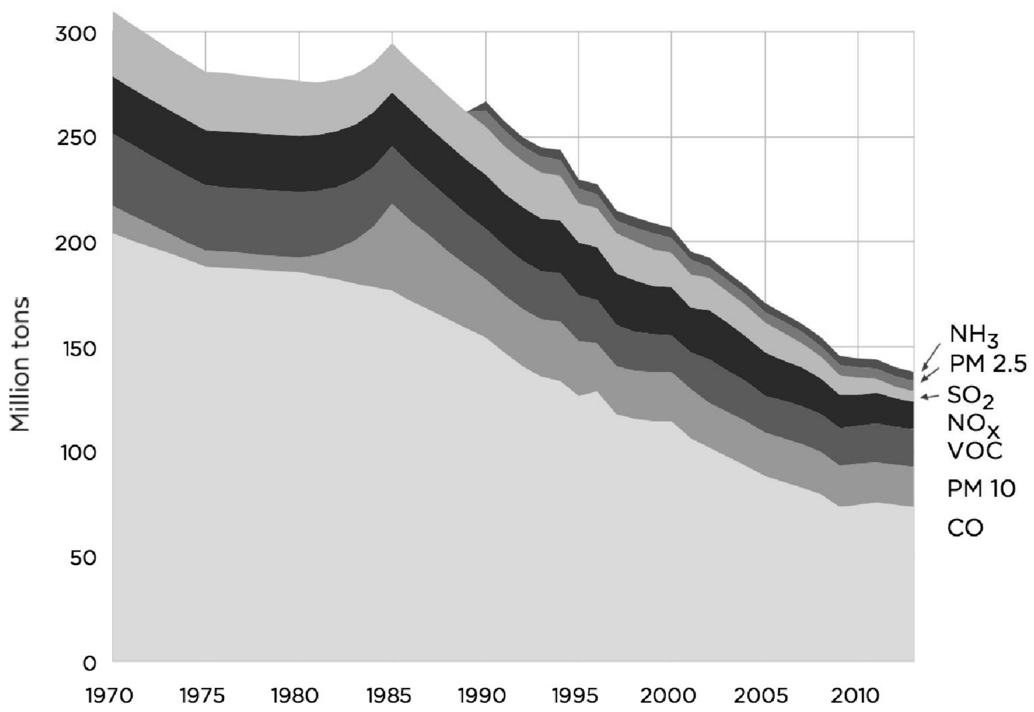
It's true that once we burn a barrel of oil, it's gone. But it's also true that *human ingenuity* can dramatically increase the amount of coal, oil, or gas that is available. It turns out that there are many times more of each in the ground than we have used in the entire history of civilization—it's just a matter of developing the technology to extract them economically.[34] And in general, human beings are amazingly good at using ingenuity to create wealth, which means to create resources. We take the materials around us and make them more valuable; that's how we went from starving in a cave to producing a cornucopia of food that we can enjoy in comfortable homes. The thought leaders did not sufficiently consider these virtues of human beings.

What about the prediction that our environment would degrade as we used more fossil fuels and more everything? Our escalating fossil fuel use was definitely supposed to be punished with a much, much dirtier environment.

What actually happened? We'll look at all major measures of environmental quality in chapter 8, but for now let's look at clean air and clean water. Both have increased substantially.

Here are measurements from the EPA of six major air pollutants. As fossil fuel use goes up, they go down.

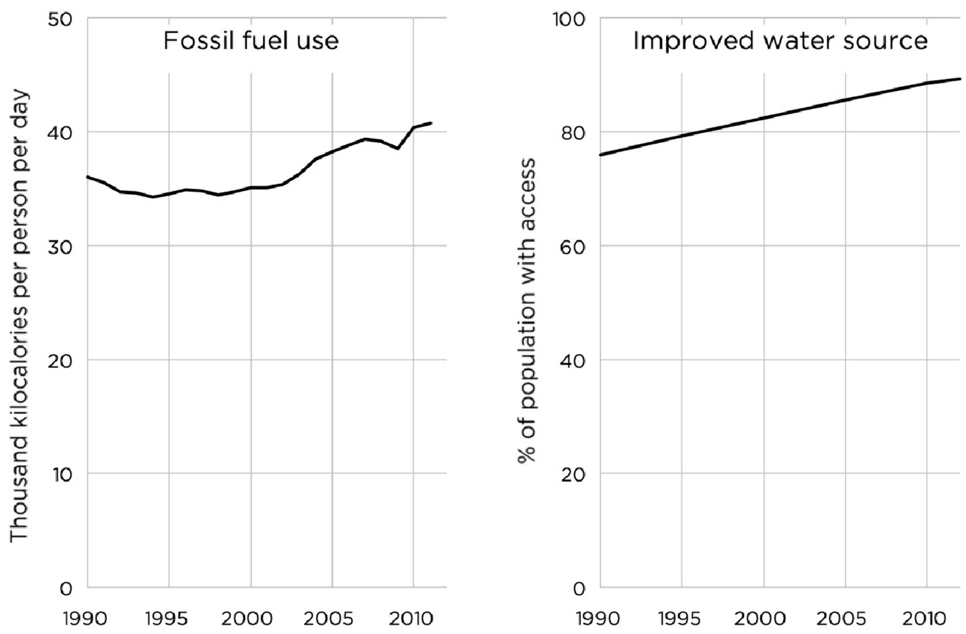
Figure 1.6: U.S. Air Pollution Goes Down Despite Increasing Fossil Fuel Use



Source: U.S. EPA National Emissions Inventory Air Pollutant Emissions Trends Data

And here are international data for the percentage of people in the world with good water quality, which has gone up dramatically in the last 25 years as countries have used more and more fossil fuels.

Figure 1.7: More Fossil Fuels, More Clean Water



Sources: BP, Statistical Review of World Energy 2013, Historical data workbook; World Bank, World Development Indicators (WDI) Online Data, April 2014

Overall, the improvement is incredible. Of course, there are places such as China that have high levels of smog—but the track record of the rest of the world indicates that this can be corrected while using ever increasing amounts of fossil fuels.

Once again, the anti–fossil fuel experts got it completely wrong. Why?

Again by not thinking big picture, by paying attention to only one half of the equation—in the case of fossil fuels, focusing only on the ways in which using them can harm our environment. But fossil fuels, as we'll discuss in chapter 6, can also *improve* our environment by powering machines that clean up nature's health hazards, such as water purification plants that protect us from naturally contaminated water and sanitation systems that protect us from natural disease and animal waste. Pessimistic predictions often assume that our environment is perfect until humans mess it up; they don't consider the possibility that we could improve our environment. But the data of the last forty years indicate that we have been doing exactly that—using fossil fuels.

Finally, we have to look at what the trend is in the realm of climate change. Catastrophic climate change is the most dire claim about fossil fuels today, and it is associated with many prominent scientific bodies, journals, and media outlets—although if we go through the writings of the 1970s and 1980s, we see those same bodies declare many things confidently about *global cooling* only to contradict themselves several years later. In 1975, the American Meteorological Society told Americans that the climate was cooling and that this meant worse weather: "Regardless of long term trends, such as the return of an Ice Age, unsettled weather conditions now appear more likely than those of the abnormally favorable period which ended in 1972."[35] In 1975, *Nature* said, "A recent flurry of papers has provided further evidence for the belief that the Earth is cooling. There now seems little doubt that changes over the past few years are more than a minor statistical fluctuation."[36]

In the late 1970s, the global cooling trend many expected to end in disaster ended with no disaster whatsoever.

Since then, those who believe in catastrophic climate change have overwhelmingly focused on global warming due to CO_2 emissions from fossil fuels. It has long been known that when CO_2 is added to the atmosphere, the greenhouse effect leads to a warming impact—but before the 1970s and

1980s, there was not much fear that it was of a significant enough magnitude to do major harm (or good, for that matter). But starting in the 1970s and especially the 1980s, claims of runaway global warming and resulting catastrophic climate change became popular. How did they fare when compared to reality?

Recall that in 1986 James Hansen predicted that "if current trends are unchanged," temperatures would rise .5 to 1.0 degree Fahrenheit in the 1990s and 2 to 4 degrees in the first decade of the 2000s.[37] According to Hansen's own department at NASA, from the beginning to the end of the 1990s, temperatures were .018 degree Fahrenheit (.01 degree Celsius) higher, and from 2000 to 2010, temperatures were .27 degree Fahrenheit (.15 degree Celsius) higher—meaning he was wrong many times over.[38]

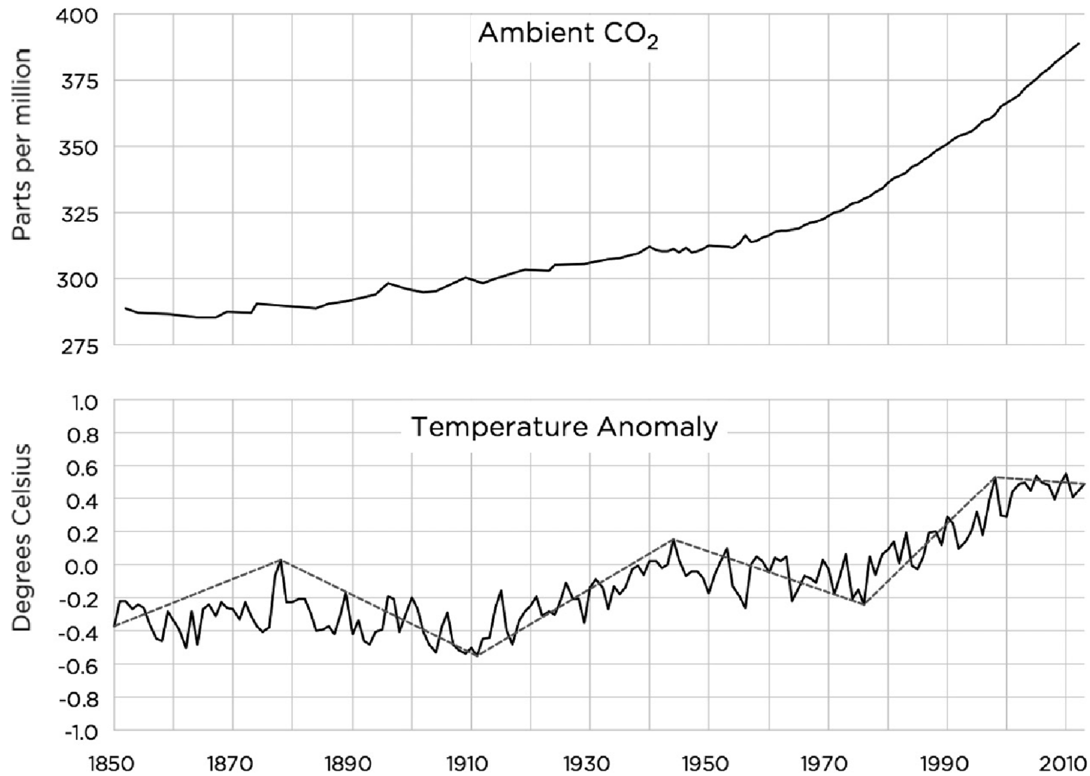
Recall also that journalist Bill McKibben, summarizing the claims of Hansen and others, confidently predicted that by now we would "burn up, to put it bluntly."[39] Looking at the actual data on a graph, it becomes clear that he was completely wrong.

Here's a graph of the last hundred-plus years of temperature compared to the amount of CO_2 in the atmosphere. We can see that CO_2 emissions rose rapidly, most rapidly in the last fifteen years. But there is not nearly the warming or the pattern of warming that we have been led to expect. We can see a very mild warming trend overall—less than 1 degree Celsius (less than 1.5 degrees Fahrenheit) over a century—which in itself is unremarkable, given that there is always a trend one way or the other, depending on the time scale you select. But notice that there are smaller trends of warming and cooling, signifying that CO_2 is not a particularly powerful driver, and especially notice that the current trend is flat when it "should be" skyrocketing.

Given how much our culture is focused on the issue of CO_2-induced global warming, it is striking how little warming there has been.

But most striking to me are the data on how *dangerous* the climate has become over the last few decades, during a time when all of the predictions said that the Earth would become progressively more deadly. The key statistic here, one that is unfortunately almost never mentioned, is "climate-related deaths." I learned about this statistic from the work of the prolific global trends researcher Indur Goklany, who tracks changes over time in how many people die from a climate-related cause, including droughts, floods, storms, and extreme temperatures.[40]

Figure 1.8: Global Warming Since 1850—the Full Story



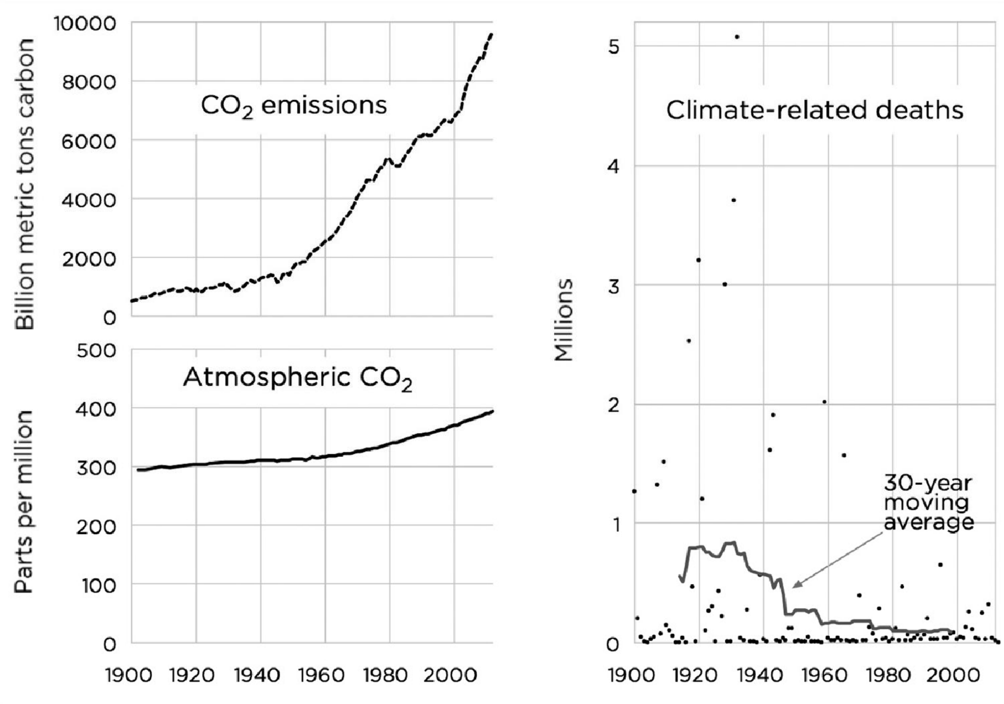
Sources: Met Office Hadley Centre HadCRUT4 dataset; Etheridge et al. (1998); Keeling et al. (2001); MacFarling Meure et al. (2006); Merged Ice-Core Record Data, Scripps Institution of Oceanography

Before you look at the data, ask yourself: Given what you hear in the news about the climate becoming more and more dangerous, what would you expect the change in the annual rate of climate-related deaths to be since CO_2 in the atmosphere started increasing significantly (about eighty years ago). When I speak at colleges, I sometimes get answers such as five times, even a hundred times greater death rates. And from the headlines, it does look as though the tragedies like Superstorm Sandy are the new normal.

The data say otherwise.

In the last eighty years, as CO_2 emissions have most rapidly escalated, the annual rate of climate-related deaths worldwide *fell* by an incredible rate of 98 percent.[41] That means the incidence of death from climate is *fifty times* lower than it was eighty years ago.

Figure 1.9: More Fossil Fuels, Fewer Climate-Related Deaths



Sources: Boden, Marland, Andres (2013); Etheridge et al. (1998); Keeling et al. (2001); MacFarling Meure et al. (2006); Merged Ice-Core Record Data, Scripps Institution of Oceanography; EM-DAT International Disaster Database

The first time I read this statistic, I didn't think it was possible. But my colleagues and I at the Center for Industrial Progress have mined the data extensively, and it is that dramatic and positive. Because the numbers are so startling, in chapter 5 I'll explain them in depth.

Once again, the leading experts we were told to rely on were 100 percent wrong. It's not that they predicted disaster and got half a disaster—it's that they predicted disaster and got dramatic *improvement*. Clearly, something was wrong with their *thinking* and we need to understand what it is because they are once again telling us to stop using the most important energy source in our civilization. And we are listening.

Why did so many predict increasing climate danger when the reality turned out to be increasing climate safety as we used more fossil fuels? Once again, they didn't think big picture—they seemed to be looking only at potential risks of fossil fuels, not the benefits. Clearly, as the climate-related death data show, there were some major benefits—namely, the power of fossil-fueled machines to build a *durable* civilization that is highly resilient to extreme heat, extreme cold, floods, storms, and so on. Why weren't those mentioned in the discussion when we talked about storms like Sandy and Irene, even though anyone going through those storms was far more protected from them than he or she would have been a century ago?

WHAT'S AT STAKE

Imagine if we had followed the advice of some of our leading advisers then, many of whom are some of our leading advisers now, to severely restrict the energy source that billions of people used to lift themselves out of poverty in the last thirty years? We would have caused billions of premature deaths—deaths that were prevented by our increasing use of fossil fuels.

What happens if today's predictions and prescriptions are just as wrong? That would mean billions of premature deaths over the next thirty years and beyond. And the loss of a potentially amazing future.

Even if their predictions are partially right—certainly, fossil fuels have risks that we need to identify and quantify so as to minimize danger and pollution—we are in danger of making bad decisions because of the tendency to ignore benefits and exaggerate risks.

Today, proposals to restrict fossil fuels are more popular than ever. As mentioned earlier, the Intergovernmental Panel on Climate Change (IPCC) has demanded that the United States and other industrialized countries cut carbon emissions to 20 percent of 1990 levels by 2050—and the United States has joined hundreds of other countries in agreeing to this goal.[42] And the UN panel reassures us that "close to 80 percent of the world's energy supply could be met by renewables by mid-century if backed by the right enabling public policies . . ."[43] Around the world, it is fashionable to attack every new fossil fuel development and every new form of fossil fuel technology, from hydraulic fracturing ("-fracking") in the United States to oil sands ("tar sands") in Canada.

To think about dire measures like this without seriously reflecting on the predictions and trends of the last forty years—and the thinking mistakes that led to those wrong predictions—is dangerous, just as it was dangerous for thought leaders to ignore the benefits of fossil fuels while focusing only on (and exaggerating) the risks. At the same time, we need expert guidance to know the *present-day* evidence about the benefits and risks of fossil fuels. History doesn't always repeat itself.

But how do we know what—and whom—to believe?

USE EXPERTS AS ADVISERS, NOT AUTHORITIES

Remember the question from my Greenpeace conversation: "So many experts predict that using fossil fuels is going to lead to catastrophe—why should I listen to you?" She—and we—shouldn't "listen" to anyone, in the sense of letting them tell us what to do.

To be sure, we absolutely need to consult experts. Experts are an indispensable source of information about the state of knowledge in specific fields—whether economics or energy or climate science—that we can use to make better decisions. But we can get this benefit only so long as the expert is clear about what he knows and how he knows it, *as well as what he doesn't know*.

Too often we are asked to take some action because an expert recommends it or because a group of experts favored it in a poll. This is a recipe for failure. We have already seen that the people revered as experts can be disastrously wrong, as Ehrlich was in his predictions from the seventies. Such errors are common, particularly among experts commenting on controversial political matters, where thinkers are rewarded for making extreme, definitive predictions. Think, for example, of all the economists who were convinced in 2007 and 2008 that the economy was healthy and who were advising people to take on more debt and purchase more property, inflating the real-estate bubble further and further, until it finally burst.

To avoid falling prey to this sort of "expert" advice, we need experts to explain to us how they reached their conclusions, and make sure they are not overstepping the bounds of their knowledge, which is incredibly common.

No scientist is an expert on everything; each specializes in some particular field. For example, a climate scientist might be a specialist in paleoclimatology (the study of using ancient evidence to deduce what ancient climates were like), and even then he might be an expert in only one period—say, the Cretaceous (one of the periods in which the dinosaurs lived). He is not going to be an expert in climate physics, and the climate physicist is also not an expert in human adaptation.

Whether our escalating use of fossil fuels is good or bad for us is a complex interdisciplinary question, and *everyone is a nonexpert in many relevant issues*. In this respect, we are all in the same boat. To reach an informed opinion, we need to draw on the work of experts in many fields, working to understand and evaluate their opinions and to interrelate them with one another and with our other knowledge.

Each of us is responsible for taking these steps—for doing his best to find the truth and to make the right decision. This means treating experts not as authority figures to be obeyed but as advisers to one's own independent thought process and decision making. An adviser is someone who knows more than you do about the specifics but knows only *part* of what you need and can be wrong. An honest and responsible expert recognizes this, and so he takes care to explain his views and his reasons for them clearly, he is up-front about any reasons there may be for doubting his conclusions, and he responds patiently to questions and criticism. He strives to give the public access to as much information as possible about his data, calculations, and reasoning. In this book, all the graphs are based on data collected from nonpartisan international sources (including arguably the three sources most respected by scholars: the World Bank, the International Energy Agency, and the BP Statistical Review of World Energy) and in-depth information about the graphs and how to re-create them can be found at www.moral caseforfossilfuels.com.

SEEK THE BIG PICTURE

Ultimately, what we're after in examining the benefits and risks of fossil fuels is to know *big picture* how they affect human life and what to do going forward.

What experts in specific fields give us is knowledge that we can *integrate* into a big-picture assessment. For example, by learning from a combination of scientists and economists and energy experts, we can know how the risks of burning coal compare to the benefits of burning coal.

Looking at the big picture requires looking at *all* the benefits and risks to human life of doing something and of not doing it. To do otherwise is to be biased in a way that could be very dangerous to human life. One thing I noticed repeatedly when looking at the wrong predictions was a distinct bias against fossil fuels. The focus would be exclusively on the negatives of fossil fuels, which were often exaggerated, and not on their *positives*, which, given the results, were clearly overwhelming.

Often the cause of bias is an unacknowledged assumption.

For example, among those who disagree with catastrophic climate change predictions, it's a common assumption that it's *impossible* for man to have a catastrophic or even a significant impact on climate. For example, Indiana Congressman Todd Rokita says, "I think it's arrogant that we think as people that we can somehow change the climate of the whole earth . . ."—as if there is some preordained guarantee that we can't significantly affect the global climate system.[44] There isn't; whether we are or not can't be known without first examining the evidence.

On the other side of the issue, among those who agree with catastrophic climate predictions, it's a common assumption that there's something *inherently* wrong with man having an impact on climate. If you hold that assumption, you're likely to assume that the impact of man-made CO_2 emissions is very negative, even if the evidence showed it was actually mild or even positive.

We cannot assume things are good or bad. We must rigorously seek out the big-picture evidence—hence the last issue: being clear on exactly what we mean by good or bad.

NAME OUR STANDARD

Ultimately, when thinking about fossil fuels, we are trying to figure out the right thing to do, the right choices to make. But what exactly do we mean by right and wrong, good and bad? What is our *standard of value*? By what standard or measure are we saying something is good or bad, great or catastrophic, right or wrong, moral or immoral?

I hold human life as the standard of value, and you can see that in my earlier arguments: I think that our fossil fuel use so far has been a moral choice *because it has enabled billions of people to live longer and more fulfilling lives,* and I think that the cuts proposed by the environmentalists of the 1970s were wrong *because of all the death and suffering they would have inflicted on human beings*.

Not everyone holds human life as their standard of value, and people often argue that things are right or wrong for reasons other than the ways they benefit or harm human beings. For example, many religious people think that it is wrong to eat certain foods or to engage in certain sexual acts, not because there is any evidence that these foods or acts are unhealthy or otherwise harmful to human beings but simply because they believe God forbids them. Their standard of value is not human life but (what they take to be) God's will.

Religion is not the only source of nonhuman standards of value. Many leading environmental thinkers, including those who predict fossil fuel catastrophe, hold as their standard of value what they call "pristine" nature or wilderness—nature unaltered by man.

For example, in a *Los Angeles Times* review of *The End of Nature,* McKibben's influential book of twenty-five years ago predicting catastrophic climate change, David M. Graber, research biologist for the National Park Service, wrote this summary of McKibben's message:

> McKibben is a biocentrist, and so am I. We are not interested in the utility of a particular species or free-flowing river, or ecosystem, to mankind. They have intrinsic value, more value—to me—than another human body, or a billion of them. Human happiness, and certainly human fecundity, are not as important as a wild and healthy planet. I know social scientists who remind me that people are part of nature, but it isn't true. Somewhere along the line—at about a billion [*sic*] years ago, maybe half that—we quit the contract and became a cancer. We have become a plague upon ourselves and upon the Earth. It is cosmically unlikely that the developed world will choose to end its orgy of fossil-energy consumption, and the Third World its suicidal consumption of landscape. Until such time as *Homo sapiens* should decide to rejoin nature, some of us can only hope for the right virus to come along.[45]

In his book, McKibben wrote that our goal should be a "humbler world," one where we have less impact on our environment and "Human happiness would be of secondary importance."[46]

What is of primary importance? *Minimizing our impact on our environment*. McKibben explains: "Though not in our time, and not in the time of our children, or their children, if we now, *today*, limited our numbers and our desires and our ambitions, perhaps nature could someday resume its independent working."[47] This implies that there should be fewer people, with fewer desires, and fewer ambitions. This is the exact opposite of holding human life as one's standard of value. It is holding *human non-impact* as one's standard of value, without regard for human life and happiness.

Earlier we saw that human beings are safer than ever from climate, despite whatever impact we have had from increasing the concentration of CO_2 in the atmosphere from .03 percent to .04 percent. And yet Bill McKibben and others call our present climate catastrophic. By what standard?

In his book *Eaarth*, McKibben argues that it's tragic for human beings to do anything that affects climate, even if it doesn't hurt human beings. He writes, referencing an earlier work:

> Merely knowing that we'd begun to alter the climate meant that the water flowing in that creek had a different, lesser meaning. "Instead of a world where rain had an independent and mysterious existence, the rain had become a subset of human activity," I wrote. "The rain bore a brand; it was a steer, not a deer."[48]

This means that something is morally diminished if human beings affect it.

If fossil fuels changed climate, but not in a way that harmed humans—or even helped them—would it be right to use them because of their benefits to human life?

On a human standard of value, the answer is absolutely yes. There is nothing intrinsically wrong with transforming our environment—to the contrary, that's our means of survival. But we do want to avoid transforming our environment in a way that harms us now or in the long term.

You might wonder how holding human life as your standard of value applies to preserving nature. It applies simply: preserve nature when doing so will benefit human life (such as a beautiful park to enjoy) and develop it when it will benefit human life. By contrast, if nonimpact, not human life, is the standard, the moral thing to do is always leave nature alone. For example, in the 1980s, India had an environmentalist movement, called the Chipko movement, that made it nearly impossible for Indians to cut down forests to engage in industrial development. It was so bad that a movement literally called Log the Forest emerged to counter it. As one Indian who tried to build a road said:

> Now they tell me that because of Chipko the road cannot be built [to her village], because everything has become *paryavaran* [environment]. . . . We cannot even get wood to build a house . . . *our haq-haqooq* [rights and concessions] *have been snatched away*. . . . I plan to contest the *panchayat* [village administrative body] elections and become the *pradhan* [village leader] next year. . . . My first fight will be for a road, *let the environmentalists do what they will.* [Italics in original][49]

This is the essence of the conflict: the humanist, which is the term I will use to describe someone on a human standard of value, treats the rest of nature as something to use for his benefit; the nonhumanist treats the rest of nature as something that must be served.

We always need to be clear about our standard of value so we know the goal we're aiming at. Aiming at human well-being, which includes transforming nature as much as necessary to meet human needs, is a lot different from aiming to *not* affect nature. The humanist believes that transforming nature is bad only if it fails to meet human needs; the nonhumanist believes that transforming nature is intrinsically bad and that doing so will inevitably somehow cause catastrophe for us in the long run.

Because many of the people predicting dire consequences from fossil fuel use avowedly do not hold a human standard of value and because the vast majority of discussions on the issue are not clear about the standard of value being used, we need to always ask, when we hear any evaluation: "By what standard of value?"

THE MORAL CASE FOR FOSSIL FUELS

In my experience, if we follow these principles to get a big-picture perspective on what will and won't benefit human life, the conclusion we'll reach is far more positive and optimistic than almost anyone would expect.

The reason is that the cheap, plentiful, reliable energy we get from fossil fuels and other forms of cheap, plentiful, reliable energy, combined with human ingenuity, gives us the ability to transform the world around us into a place that is far safer from any health hazards (man-made or natural), far safer from any climate change (man-made or natural), and far richer in resources now and in the future.

Fossil fuel technology transforms nature to improve human life on an epic scale. It is the only energy technology that can currently meet the energy needs of all 7+ billion people on this planet. While there are some truly exciting supplemental technologies that may rise to dominance in some distant decade, that does not diminish the greatness or immense value of fossil fuel technology.

• • •

Ultimately, the moral case for fossil fuels is not about fossil fuels; it's the moral case for using cheap, plentiful, reliable energy to amplify our abilities to make the world a better place—a better place *for human beings.*

That's where we will start. In chapters 2 and 3, I will make the case that no other energy technology besides fossil fuels can even come close to producing that energy for the foreseeable future (although several can be valuable supplements).

In chapters 4, 5, 6, and 7, I will make the case that just as energy dramatically improves our ability to deal with any aspect of life by using machines—increasing our mental capacities with computers, our medical capabilities with MRI machines, and our agricultural capabilities with high-powered farming equipment—so it dramatically improves our ability to make our environment healthier and safer from natural and man-made threats. The data clearly show that we have never had higher environmental quality and we have never been safer from climate, despite—no, because of—record fossil fuel use.

In chapter 8, I will make the case that fossil fuel use is not "unsustainable" but progressive—by using the best energy technology today and in the coming decades, we pave the way for fossil fuel technologies not only to harness the copious amounts of fossil fuels remaining in the ground, of which we have just scratched the surface, but also to create the resources and time necessary to develop the next great energy technology.

Finally, in chapter 9, I will make the case that we are at one of those points in history where we are at a fork between a dream and a nightmare and that the nightmare side is winning, thanks to decades of underappreciation of fossil fuels' benefits and massive misrepresentations of fossil fuels' risks. But the dream is absolutely possible. It just requires that we truly, to our core, understand the value of energy to human life.

2

THE ENERGY CHALLENGE: CHEAP, PLENTIFUL, RELIABLE ENERGY . . . FOR 7 BILLION PEOPLE

ENERGY AND LIFE

Tell me if this is motivating: This year humanity will use some 560 quadrillion BTU of energy, which averages out to around 215,000 BTU per person per day—and some people have access to less than 25,000 BTU per day.[1]

No?

Unfortunately, discussions of energy are often extremely abstract and technical, causing us not to think about energy in a very personal, meaningful way. Before I studied energy professionally, I thought of it mostly when I filled up my car, when I paid my power bill, and when I followed controversies about allegedly bad things the energy industry (usually the fossil fuel industry) was doing.

But the reality is that energy affects nearly every aspect of life. Almost nothing matters more to our lives, the lives of those you care about, and the lives of billions of others around the world than the existence of cheap, plentiful, reliable energy. To give you a sense of what I mean, here's a story from The Gambia about what electricity means to a woman having a child.

THE GAMBIA

June 2006

At 4 p.m. on a Saturday afternoon, I was startled when the lights came on; the lights never came on after 2 p.m. on the weekends. The adrenaline really kicked in when I was invited to observe an emergency cesarean section—a first for me. When the infant emerged I felt my heart racing from excitement and awe!

But no matter how many times the technician suctioned out the nose and mouth, the infant did not utter a sound. After twenty five minutes the technician and nurse both gave up. The surgeon later explained that the baby had suffocated in utero. If only they had had enough power to use the ultrasound machine for each pregnancy, he would have detected the problem earlier and been able to plan the C-section. Without early detection, the C-section became an emergency, moreover, the surgery had to wait for the generator to be powered on. The loss of precious minutes meant the loss of a precious life. At that time, in that place, all I could do was cry.

And later, when the maternity ward was too hushed, I cried again. A full-term infant was born weighing only 3.5 pounds. In the U.S., the solution would have been obvious and effective: incuba-

> tion. But without reliable electricity, the hospital did not even contemplate owning an incubator. This seemingly simple solution was not available to this newborn girl, and she perished needlessly.
>
> Reliable electricity is at the forefront of every staff members' thoughts. With it, they can conduct tests with electrically powered medical equipment, use vaccines and antibiotics requiring refrigeration, and plan surgeries to meet patients' needs. Without it, they will continue to give their patients the best care available, but in a country with an average life expectancy of only 54 years of age, it's a hard fight to win.[2]

This story should remind us of how "unnatural" our lives are—and why that's a good thing. It's easy to take for granted that we have the ability to detect early problems with babies—not thinking that absent the machine that can detect them and the energy to power that machine, human beings past and present have lost untold millions of babies. It's easy to take for granted that we have the ability to keep a three-and-a-half-pound baby alive—not thinking that absent the machine that can incubate it and the energy to power that machine, most of people's beloved children who were underweight babies would have died.

This is a microcosm of the central idea of this book—that more energy means more *ability* to improve our lives; less energy means less ability—more *helplessness*, more suffering, and more death. Of course, this book is focused on *fossil fuel* energy—but only, as you'll see, because I believe that it is the most essential technology for producing energy for 7 billion people to improve their lives, at least over the next several decades. If there was a better form of energy and it was under attack in a way that wildly exaggerated its negatives and undervalued its positives, I'd be writing the moral case for *that* form of energy.

There are two facts about energy that are missing from our discussion: one, people around the world need much, much more energy, and two, it's extremely difficult to produce that energy cheaply and reliably.

MACHINE CALORIES

Humanity needs as much energy as it can get.

First: What exactly is energy? The technical definition is "the capacity to do work" but my favorite way to sum it up is with two words: "machine calories."

Every human being runs off the calories he or she consumes; those calories are our *energy*, our *ability to act*. If we run out of calories, we can't act—we die.

The same is true of the machines we use to improve our lives. Whether we're talking about the ultrasound and incubation machines that enable us to save babies, the computers that enable us to gain or discover knowledge, the planes that enable us to visit family members across the globe, or the factories that make it possible for all of those things to be affordable, every aspect of our lives is improved dramatically by machines. Those machines live on energy—*their* ability to act—and without energy, they are the same as the energy-starved machines that can't save the Gambian babies: useless.

And we desperately need machines to do work for us because we are naturally *very weak*. Without machines to help us, we don't have anywhere near all the energy that we need to survive and flourish.

The average human being needs about 2,000 calories a day to give him enough energy to do everything he needs to do—from going to the office to taking a walk to manual labor to sleeping. That's equal to 2,326 watt-hours, which is the amount of energy it takes to power a 100-watt lightbulb for 23.26 hours. Essentially, your body uses the same amount of energy as a 100-watt lightbulb. Pretty interesting, right?

The more physical work you need to do, the more calories you use. A farmer doing vigorous physical work for a day might exert 4,000 calories.[3] An Olympic athlete like Michael Phelps might use 8,000 calories of energy a day.[4]

The more energy you are using at any time, the more *power* you are exerting. Power is defined as the rate of energy use. Power is energy in action; the gasoline is the energy, the engine turns it into power.

And here's where the problem of human weakness comes in. We are not very powerful—about one tenth as powerful as a horse that's one two-hundredth the power of the average car—and thus we can use only so much energy and do only so much work, not nearly enough for a good standard of living.

The story of energy for over 99 percent of history is that human beings couldn't get enough of it to live, and if they could, they could make very limited use of it, because they lacked *power*. Thus they spent their lives engaging in grueling physical labor just to keep their bodies going long enough to engage in the next day of grueling physical labor.

Now if we were all like Superman, it would be a different story. Imagine if Superman, instead of devoting himself to saving Lois Lane and others, decided to help poor countries industrialize. He would be amazing! Superman's superpower, after all, is *power*. He is a high-powered machine that stores a lot of energy in his body. He can melt iron, forge steel, plow fields, build buildings, even run an electrical system by turning some sort of especially large crank. *He could transform any place for the better.*

And so can we, with enough energy and high-powered machines. Using human ingenuity, we have made ourselves into supermen.

Consider the amount of energy at the average American's disposal. The average American's total machine energy use is 186,000 calories a day—ninety-three humans (or twenty-three Michael Phelpses)![5] This is one of the greatest achievements in human history. In the past, before modern energy technology, the main way to overcome the problem of human weakness was putting others into a state of servitude or slavery—which meant that only some could prosper, and at the great expense of others. But with machine energy and machine servants, no one has to suffer; in fact, the more people, the merrier.

The most memorable summary I've read about this amazing development is by economist Milton Friedman:

> Industrial progress, mechanical improvement, all of the great wonders of the modern era have meant little to the wealthy. The rich in ancient Greece would have benefited hardly at all from modern plumbing—running servants replaced running water. Television and radio—the patricians of Rome could enjoy the leading musicians and actors in their home, could have the leading artists as domestic retainers. Ready-to-wear clothing, supermarkets—all these and many other modern developments would have added little to their life. They would have welcomed the improvements in transportation and in medicine, but for the rest, the great achievements of western capitalism have redounded primarily to the benefit of the ordinary person. These achievements have made available to the masses conveniences and amenities that were previously the exclusive prerogative of the rich and powerful.[6]

"Running servants replaced running water"—I'll never forget that.

THE ENERGY CHALLENGE: CHEAP, PLENTIFUL, RELIABLE, SCALABLE

If our ability to act to improve our lives depends on energy, we have an epic challenge.

There are 7 billion people in the world, but 1.3 billion have no electricity.[7] Over 3 billion are classified as not having "adequate electricity"—a threshold that is far less than we enjoy and take for granted.[8] For everyone to have as much access to energy as the average American, the world's energy production would have to quadruple.[9] And we Americans would benefit greatly from even more cheap, plentiful, reliable energy.

So where are we going to get it from?

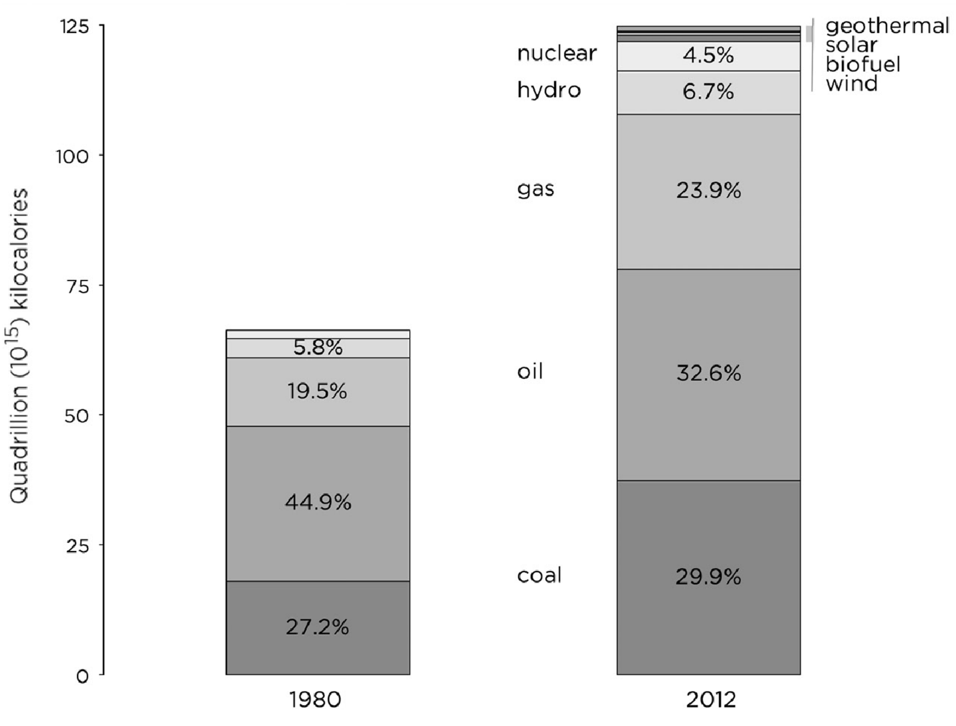
In this chapter and the next, we're going to examine every major energy technology, including all the non–fossil fuel sources of energy, to get an idea of how much they can contribute to energy production going forward. This is important because, assuming you can do it safely, the more energy production, the better and also because there are concerns about the future supply of fossil fuels and the present and future *risks* of fossil fuels. We'll cover future supply in the next chapter and in chapter 8, and the risks in chapters 4–6, but as a matter of principle, anytime we are worried about the risks of one way of doing things (here, using fossil fuel energy) we need to know the benefits and risks of the alternatives.

Nineteenth-century coal technology is justifiably illegal today. The hazardous smoke that would be generated is now *preventable* by far more advanced, cleaner coal-burning technologies. But in the 1800s, it was and should have been perfectly legal to burn coal this way—because the alternative was death by cold or starvation or wretched poverty.

By the same token, the degree of risk we would theoretically be willing to accept from fossil fuels will depend in large part on *what the alternatives are.* Let's say—and I am completely making this up—we could prove that burning fossil fuels will cause ten times more hurricanes for the next fifty years. Should the government take action? Well, if there is a technology that is more affordable and can scale to produce cheaper, more plentiful, reliable energy for 7 billion people, then quite possibly. But if there is no equal or superior alternative, then any government action against fossil fuels, let alone the 50–95 percent bans over the next several decades that have been proposed, is a *guaranteed early death sentence* for billions—we would be willing to accept ten times more hurricanes if we had to. Energy is that important.

To get a sense of where things stand today and where they stood in the past, when "renewables" were predicted to be the future, let's look at how much energy use comes from what sources.

Figure 2.1: The Truth About Global Energy Use



Source: BP, Statistical Review of World Energy 2013, Historical data workbook

Note the difference. Solar and wind produce a combined 1 percent of the energy we use, whereas fossil fuel energy—coal, oil, and natural gas—produces 86 percent, more than five times all other sources combined. That 86 percent is only 7 percent less than 1980's 93 percent. But the total is what matters most—note that our total fossil fuel use is now far, far greater. *Other sources of energy, particularly nuclear and hydro, have been supplements, not replacements for fossil fuels.*

And note that in many ways people have been discouraged from using fossil fuels. For the last thirty years, governments around the world—particularly European governments like Germany, Spain, and Denmark—have gone out of their way to promote non-fossil forms of energy, such as solar, wind, and biofuels. Nevertheless, fossil fuels have remained the energy source of choice.

Why? Or to put it in reverse, why is so much energy *not* made from alternatives?

THE HAZELNUT ENERGY PROBLEM

The simple answer is: because it's a really, really, really hard challenge to produce cheap, plentiful, reliable energy for billions of people—and the fossil fuel industry is the only one, by a mile, that's figured out a solution. (Although there's one source of energy that may well outcompete fossil fuels in three to five decades—stay tuned.)

A brilliant illustration of this appeared on, of all places, *Saturday Night Live* a few years ago. The host of the "Weekend Update" segment at the time, Jimmy Fallon, commented on a plan to use oil derived from hazelnuts to power a car. I have no doubt that this could work technically—vegetable oil and petroleum oil are extremely similar chemically. But I wasn't excited, and neither was Fallon:

> *New Scientist* magazine reported that in the future, cars could be powered by hazelnuts. That's encouraging, considering an eight-ounce jar of hazelnuts costs about nine dollars. Yeah, I've got an idea for a car that runs on bald eagle heads and Fabergé eggs.[10]

I thought that was brilliant. But here's the question I wished Fallon, a member of Artists Against Fracking and thus a public opponent of fossil fuels, had asked: Why are "renewable" hazelnuts so expensive? After all, their energy comes from the sun, which is free, right?

He probably would have responded that while the sun is free, there were other factors in the *process* of producing hazelnuts that make them expensive.

And there are.

Here's a key principle for understanding what makes energy, or anything else, cheap and plentiful. *For something to be cheap and plentiful, every part of the process to produce it, including every input that goes into it, must be cheap and plentiful.* With hazelnuts, not only do you have, as in any process, materials, machines, and manpower, you have a huge limiting factor in that the *land* needed is far from plentiful. Hazelnuts require land with a unique combination of rainfall or irrigation, mild summer climate and cold winter climate, and fertile soil. This happens overwhelmingly in one place, Turkey, which dominates the market, and this ideal hazelnut habitat generates only one crop a year.[11]

What we can call the hazelnut problem comes up over and over again with most of the alternatives to fossil fuels. In some cases, they may be cheap and reliable in small quantities—some people use French fry oil to power their cars—but making them cheap and reliable in large quantities, quantities sufficient to power the lives of billions of people, is a major feat.

Just as it's a mistake to assume that because the sun is free, solar-powered hazelnuts will be cheap, so it is a mistake to assume that solar-powered energy can or will be cheap. Whether that's true or not depends on all the materials, manpower, and machines involved in the entire *process* of harnessing the sun's power.

Every energy process requires taking a form of raw energy—there is no ready-made machine energy—and *transforming* it into usable form so that it becomes the heat in our homes, the mechanical power of our cars, and the electricity that powers the Internet. This is a process that takes time and resources, and the key is to make it take as little time and as few resources as possible, so that it can be *workable* (including reliable), cheap, and plentiful.

Workable is a challenge. Cheap and plentiful are an incredible challenge.

Hazelnut energy is workable; it just isn't likely going to be cheap and plentiful.

Another related challenge is dealing with risks and by-products. Every time energy is transformed, there is the risk of something going wrong (explosion, electrocution), and there are by-products that can be harmful (such as sulfur dioxide from coal or radioactive waste generated when mining the metals that go into windmills).

Let's look at which technologies work worst and best at providing cheap, plentiful, reliable energy—and by plentiful I mean on the scale of *billions* of people. For each one, I'll give a brief summary of how it works, how successful it has been at producing cheap, plentiful, reliable energy, and how it is positioned for the future. I'll start with the most culturally popular energy technologies: solar and wind.

THE EFFICIENCY PROBLEMS OF SOLAR AND WIND: DILUTENESS AND INTERMITTENCY

Solar and wind energy both work with energy flowing directly from the sun; solar through sunlight and wind through the sun's heating of different parts of the atmosphere, which is the main cause of wind.

Solar energy typically works in one of two ways: solar photovoltaic (abbreviated solar PV) and concentrated solar power (CSP). Solar PV generates electricity through a phenomenon, discovered around 1839 by Edmond Becquerel, called the photovoltaic effect, by which certain materials emit electrons when hit by light. Through extremely impressive feats of engineering involving precision (and often expensive) materials, solar PV can generate an electric current when it is exposed to sunlight. The first "solar cell" was patented in the United States in *1888.* CSP, by contrast, concentrates sunlight into heat, much as a child with a magnifying glass does when he uses the sun to ignite a dried leaf. Using, in effect, a massive array of magnifying glasses (in this case, mirrors), CSP concentrates sunlight into heat, which is used to heat a liquid, which generates steam that can power an engine.

Wind electricity works when high-velocity wind turns the blades of a wind turbine, which are connected to a generator that converts the wind's power into electric current.

In practice, solar and wind technologies have, as we saw before, produced very, very little energy.

The top five countries ranked by solar energy consumption are Germany, Italy, Spain, Japan, and China. The percentage of each country's electricity that comes from solar energy is, respectively: 4.5 percent, 6.3 percent, 4.0 percent, .09 percent, and .6 percent.[12]

The top five countries ranked by wind consumption are the United States, China, Spain, Germany, and India. Faring slightly better than solar, the percentage of each country's electricity that comes from wind energy is, respectively: 3.3 percent, 2.03 percent, 16.5 percent, 7.44 percent, and 2.96 percent.[13] (If this seems impossibly low, because we frequently hear numbers such as "50 percent solar and wind," stay tuned.)

Don't let the 16.5 percent in Spain mislead you. Spain suffered financial devastation from its investment in wind, among other bad investments.[14] But more important, certain fundamental problems with solar and wind mean that the more energy they attempt to produce, the more of a problem they create.

Why?

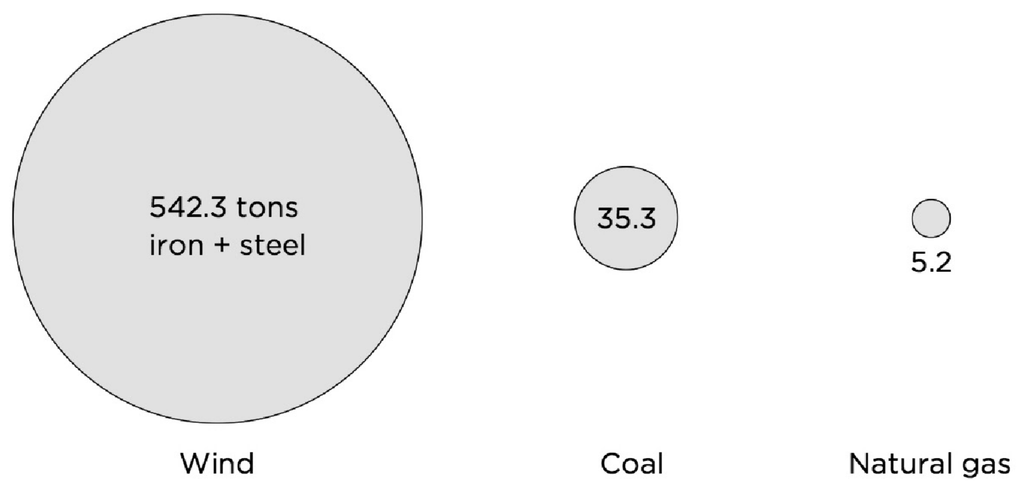
The basic problem is that the *process* for solar and wind to generate reliable electricity requires so many resources that it has never been cheap and plentiful. In fact, *modern solar and wind technology do not produce reliable energy, period.*

Traditionally in discussions of solar and wind there are two problems cited: the diluteness problem and the intermittency problem.

The diluteness problem is that the sun and the wind don't deliver concentrated energy, which means you need a lot of materials per unit of energy produced. For solar, such materials can include highly purified silicon, phosphorus, boron, and compounds like titanium dioxide, cadmium telluride, and copper indium gallium selenide.[15] For wind, they can include high-performance compounds (like those used in the aircraft industry) for turbine blades and the rare-earth metal neodymium for lightweight, high-performance magnets, as well as the steel and concrete necessary to build thousands or tens of thousands of structures as tall as skyscrapers.[16]

Figure 2.2 indicates how steel (and iron) intensive it is to generate electricity from wind as compared with coal, nuclear, or natural gas.

Figure 2.2: Steel and Iron Required per Megawatt for Wind, Coal, and Natural Gas



Sources: ALPINE Bau GmbH, July 2014; Peterson, Zhao, Petroski (2005); Wilburn 2011

Such resource requirements are a big cost problem, to be sure, and would be one even if the sun shone all the time and the wind blew all the time. But it's an even bigger problem that the sun and wind don't work that way. That's the real problem—the intermittency problem, or more colloquially, the unreliability problem.

As we saw in the Gambian hospital, it is of life and death importance that energy be reliable. There are some situations where it isn't, to be sure, and solar has a place there—such as solar hot water heaters or swimming pool heating systems. But for just about everything we do, reliable, on-demand energy is vital—and without it, our electricity grid blacks out.

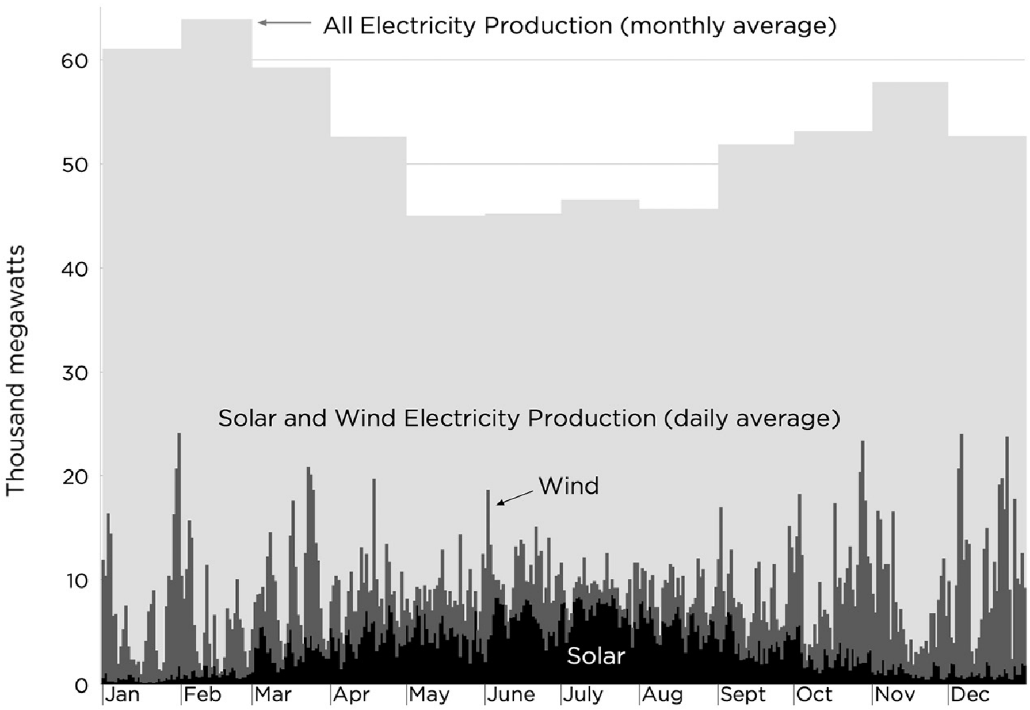
We know from experience that the sun doesn't shine all the time, let alone with the same intensity all the time, and the wind doesn't blow all the time—and leaving aside the assurance that the sun will be "off" at night, they can be extremely unpredictable.

To hear opponents of fossil fuels discuss the issue, though, the unreliability of solar and wind is no obstacle at all, as evidenced by, above all, the success of Germany in powering itself via solar and wind.

In late 2012, Bill McKibben described "what's going on in Germany" as "un-[expletive]-believable" and said "there were days this month [December] when they got half their energy from solar panels."[17]

And it appears that the news is just getting better. The Center for American Progress reported on May 13, 2014, that "Germany Sets New Record, Generating 74 Percent of Power Needs from Renewable Energy."[18] But taking a look at Germany's official energy statistics tells a very different story. Figure 2.3 shows how much of Germany's energy actually came from solar and wind throughout 2013, compared with how much was typically needed during each month.[19] Notice how unreliable the quantity of solar and wind electricity is. Wind is constantly varying, sometimes disappearing nearly completely, and solar produces very little in the winter months, when Germany most needs energy.

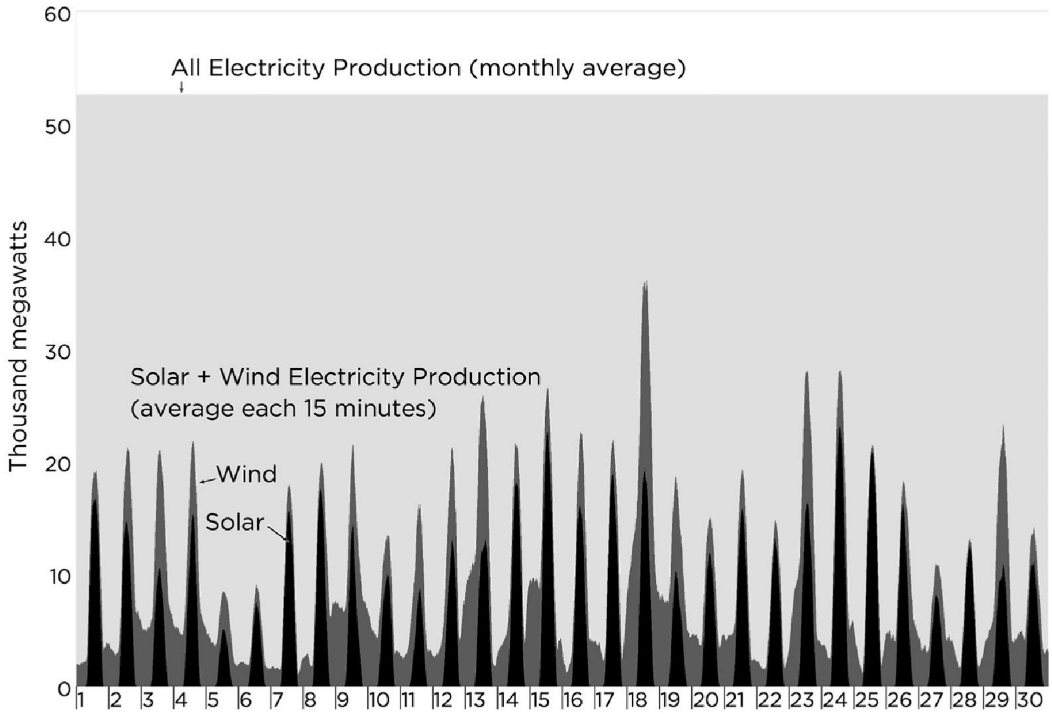
Figure 2.3: Solar and Wind Provide a Small, Unreliable Fraction of Germany's Electricity



Sources: European Energy Exchange Transparency Platform Data (2013); Federal Statistical Office of Germany

How, then, can so many say that solar or wind generates over 50 percent of Germany's energy? What they are referring to is the fact that because solar and wind are so variable, at any given *moment* solar can generate 50 percent of the electricity being used. It can also generate 0 percent of the electricity generated at any given moment. Here is a graph of German solar and wind production in April 2013 based on the average amount of electric power generated every fifteen minutes. Notice that sometimes the combined output of solar and wind is relatively high—and sometimes it is nothing; that is the nature of an intermittent, unreliable source.

Figure 2.4: Solar and Wind: The Closer You Look, the Less Reliable They Are



Sources: European Energy Exchange Transparency Platform Data (2013); Federal Statistical Office of Germany

As you look at the jagged and woefully insufficient bursts of electricity from solar and wind, remember this: *some reliable source of energy needed to do the heavy lifting*. In the case of Germany, much of that energy is coal. As Germany has paid tens of billions of dollars to subsidize solar panels and windmills, fossil fuel capacity, especially coal, has not been shut down—it has increased.[20]

Why? Because Germans need more energy, and they cannot *rely* on the renewables.

In a given week in Germany, the world leader in solar and number three in wind, their solar panels and windmills may generate less than 5 percent of needed electricity.[21] What happens then? Reliable sources of energy, in Germany's case coal, have to produce more electricity. For various technical reasons, this is even more inefficient than it sounds. For example, because the reliable sources have to move up and down quickly to adjust to the whims of the sunlight and wind, they become inefficient—just like your car in stop-and-go-traffic—which means more energy use and incidentally more emissions (including CO_2). And what about when there's a particularly large amount of sunlight or wind? For an electric grid, too much electricity will cause a blackout just as too little will—so then Germany has to shut down its coal plants and be ready to start them up again (more stop and go). In practice they often have so much excess that they have to *pay* other countries to take their electricity—which requires the other countries to inefficiently decelerate *their* reliable power plants to accommodate the influx. This is obviously not scalable; if everyone's electrical generation was as unreliable as Germany's, there would be no one to absorb their peaks.

The only way for solar and wind to be truly useful, reliable sources of energy would be to combine them with some form of extremely inexpensive mass-storage system. No such mass-storage system exists, because storing energy in a compact space itself takes a lot of resources. Which is why, in the entire world, there is not one real or proposed independent, freestanding solar or wind power plant. All of them require backup—except that "backup" implies that solar and wind work most of the time. It's more accurate to say that solar and wind are parasites that require a host.

Here's an analogy. Imagine you have a company of highly productive, efficient, reliable workers. Then there is an initiative to bring in "renewable" workers, who will supposedly live forever, but they are expensive and you don't know when they'll show up. A document produced by them is not as valuable as a document produced by someone else—because you don't know when theirs will arrive. A company can handle a few such workers, but it can't be run by them.

I remember watching an interview of a doctor in Kenya who had to try to run his practice with renewable energy. His clinic was run on solar and could not produce enough electricity to keep both the lights and the refrigerator on at all times, so he had to choose one or the other. When he tried switching on both, an alarm sounded, signifying "out of power."[22] Out of power is exactly the danger to the extent we try to substitute solar and wind for fossil fuels.

Another Kenyan, James Shikwati of the Inter Region Economic Network, explains why he resents programs to encourage underdeveloped countries to use solar or wind.

> The rich countries can afford to engage in some luxurious experimentation with other forms of energy, but for us we are still at the stage of survival. I don't see how a solar panel is going to power a steel industry, how a solar panel is going to power a railway network, it might work, maybe, to power a small transistor radio.[23]

Why do environmentalists focus so much on solar and wind, despite their intractable problems? The traditional explanation is that they don't generate CO_2—leaving aside the coal and oil needed to manufacture them (you can't build a windmill with a windmill). But as we'll see later, there are other, much more scalable forms of energy that don't generate CO_2 (hydroelectric and nuclear), which environmental leaders *oppose*.

Regardless of one's views on the risks of fossil fuels, it is profoundly irresponsible to claim, as many advocates of solar and wind do, that they are powering Germany, let alone supplying 50 percent of the power. Energy is a life and death issue—it is not one where we can afford to be sloppy in our thinking and seize upon statistics that seem to confirm our worldview.

It seems that there's more focus on getting energy directly from the sun, which is often considered "natural," than there is on getting it in a way that will maximize human life. It is deeply irresponsible and disturbing that environmental leaders are telling us to deprive ourselves of fossil fuels on the promise of what can charitably be described as a highly speculative experiment, and can less charitably be described as an ill-conceived, resource-wasting, perennial failure.

There is one much more reliable source of renewable energy that is endorsed by many environmental leaders, though with some reluctance: biomass energy. For example, in order to meet renewability mandates, which usually exclude hydroelectric power, Germany and various other countries are turning to a renewable biomass fuel from the past to make up for the fact that solar and wind scale so poorly: wood.

THE PROBLEMS WITH BIOMASS: PROCESSING AND SCALABILITY

Biomass energy is derived from plant or animal matter, whether wood, crops, crop waste, grass, or even manure. Biomass includes biofuels, which are liquid fuels, usually alcohol, derived from these sources and used for mobile power. Other forms of biomass are used for fixed electrical power or directly for heat (such as wood or animal dung burned to stay warm).

In practice, biomass has, like solar and wind, produced a small amount of energy worldwide—although considerably more than solar and wind.

Why?

Biomass is renewable and natural, because the energy comes from the sun—but not all the inputs in the process can scale. It resembles hazelnut energy; in fact, hazelnut energy is a form of biomass energy.

To its credit, biomass has a storage system, unlike solar and wind—plants store energy from the sun through photosynthesis. The problem is, it takes a lot of resources to grow them—namely the resources involved in farming, including large amounts of energy, land, machinery, water, fertilizer—just like it takes a lot of water to build solar and wind installations. But while solar and wind installations can be built in many places (though part of their problem is that northern and southern latitudes don't give them good sunlight for many hours), biofuels need to be grown on relatively scarce farmland, which starts to bring us into hazelnut energy territory. It means that biomass scales badly—often, the more of it we try to produce, the more scarce and expensive the inputs become, and the more expensive our energy becomes.

Biofuels like ethanol from corn or sugarcane, or biomass from wood, compete with cropland or forest land, driving prices up for both fuel and food.[24] Scalability has been the problem for every biofuel that works (the Bush administration tried to force us to use cellulosic ethanol, a form of ethanol from nonfood sources that has been promoted since the 1920s but still doesn't work) at a smaller scale. But even if nonfood biomass worked better than it does, it would still be extremely resource intensive to regrow over and over.

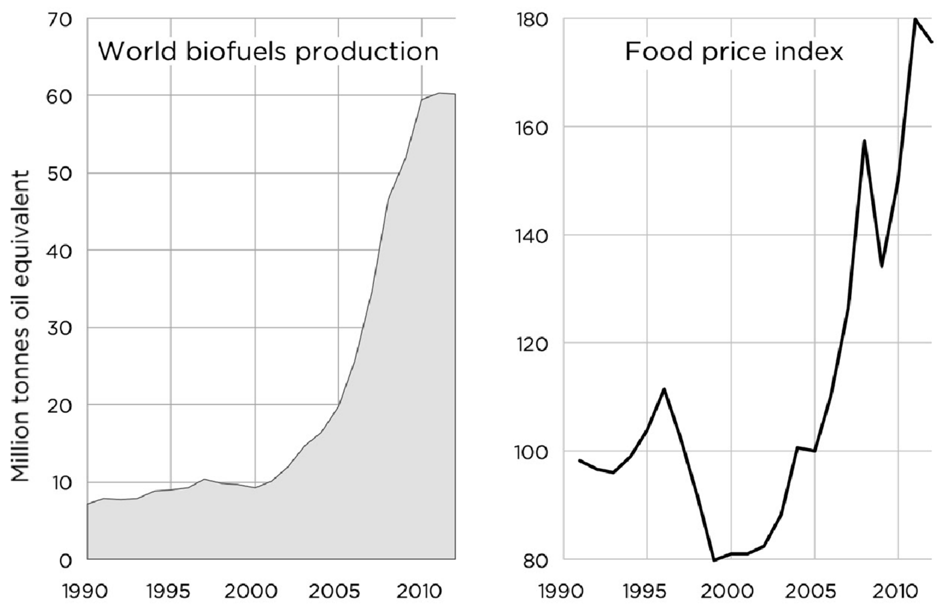
A thought: Throughout history it has been a challenge for human beings to produce enough crops to feed us, because agriculture requires a lot of resources just to produce our meager number of calories. We need many dozens of times as many calories for our machines as we do from our food! If we could eat oil or electricity, we would, because it's much cheaper per unit of energy. Why should we feed human food to machines with hundreds of times our appetites?

Already, the increased use of biomass energy has strongly correlated with a rise in food prices—see Figure 2.5. The idea of scaling it ten times or more, to even make a dent in fossil fuels' energy production, is unthinkable, given all of the evidence we have.

According to a recent report from the United Nations, *The State of Food Insecurity in the World,*

> High and volatile food prices are likely to continue. Demand from consumers in rapidly growing economies will increase, population continues to grow, and any further growth in biofuels will place additional demands on the food system.[25]

Figure 2.5: Comparison of Food Price Index to Biofuel Production



Sources: index mundi Commodity Food Price Index, 2014; BP, Statistical Review of World Energy 2013, Historical data workbook

Biomass energy is not providing scalable energy, but it is making it difficult for farmers to provide scalable *food*.

Here's the bottom line with solar, wind, and biofuels—the three types of energy typically promoted in renewables mandates. There is zero evidence that solar, wind, and biomass energy can meaningfully *supplement* fossil fuel energy, let alone replace it, let alone provide the energy *growth* that is desperately needed. If, in the future, those industries are able to overcome the many intractable problems involved in making dilute, unreliable energy into cheap, plentiful, reliable energy on a world scale, that would be fantastic. But it is dishonest to pretend that anything like that has happened or that there is a reason to think it will happen.

To be sure, solar, wind, and biomass may have their utility for niche uses of energy. If you're living off the grid and can afford it, an installation with a battery that can power a few appliances might be better than the alternative (no energy, or frequently returning to civilization for diesel fuel), but they are essentially useless in providing cheap, plentiful, reliable energy for 7 billion people—and to try to rely on them would be deadly.

And yet our leaders propose massive bans on fossil fuels with the promise that *these* radically inferior technologies will be replacements. That reflects an ignorance of, or indifference to, the need for efficient energy and the value of cheap, plentiful, reliable energy. Any leader who is thinking about making policy decisions with our energy, and ultimately the energy and therefore the opportunities of 7 billion people, had better take the truth about renewables into account.

THE SECRET TO ENERGY SUCCESS: NATURALLY CONCENTRATED, STORED, PLENTIFUL ENERGY

One lesson of the failure of renewables is that *renewable* is not a useful criterion for a good energy source. It says only that one of the inputs is derived from the sun; it says nothing about how long the other inputs will last, and, most important, it says nothing about whether the technology can generate energy that is cheap, plentiful, and reliable. There's no reason to aspire to use an energy technology that we will use forever. The real question is: For the relevant time horizon, what's the most efficient combination of elements that we can transform efficiently into the kind of energy we need in a way that is cheap, plentiful, and reliable?

And so far in history, there has been one necessary ingredient to that: instead of spending huge amounts of resources concentrating and storing a dilute and intermittent source, working with a source that nature has already concentrated and stored for us—such as water (hydropower), the forces holding an atom together (nuclear power), or the powerful chemical bonds of the copious amounts of ancient, dead plants lying around from previous eons (fossil fuels).

It is their preconcentrated, prestored, plentiful energy content that has made fossil fuels—and to a much less but still important extent hydroelectric power and nuclear power—cheap, plentiful, reliable energy sources.

HYDRO TECHNOLOGY: CHEAP, RELIABLE, MEDIUM-SCALE ENERGY

If you've ever been in a rapidly flowing river, you can *feel* the energy stored in the moving water. Hydroelectric energy technology transforms some of the power of that flowing water into usable, cheap, reliable electricity using a turbine—much like a wind turbine, except driven by a far more powerful and reliable force. Often a dam is used to store water near the source of a river and precisely control the downward flow.

Historically, hydropower has faced two types of limitations that have prevented it from producing much more than 6 percent of the world's power.[26] One category is natural limitations; the other is political limitations.

The main limitation of hydroelectric power is there aren't nearly enough suitable water sites for it to be a global source of energy. In China and Brazil, the top two consumers of hydropower, you can get a lot of electricity from it; in Nebraska, you can't.[27] The United States has maintained a fairly constant hydropower consumption because we've run out of rivers to dam (which is unfortunate, because hydropower lasts for decades; the Hoover Dam was built in the 1930s).

But there is considerably more opportunity to develop hydro around the world. Based on the number of dammable rivers left, the International Energy Agency estimates that hydroelectricity has the technical potential to grow by 92 percent in Africa and 80 percent in Asia.[28] Worldwide, according to an estimate by the International Energy Agency, hydro has the technical potential to produce twice as much energy as it does today; it is currently around 6 percent of global production.[29] That is an exciting prospect . . . but not for most prominent environmental groups, whom you might think would welcome a four times greater supply of cheap, reliable, non- CO_2-emitting hydroelectric energy.

Environmental activists have spent decades shutting down as many hydroelectric dams as possible, particularly large hydroelectric dams, despite hydro's proven track record as a cheap, reliable source of CO_2-free power, in the name of protecting species of fish, free-flowing rivers, and other justifications that focus on nonhuman nature.[30] The Sierra Club on its list of accomplishments on its Web site lists dams it has prevented or shut down.[31]

If the standard is improving human life, those who believe that catastrophic climate change is coming unless we reduce CO_2 emissions should favor damming every possible river to generate reliable CO_2-free power. And for those who don't believe CO_2's climate impact is a major problem, there's still a huge burden of proof on anyone to justify depriving people of a cheap, plentiful, reliable source of energy.

NUCLEAR TECHNOLOGY: RELIABLE, SCALABLE . . . CHEAP?

With hydroelectric, we saw that a *naturally concentrated, stored source* of energy was a big benefit. This is the reason why the potential of nuclear power has enchanted many in the energy world, this author included.

If natural concentration is a benefit, there is no more naturally concentrated energy source than the uranium or other radioactive metals used to generate nuclear power. Oil is an amazingly concentrated source of energy, which is why it is the transportation fuel of choice. Well, the concentration of energy in uranium is more than a *million* times that of oil and 2 million times that of coal—although given current technology, in practice it "only" delivers *thousands* of times more energy per unit of input.[32]

Nuclear's presence in generating energy around the world is slowly growing. There are two factors, which can be hard to separate, that hold back nuclear's progress: the difficulty of doing it cheaply and the perceived difficulty of doing it safely.

While many feel that the focus in the nuclear process should be on safety, I think the evidence shows that the real controversy should be on *price.*

Recall that to produce cheap, plentiful, and reliable energy, every element of the energy production process has to be cheap, plentiful, and reliable. Nuclear power uses uranium, which exists in enormous quantities around the world, and can also use thorium, an even more abundant material. Even using current technology, we are talking about time horizons upwards of thousands of years. The trickier part of the process is transforming that material into energy, which is much more complex than, say, burning natural gas to generate electricity. It involves producing energy by releasing the immense forces within a radioactive atom. Absent proper safety technology, human exposure to large amounts of radioactivity can lead to radiation poisoning or, in the longer term, cancers. At the same time, below a certain threshold, radioactivity is not harmful; we ourselves are radioactive and emit radioactivity. Unfortunately, radioactivity is commonly viewed as deadly *as such,* so critics of nuclear power can cite amounts of radiation coming from, for example, the Fukushima accident, and it sounds scary—even though the amount is not enough for anyone to die now (of radiation poisoning) or in the future (from cancer).

The issue of nuclear safety is full of so much rhetoric and emotion that it can be hard to sort through. But as a starting point, let's ask: How do we know how safe it is? I think the most reliable indication of a technology's safety is how many deaths it has caused per unit of energy produced. In the free world, nuclear power in its entire commercial history has not led to a single death—including from much-publicized failures at Three Mile Island and Fukushima.[33]

Unfortunately, activists use inaccurate characterizations to make it extremely time consuming and expensive to build new plants. Nuclear power is radioactive, they say—not mentioning that so is the sun and that taking a walk, let alone an airplane ride, exposes you to far more radioactivity than does living next to a nuclear power plant.[34] A nuclear plant could be bombed by terrorists and bring about some sort of Hiroshima 2, they say—not mentioning that the type of uranium used in a nuclear plant literally can't explode.

All of these fears are plausible because we have been taught to think of changing our environment in new ways as inherently dangerous. Nuclear power, in addition to requiring large industrial structures, deals in "unnatural" high-energy, radioactive materials and processes. Thus there is an *expectation* that it is uniquely dangerous, even though it is uniquely safe.

The opposition has led nuclear power to be considered far more dangerous than other sources, unjustifiably. And it means that the nuclear industry has become an essentially government-controlled industry—which, like many a government-controlled industry, has higher prices than others. Thus we don't really know what nuclear would cost without the pseudoscientific opposition. What we do know is that, besides fossil fuel energy, it is by far the most *scalable* form of energy in the world.

In the best-case scenario, though, nuclear is still decades away from scaling to becoming a leading global source of electricity, let alone somehow providing transportation solutions at the level oil can. Thus there is no prospect of nuclear "replacing" fossil fuels anytime soon.

3

THE GREATEST ENERGY TECHNOLOGY OF ALL TIME

FOSSIL FUEL POWER: CHEAP, PLENTIFUL, RELIABLE, SCALABLE—INDISPENSABLE

This is the challenge: finding a source of energy that is cheap, plentiful, reliable, and scalable. As we've seen, it's a challenge that is incredibly difficult to overcome. Power from sunlight has the problems of diluteness and intermittency and so requires too many resources to concentrate and store in order to create an independent, scalable power source. And plants are a form of storing solar energy, but they don't scale well because of the resources needed to grow them and the amount of land available to grow them on.

Well, there is good news. There is a form of solar energy, a biofuel that has none of these problems because nature has already concentrated and stored the sunlight of plants that lived hundreds of millions of years ago. Those dead plants are called fossil fuels.

Fossil fuels are so called because they are (in most theories) high-energy concentrations of ancient dead plants. Our entire civilization is based on burning these dead plants, which are made up of hydrogen and carbon atoms connected by powerful chemical bonds. When you burn gasoline in your car or coal in a power plant or gas to heat your home, those bonds break apart, releasing enormous amounts of energy. They exist in solid (coal), liquid (oil), and gas (natural gas) form.

If you've ever used charcoal instead of wood to grill food, you grasp the basic advantage of using ancient dead plant fuel. The charcoal can generate more heat in less space because it has been "cooked"—primarily, the water has been taken out of it, producing a higher concentration of energy ("burning" water doesn't release much energy).[1] Well, fossil fuels are naturally, thoroughly "cooked" plant energy. Over millions of years, as plants pile up and are covered by more and more layers of soil, the natural forces of the Earth heat them up and concentrate them into far purer forms of energy than wood or charcoal. Thus they have the advantage of being naturally concentrated and stored.

The other advantage they have is that they exist in astonishingly, astonishingly large quantities. For example, the world has an estimated 3,050 years (at current usage rates) of "total remaining recoverable reserves" of coal.[2]

But there is a big challenge to using fossil fuels for energy. These quantities of coal, oil, and gas aren't lying around to be plucked. They are *hidden and trapped* underground—sometimes thousands and thousands of feet underground, often in forms, such as being trapped in stone, that are difficult to get out even if you know where they are.

Fortunately for us, the fossil fuel industry is very, very good at using *technology* to extract these hidden, trapped, and otherwise useless materials, which no one knew about or cared about through most of human history, and turning them into the energy of life.