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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.

The technical term for fossil fuels is *hydrocarbons,* because they are primarily made of carbon and hydrogen atoms. Also, there is some debate over whether all of them come from plants (fossils); some say that many or most of them come from deep in the Earth, far below where any plants could end up. In either case, there are astonishing quantities of hydrocarbons. With ever-evolving technology, they give us an unparalleled source of concentrated, stored, and scalable energy.

Fossil fuels come in three major forms—coal, oil, and natural gas—with different strengths and weaknesses.

COAL

Coal is the world's leading fuel for electricity—producing 41 percent of the world's electricity in 2011—and is expected to become the leading source of energy overall.[3] In the developing world, it has been the overwhelming choice for every country that has industrialized recently.

Since the 1980s, the world has experienced record increases in coal consumption: in Brazil, by 144 percent; in India, by 425 percent; in China, by 514 percent.[4] It is no coincidence that countries with increased coal consumption also experience better lives overall—as electricity consumption increases, infant mortality rate decreases rapidly and access to improved drinking water sources increases.[5]

The reason coal is particularly well suited for cheap electricity around the world is that it is plentiful, widely distributed, and relatively easy to extract. Coal is also relatively easy to transport. It exists in a convenient form, and unlike most mine products, which require you to separate large amounts of material from the small amount of material you want, coal requires relatively little processing.

But because of its plant origins and underground locations, some of coal's carbon and hydrogen are bonded to potentially significant quantities of sulfur and nitrogen. When burned, these become sulfur dioxide and various nitrogen oxides, which above certain concentrations can be harmful, requiring various filtration and dilution technologies (more on this in chapter 6). Coal has the highest percentage of carbon atoms of all the fossil fuels, so when burned, it emits the most carbon dioxide, whose impact we will examine in chapter 4.

Coal has been used for transportation fuel and was the dominant form of energy for locomotives and steamships when the steam engine was still the main source of motive power.[6] Eventually the steam engine was supplanted by the much more versatile internal combustion engine, which has nearly eliminated coal's use as a transportation fuel in favor of oil. Because the fossil fuels' value comes from their being hydrocarbons—combinations of hydrogen and carbon—each of them can be made to have many of the properties of the others, but that transformation requires energy and resources, like any transformation, and is not often worth it. But in the future, it might be worth it—which means that claims that we'll "run out of oil" are misguided, as coal and gas can effectively produce oil if needed.

For example, coal can be transformed into liquid fuel; the South African energy company SASOL says it can be done for less than eighty dollars per barrel.[7] Coal can also be transformed into methanol—methyl alcohol, an alcohol that like ethanol can come from plants but can also come from coal and gas. Methanol, like any fuel, has its own risks and by-products, and it has only half the energy per gallon as gasoline, but it is still a potential substitute for oil fuel as markets evolve.

Coal use is growing quickly and could grow even more quickly. The United States could be a major contributor; we have been called the Saudi Arabia of coal and have the potential to become a huge coal exporter, feeding cheap energy to machines around the world.

The bottom line: If people are free to use it and the industry is free to produce it, coal energy will provide billions with cheap, plentiful, reliable energy for decades to come.

NATURAL GAS

Natural gas is the world leader at an essential type of electricity—called *peak load* electricity.

Just as your energy use varies during the course of a day, so the electric grid as a whole uses different amounts of electricity at various times during the day. There is a minimum amount of electricity use that will almost always be needed, called base-load power. Above that, we need a technology that can quickly adjust to changes in electricity needs—such as powering a lot of air conditioners on a hot summer day so that we can be comfortable and avoid heatstroke. This is called peak load electricity, and it is natural gas's specialty. (Coal, nuclear, and hydro specialize in base-load power.) Natural gas electricity, which uses the same basic technology as a jet engine, is very good at scaling up and down.

Natural gas is also an extremely clean-burning fuel, composed almost exclusively of pure carbon and hydrogen, which makes it ideal to burn for affordable home heating. In addition, it serves as an affordable, abundant raw material for thousands of "petroleum products"—which we will discuss in the next section.

The disadvantage of natural gas is in its name—it's naturally a gas. Gases are harder to move long distances than liquids or solids due to their large volume. So while oil and coal can be moved relatively easily around the world, gas has long been a local market. This causes supply security issues in which one country is dependent on an unreliable country for gas supplies—the case with many European countries that depend on gas from Russia.

However, new technological developments are overcoming these obstacles.

One is shale energy technology, often referred to as fracking in the media and fracing in the industry. Fracking is short for hydraulic fracturing, one of several technologies that can be used to get natural gas out of shale. This technology has attracted attention based on claims that it contaminates groundwater. As we'll discuss more in chapter 7, the controversy here, as with nuclear, is more ideological than technical.

The shale energy revolution has led to a rapid increase in natural gas and oil production in the last decade and has the potential to do much more.[8] The combination of horizontal drilling and fracking has turned previously known but economically unreachable reserves of natural gas into easily accessible and cheap natural gas. In the United States, proven reserves of natural gas have increased 46 percent since 2005.[9]

There are opportunities all around the world to produce shale energy, and the United States is a pioneer. There are estimated to be far more natural gas supplies in what are called methane hydrates, natural gas deposits in frozen form, which exist at the bottom of the ocean.[10] Thus the potential supply of natural gas could extend many centuries, at least.

At the same time, advances in compressing and liquefying natural gas are making it more prominent as a fuel and make it easier to transport around the world. This is the source of opportunities and controversies for LNG (liquefied natural gas) terminals.

Gas can also be turned into fuel oil and methanol, and it powers vehicles in compressed or liquefied form. Still, when it comes to transportation, nothing can yet compete with what is far and away the world's leading transportation fuel: oil.

OIL

Oil is the most coveted (and controversial) fuel in the world because it is almost eerily engineered by natural processes, not just for cheapness, not just for reliability, not just for scalability, but also for another characteristic crucial to a functional civilization: *portability.*

Oil is an ultraconcentrated form of energy—liquid energy—so it's ideal for any moving vehicle. Every portable power source needs to carry its fuel with it, which means that size and weight are of paramount consideration. Oil, in effect, has the ultimate strength to weight ratio. A gallon of gasoline has 31,000 calories—the amount of energy you use in *fifteen days*. Oil can be refined into stable, potent liquid fuels—gasoline, diesel, and jet fuel.

Oil's dominance as *the* transportation fuel has gone hand in hand with the development of mobile engines: the gasoline engines in most cars, the diesel engines powering semitrucks and global shipping, and the jet engines powering aircraft all eat oil fuel.

Oil is used for the vast, vast majority of transportation—93 percent in the United States.[11] Other technologies struggle to mimic it.

Oil's value leads to continuous large investments in exploration and extraction technology. Whereas oil deposits were once completely invisible to industry, today modern imaging, called 3D seismic imaging, can get us a far clearer idea of what's going on below the surface and how it changes over time. We can get oil out of hard rock (shale oil). In oil sands, we've created technology that acts as a ground decongestant—releasing oil from the sands that have held it in place for decades.

Portability is valuable for many reasons. Personally, oil is the fuel of freedom—the fuel that liberated Americans to go where they want, when they want. Economically, oil is the fuel of trade. Our entire standard of living depends on *specialization*—on people doing what they do best, wherever they are, and then being able to cheaply move their products to those who most need them. The higher the price of portable power, the slower the world economy moves.

In the future, it is quite possible that battery-powered vehicles will replace oil-powered vehicles for certain purposes. The limits are based on the energy concentration or energy density of the batteries; for example, the Tesla Roadster battery has an energy density that is 107 times *less* than gasoline—though the battery's electric motor can convert more than twice as much of that energy into usable energy as the engine in a gasoline-powered car, so in practice the Tesla battery might be 35 times less dense.[12]

For various technical reasons, progress in battery technology is extremely slow—electric cars have been around longer than gasoline-powered cars—and it may well be that another, nonbattery storage solution will win out. For now, though, oil is the greatest portable fuel the world has ever known, and we are willing to pay a premium for it; per unit of energy, we sometimes pay five times as much for oil as for natural gas.

Oil is also coveted as the world's most versatile raw material for making synthetic materials. You are probably sitting in a room with at least fifty things derived from oil, from the insulation in your wall to the carpet under your feet to the laminate on your table to the screen on your computer. Oil is everywhere—that is how the average American uses 2.5 gallons each day.[13]

Like coal and gas, there is enormous future potential for oil production—if the industry can keep developing better technologies. The shale energy revolution is bringing supplies some never expected, and the Earth still contains many times more oil than we have used in the entire history of civilization.

FUTURE ENERGY RESOURCES

Here's a trick question I like to ask when I do public speaking: "Is oil a valuable natural resource?" Almost everyone answers yes, even when I tell them it's a trick question.

My answer is no. Because oil—or coal, or natural gas, or uranium, or aluminum for that matter—is not naturally a resource.

If we understand this, we understand why we can be incredibly optimistic about the future potential of fossil fuels and future sources of energy.

A resource is something that's available and usable for human benefit. I'll focus on oil here because that is the resource that people most fear will disappear.

Before the 1850s, oil was not a resource—it was naturally useless. It was a distinct *raw material,* to be sure, with the potential to become valuable, just as sand has the potential to become a microchip. But oil had very little use; in fact, in many cases, it was a nuisance. Drillers seeking underground saltwater deposits to distill into salt were annoyed by the presence of this "rock oil."[14] Additionally, oil was not a resource because it was hidden and trapped, invisible and inaccessible.

What turned oil from a potential resource to an actual resource was human ingenuity—the ingenuity of the chemist Benjamin Silliman Jr., who refined petroleum into kerosene, the ingenuity of George Bissell, who targeted Titusville, Pennsylvania, as a location likely to have underground oil, and the ingenuity of Edwin Drake, who created the first successful oil well in 1859 at 69.5 feet underground.[15]

It was only thanks to their ingenuity that useless goo became a resource.

The history of oil is a history of *resource creation*. For example, crude oil, through a process of boiling (distilling), could be refined into 50 or 60 percent kerosene, used for lighting. But then the rest of the crude oil wasn't a resource—it was often pure waste, dumped in a lake—until human ingenuity made it so. In the nineteenth century, John D. Rockefeller's Standard Oil progressively figured out how to create value out of every "fraction" of a barrel—a barrel containing numerous types of hydrocarbons of different shapes, sizes, and masses. They created wax out of one part of the barrel, lubricants (over three hundred varieties) out of another, and asphalt out of another.

In the twentieth century, modern chemistry made oil not only the most important fuel, but also the most important raw material in civilization. Chemists can "crack"—break down—the molecules in a barrel of oil into small parts, and then reassemble them into an unbelievable variety of polymers, including modern plastics. While you think of oil in your car as in the gas tank, in fact there is more oil in the materials in the car than in the gas tank. The rubber tires are made of oil, the paint and waterproofing are made of oil, the plastic, dent-resistant bumper is made of oil, the stuffing inside the seats is made of oil, and in most cars, the entire interior is one form of oil fabric or synthetic material or another—because oil is such a cheap and effective way to make things.

When a policeman has his life saved by a bulletproof vest, when a firefighter has his life saved by a fireproof jacket, that is oil—that is something that was once a useless raw material, now made into a resource.

What is true of oil is true of essentially every other resource: They need to be *created* by transforming potential into actual. Coal was not an electricity resource or a source of motive power until the coal-fired steam engine. Natural gas was actually a deadly force, something that exploded when you drilled for oil, until safe drilling and storage technologies could harness it. Aluminum, one of the most abundant elements in the Earth's crust, was completely useless a few hundred years ago.

Ultimately, an "energy resource" is just matter and energy transformed to meet human needs. Well, the planet we live on is 100 percent matter and energy—100 percent potential resource. To say we've only scratched the surface is to significantly understate how little of this planet's potential we've unlocked. We already know that we have enough of a combination of fossil fuels and nuclear power to last thousands and thousands of years. For us today, that's morally enough—it's time to focus on the 7 billion of us, here and now, who will live better with more energy and live worse or not at all with less.

What energy resources should we use now and in the future? We have a brilliant system for deciding this: the price system of supply and demand. All things being equal, if it takes fewer resources, including human time, to produce something, the price goes down; if it takes more resources, the price goes up.

Thus, prices reflect how *efficient* a use of existing resources it is to create a new resource for a given purpose. When the cost of computers comes down, that means that all the components and their composition can be created more cheaply than before. Similarly, the form of energy we use will be the one that, based on the best technology available (which is always evolving), can do the best job for the lowest price.

Every day, we make a choice. Is coal or oil or gas the best way of accomplishing a given goal—or is something else? For the last several hundred years, the answer to "What do we replace yesterday's fossil fuels with?" has been "New fossil fuels." As soon as that doesn't make sense (typically, when it becomes prohibitively expensive or when a better alternative is available), it won't happen.

Part of the process of resource evolution is that we will find new ways to get what is considered to be the same resource by more technically complicated means. This is often characterized negatively, with such expressions as "We've gotten all the easy oil, and now we're going after the dirtiest oil" or "We're scraping the bottom of the barrel."[16] (The expression "scraping the bottom of the barrel" comes from the phenomenon of the oil in a barrel existing in different fractions, from heavy to light. The heavy fractions sit at the bottom of the barrel, and the heaviest, like asphaltum, which goes into asphalt, can be hard to scrape out and impossible to use.)

The view is that when we use a finite, nonrenewable resource like fossil fuels, we will have to go to progressively more difficult places to get it—which is assumed to be a bad thing. But why? Every resource technology involves starting with easier problems and moving toward harder problems.

When I read "We're using dirtier and dirtier oil" or "We're having to scour further depths to get oil," I think, *What is the "appropriate'" length to go to get oil? Should we have stopped at 69.5 feet?* At every stage, one could be accused of "scraping the bottom of the barrel." But think forward two hundred years. The Earth is full of elements at the crust and below. Ditto for the bottom of the ocean. Someday we will likely have technology to mine the ocean floor more efficiently than we can mine at the surface today. What is wrong with going to that frontier? How is that any different than going to space?

Now, it makes no sense to go to such great lengths to get oil if it's not efficient, i.e., if there are better alternatives. But there will likely be some element that is most efficient to get from very far below the ground.

The most forward-looking policy toward energy use is to always use the most competitive form of energy. I like to call the most competitive ones *progressive energy,* because they are part of a process of continual improvement, of finding the best way to get energy from the Earth's effectively unlimited stockpile of potential energy resources.

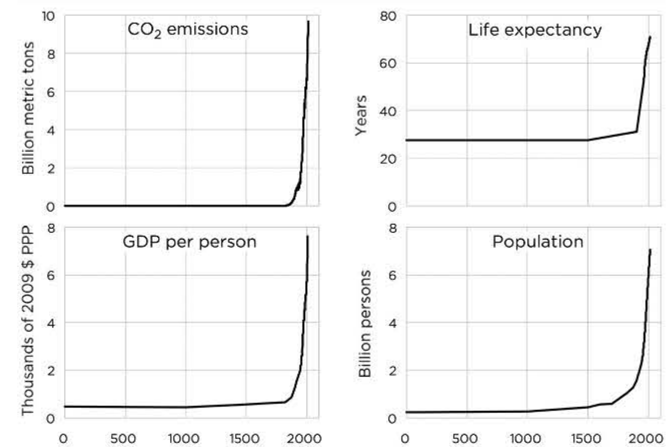
Our concern for the future should not be running out of energy resources; it should be running out of the *freedom* to create energy resources, including our number-one energy resource today, fossil fuels.

EVERY CALORIE MATTERS

Because we have never lived without fossil fuel energy, it's hard to imagine life without its benefits. But given that thought leaders are proposing exactly that, it's important to grasp just how big a difference fossil fuels have made in our lives.

To get a big-picture view of the difference energy and machines make in our lives, look at this graph of human progress from A.D. 1 to the present, featuring data from the Angus Maddison survey, the most comprehensive survey of quality of life over the last two millennia.

Figure 3.1: Fossil Fuel Use and Human Progress—the Big Picture



Sources: Boden, Marland, Andres (2010); Bolt and van Zanden (2013); World Bank, World Development Indicators (WDI) Online Data, April 2014

Notice that starting in the year 1800, the metrics of life expectancy and GDP rocket up. In school, we learn that this was the time of the Industrial Revolution—although at least in my case, the problems of it were emphasized much more than the doubling of human life expectancy and the far more than doubling of individual income. What exactly does the term *industrial revolution* mean? Well, it was a revolution in industry, which means in our ability to do physical work to be more productive, which in practice meant an *energy* revolution. Thanks to the world's first source of cheap, plentiful, reliable energy, coal-powered steam engine technology, every industry became more productive—agriculture, manufacturing, transportation.

The people who went through the industrial revolution had a perspective that is hard for us to recapture but is essential for us to get: an understanding of just how vital it is for us to have access to cheap, plentiful, reliable energy, because the more we have, the more ability we have, and the less we have, the more we see just how weak we are without high-energy machines. I stress "cheap, plentiful, and reliable" because anything less than that isn't useful, just like the expensive, scarce, unreliable electricity at the Gambian hospital. Before the industrial revolution, there were machines and there were sources of energy—there just wasn't cheap, plentiful, reliable energy for the vast majority of people.

Take this 1865 comment by William Stanley Jevons, a legendary theoretical and applied economist, in his book *The Coal Question.* Coal was then the cheapest and most reliable source of energy, not only for illumination, which is only one use of energy, but also for powering machines to do far more mechanical work than human beings can with our muscles.

> Coal in truth stands not beside but entirely above all other commodities. It is the material energy of the country—the universal aid—the factor in everything we do . . . new applications of coal are of an unlimited character. In the command of force, molecular and mechanical, we have the key to all the infinite varieties of change in place or kind of which nature is capable. No chemical or mechanical operation, perhaps, is quite impossible to us, and invention consists in discovering those which are useful and commercially practicable. . . .[17]

Jevons was worried that we were running out of coal (a concern we'll discuss later in this chapter). Notice how emotional he is about it:

> With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times.[18]

A letter in response to Jevons is even more vivid about what the loss of coal energy would have meant:

> Coal is everything to us. Without coal, our factories will become idle, our foundries and workshops be still as the grave; the locomotive will rust in the shed, and the rail be buried in the weeds. Our streets will be dark, our houses uninhabitable. Our rivers will forget the paddlewheel, and we shall again be separated by days from France, by months from the United States. The post will lengthen its periods and protract its dates. A thousand special arts and manufacturers, one by one, then in a crowd, will fly the empty soil, as boon companions are said to disappear when the cask is dry.[19]

And here's how it ends: "We shall miss our grand dependence, as a man misses his companion, his fortune, or a limb, every hour and at every turn reminded of the irreparable loss."[20]

One thing to note: This was at a time in history when, because of early-stage technology, coal pollution in England was far, far worse than, say, even China experiences today—and yet these commentators don't even mention it; that's how valuable they saw energy as being to their very ability to survive. Nothing was more important. As we'll see looking at modern fossil fuel technology, we have progressed incredibly in pollution-reduction technology, but it's worth remembering that to the people who experience the need for energy most directly, it's worth pretty much any price, in the same way that you'll put up with a lot of side effects to take a lifesaving drug. And lifesaving drugs, like everything else we value, depend on access to cheap, plentiful, reliable energy—to produce, to transport, to package, to refrigerate.

When we talk about different sources of energy, we are talking about different technologies that are better or worse at producing energy with the resources we have. If we choose the most capable technologies, we get more energy. If we choose less capable ones, we get less. It's that simple. When someone says, "Let's use solar," he is, usually unwittingly, saying, "Let's have less energy with which to improve our lives." There is no limit to the amount of energy we can use to improve our lives. And in a world where we produce only one fourth as much energy as would be necessary for everyone to live like Americans, every machine calorie counts.

One realm in which energy is particularly life or death is in agriculture. The fossil fuel industry has revolutionized acriculture to the benefit of billions—and gotten no credit.

MORE FOSSIL FUELS, MORE FOOD: HOW THE OIL INDUSTRY SOLVED WORLD HUNGER

Paul Ehrlich declared in the 1968 sensation *The Population Bomb* that "the battle to feed humanity is over"—and he was in good company.[21] In 1969, the *New York Times* reported: "While there have always been famines and warnings of famine, food experts generally agree that the situation now is substantially different. The problem is becoming so acute that every nation, institution, and every human being will ultimately be affected."[22] A group of leading American intellectuals wrote an open letter declaring: "The world as we know it will likely be ruined before the year 2000. . . . World food production cannot keep pace with the galloping growth of population."[23]

In 1968, the world's population was 3.6 billion people.[24] Since then, it has doubled, yet the average person is *better fed* than he was in 1968.[25] This seeming miracle was due to a combination of the fossil fuel industry and genetic science—such as the achievements of the great Norman Borlaug, who bred new revolutionary wheat varieties and introduced new farming techniques to Mexico, India, Pakistan, China, and parts of South America.

Modern agriculture, like every modern industry, runs on machines, and fossil fuel energy is our leading source of machine food. Therefore, fossil fuel energy is the food of food.

For example, oil-powered *mechanization* causes a dramatic increase in the amount of farmland that can be cultivated per worker.

For most of human history, agricultural work was done by the muscle power of humans or draft animals, placing a low ceiling on the amount of farmland that could be harvested—and requiring often 90 percent of populations to be devoted to farm labor. The oil industry changed that by making available cheap, concentrated energy that could power tractors, combines, and other forms of high-powered farm equipment. Matt Ridley, author of the valuable survey of human progress, *The Rational Optimist,* describes the value of mechanization on his own farm: "A modern combine harvester, driven by a single man, can reap enough wheat in a single day to make half a million loaves."[26] A single man, made into an agricultural Superman by the power of oil.

Another example: Oil-based *transportation* causes a dramatic increase in the amount of farm products that can be brought to market.

For the vast majority of human history, the world was full of patches of useless potential farmland—useless because the land was too far to ship from. When men and goods travel by horse or mule, let alone on foot, the shipping costs quickly exceed the value of the cargo. But the twentieth century's gradual increase in oil-powered transportation—railroads (modern railroads are powered by diesel engines), freighters, and trucks, especially—brought an enormous amount of remote farmland, once too expensive to ship from, within the reach of anyone in the city, state, country, and eventually the world. The cheaper transportation became, the more farmland came into the global agricultural economy, and the more plentiful and affordable food became.

By the same token, the cheaper transportation became, the more new seeds and other supplies could be brought to new locations to make previously low-performing land yield a giant amount of crops. Much of the green revolution led by Norman Borlaug involved bringing in new, more resilient forms of wheat and rice to places like India; this was expedited and amplified by cheap, global, oil-powered transportation.

Another example: Gas-based *fertilization* increases the amount of crops that can be grown per unit of farmland.

The amount of crops we can grow today is an utterly "unnatural" phenomenon—that is, it is way beyond the natural capacity of the nutrients in land to nourish crops in one season, let alone season after season. One solution to the problem of fertilizing was manure or some other organic fertilizer, which increased the amount of nitrogen plants could absorb and thus the amount of them that could grow. The use of such fertilizer allowed population growth and living standards to rise throughout the nineteenth century. But there was a problem; as population grew, it was harder to find enough manure to collect. The supplies of guano off the coasts of South America and South Africa were being exhausted, which caused eminent chemist William Crookes to declare in 1898 that "all civilisations stand in deadly peril of not having enough to eat."[27]

The solution was Fritz Haber and Carl Bosch's process of making large quantities of synthetic nitrogen fertilizer using enormous amounts of methane—the predominant component of natural gas.[28]

Another example: Electricity-based (usually coal-based) or diesel-based *irrigation* increases the amount and reliability of water going to crops. Irrigated lands average more than *three times* the crop yields of rain-fed areas. Sometimes irrigation occurs via gravity, but when it doesn't, it takes a lot of energy—usually fossil fuel energy—to move the water.[29]

Finally, the achievements of Norman Borlaug and other great food scientists, often called the green revolution (not related to the modern Green movement), were possible only because of the *time* created by fossil-fueled civilization to engage in intensive research, because high-powered machines have made it unnecessary for all of us to do physical labor.

Fossil fuel energy is the food of food.

It is an undeniable truth that, in providing the fuel that makes modern, industrialized, globalized, fertilized agriculture possible, the oil industry has sustained and improved billions and billions of lives. If we rate achievements by their contribution to human well-being, surely this must rank as one of the great achievements of our time, and when we consider the problems with that industry, shouldn't we take into account that it fed and feeds the world? And yet have you ever—and I mean ever—heard any major public or private figure give the oil industry credit for it? I see Bono and other celebrity activists get credit for caring but not the oil and energy industries for *doing*.

MORE FOSSIL FUELS, MORE ABILITY

Without the energy industry, the agricultural industry would not exist; the world could not support a population of 7 billion or 3.6 billion and perhaps not even 1 billion. To starve our machines of energy would be to starve ourselves.

What is true of agriculture is true of every industry. The energy industry has a special place in human productivity, prosperity, and progress. As the industry that powers every other industry, it can be considered *the master industry*. Whether we are talking about the computer industry, the electronics industry, the health-care industry, or the pharmaceutical industry, every industry uses machines, uses resources that are manufactured using energy, and uses *time* that is available because of our high-energy society's productivity. The less energy we have, the fewer machines an industry can use, the fewer resources an industry has, and the less time it has. And what happens to industry happens to the rest of life. The less productive industry is, the less time, resources, and machinery we have to enjoy our lives.

And I want to stress *enjoy our lives,* because this is not something we typically think about when we think of energy—but we should, because more energy means more ability to enjoy our lives.

If our standard of value is human life, the ultimate benefit that a commodity like fossil fuel energy can deliver is to contribute to the pursuit of happiness. If we can only survive in a way that is miserable, why survive? Happiness is the reward of life. And energy is a great enabler of happiness—including forms of happiness that we are taught to associate with people who decry large amounts of energy use.

Take traveling to places that excite us. In my life, I have been fortunate enough to travel to many such places. I've spent fifteen days river-rafting in the Grand Canyon, several hundred days snowboarding or skiing on faraway mountains, and gone to Italy, France, Israel, Turkey, and other faraway lands. I'm not setting any travel records here, but no doubt I've used a lot of cheap energy to enjoy what the world has to offer. On a more local level, I love living in Southern California and being able to get to a lot of places easily by car (assuming I time the traffic properly). I enjoy martial arts, specifically Brazilian Jiu-Jitsu, as a hobby, and for years I would happily drive an hour after work almost every day to get to my favorite Jiu-Jitsu school. I was using a lot of cheap energy, and if it hadn't been cheap, I wouldn't have been able to afford it.

More fossil fuel energy, more ability to pursue happiness.

I keep stressing that more energy means more ability to take the actions necessary to flourish, because I want it to be in our minds at all times that when we talk about more or less energy, we are talking about more or less ability, and everything we want in life depends on ability. Thus in every realm that affects our lives, we should expect to discover that more energy can play an amazingly positive role.

That includes our *environment*, including our climate.

FOSSIL FUEL ENERGY AND OUR ENVIRONMENT

The relationship between energy and environment is usually considered in a negative way; how can we use the energy that will least "impact the environment"? But we have to be careful; if we're on a human standard of value, we *need* to have an impact on our environment. Transforming our environment is how we survive. Every animal survives in a way that affects its environment; we just do it on a greater scale with far greater ability. We have to be clear: Is human life our standard of value or is "lack of impact" our standard of value?

If we're on a human standard, we should be concerned in a negative way only about impacts of energy use that harm our environment *from a human perspective*—such as dumping toxic waste in a nearby river or filling a city with smog.

But we should also assume that energy gives us more ability to *improve* our environment, to make it healthier and safer for human beings. I'll explore this in detail in chapters 4–7, but for now I'll just observe that the natural environment is not naturally a healthy, safe place; that's why human beings historically had a life expectancy of thirty. Absent human action, our natural environment threatens us with organisms eager to kill us and natural forces, including natural climate dangers, that can easily overwhelm us.

It is only thanks to cheap, plentiful, reliable energy that we live in an environment where the water we drink and the food we eat will not make us sick and where we can cope with the often hostile climate of Mother Nature. Energy is what we need to build sturdy homes, to purify water, to produce huge amounts of fresh food, to generate heat and air-conditioning, to irrigate deserts, to dry malaria-infested swamps, to build hospitals, and to manufacture pharmaceuticals, among many other things. And those of us who enjoy exploring the rest of nature should never forget that energy is what enables us to explore to our heart's content, which preindustrial people didn't have the time, wealth, energy, or technology to do.

We'll revisit this topic later; for now, I just want to stress that whenever we have more energy, we have more ability *everywhere*—including the places we can do damage. So when we look at the damage or the risks of damage, we have to take into account the positive as well. Once again, we're always looking for the big picture about what benefits human life.

THE BIG PICTURE

We have seen that the non–fossil fuel attempts at cheap, plentiful, reliable energy for billions of people fall short—because none of them involve a process wherein *every element* can be scaled cheaply and reliably.

But fossil fuel technology puts everything together: It can get a plentiful fuel source cheaply and convert it to energy cheaply—on a scale that can power life for billions of people. This is why when people choose to use energy to improve their lives, 87 percent of the time they choose fossil fuel energy.[30] The technology is that far ahead of the competition. If we want cheap, plentiful, reliable energy around the globe, we absolutely need to use fossil fuel technology. If we want to flourish, we need fossil fuel technology.

And yet opponents of fossil fuel energy claim there are catastrophic consequences to using fossil fuels that will *prevent* us from flourishing. That will be our subject for the next several chapters.

But before we get there, let's be clear: *If* fossil fuels have catastrophic consequences and it makes sense to use a lot less of them, that would be an epic tragedy, given the state of the alternatives right now. Being forced to rely on solar, wind, and biofuels would be a horror beyond anything we can imagine, as a civilization that runs on cheap, plentiful, reliable energy would see its machines dead, its productivity destroyed, its resources disappearing.

Thus it is disturbing to hear politicians talk about restricting fossil fuels as an "exciting opportunity." John Kerry, our secretary of state, whose job is to represent the mainstream views of America to the rest of the world, described the prospect of outlawing the vast majority of fossil fuels, even if there were no catastrophic climate change, this way:

> If the worst-case scenario about climate change, all the worst predictions, if they never materialize, what will be the harm that is done from having made the decision to respond to it? We would actually leave our air cleaner. We would leave our water cleaner. We would actually make our food supply more secure. Our populations would be healthier because of fewer particulates of pollution in the air—less cost to health care. Those are the things that would happen if we happen to be wrong and we responded.[31]

Actually, the type of "response" governments around the world have embraced—an 80 percent reduction in CO_2 emissions over several decades—would, by all the evidence we have, lead to billions of premature deaths.

Fossil fuel energy is, for the foreseeable future, necessary to life. The more of it we produce, the more people will have the ability to improve their lives. The less of it we produce, the more preventable suffering and death will exist. To not use fossil fuels, therefore, is beyond a risk—it is certain mortal peril for mankind.

That brings us to the issue of the major risks cited with fossil-fuel use: climate change and environmental degradation. As we begin to think about risks, we need to keep this in mind: The reason we care about risk is because it is a danger to human life. Thus if something is essential to human life, like fossil fuels, we need to assess all risks in that context.

We need a rigorous, big-picture examination of fossil fuels' impact on climate and other environmental issues. We must clearly hold human life as our standard of value, or if we don't, we must make clear that we are willing to sacrifice human life for something we think is more important. With that standard, we must look at the big picture, the full context. And we must use experts as advisers, not authorities, getting precise explanations from them about what is known and what is not known, so that we as individuals can make the most informed decision.

4

THE GREENHOUSE EFFECT AND THE FERTILIZER EFFECT

CLIMATE CONFUSION

Growing up in Chevy Chase, Maryland, a suburb inside the Beltway of the D.C. metro area, I learned only one thing about fossil fuels in school for the first eighteen years of my life: They were bad because they were causing global warming. It wasn't very clear in my mind what warming was or how it worked, but the gist was this: The CO_2 my parents' SUV was spewing in the air was making the Earth a lot hotter, and that would make a lot of things worse. Oh, and there was one more thing I learned: that everyone who knew the relevant science agreed with this.

Perhaps this would make a better story if I told you that I promptly joined Greenpeace and fought fossil fuels until discovering a massive hoax that I will reveal later in this chapter.

But that's not quite how it went. As a young free-marketer, my sixteen-year-old self did not like all the talk of political restrictions that went along with global warming. So I wasn't going anywhere near Greenpeace. But at the same time, the idea that this was a matter of established science was extremely significant to me. I come from a family of scientists (two of my grandparents were physicists, two were chemists) and I was being told about global warming not by scientifically illiterate teachers who repeated what they read in the paper (well, not only by those), but by my math and science teachers at the internationally renowned Math, Science, and Computer Science Magnet Program at Montgomery Blair High School.

My strongest memory from my senior year statistics class is of the time when my teacher, a very bright woman, stopped talking about statistics one day and started talking about the perils of global warming. That she brought it up in statistics class and that she was so adamant about it gave all of us the impression that this was an issue the scientifically minded should get involved with.

It was the same story at Duke. In freshman chemistry, local legend teacher James Bonk explained that the greenhouse effect was simple physics and chemistry and denounced the Republicans who denied it.

At that time, as I went searching for alternative views, I became familiar with the existence of professionals in climate science, such as Richard Lindzen of MIT and Patrick Michaels of the University of Virginia, who argued that global warming wasn't the big deal it was made out to be.[1]

What was I supposed to make of all this? Should I go by the more popular position? My science teachers had taught me that this, historically, was a recipe for failure, and that we should believe things only if someone can give compelling evidence for them.

But there was so much going on in discussions of global warming, I didn't know how to decide where the evidence lay. I would hear different sides say different things about sea levels, polar bears, wildfires, droughts, hurricanes, temperature increases, what was and wasn't caused by global warming, and on and on.

With such a mess to work with, I—like most, I think—tended to side with the scientists or commentators whose conclusions were more congenial to me. I will admit to reiterating the arguments of skeptics of catastrophic global warming with the lack of rigor I think is extremely common among believers. But I didn't do this for long. I acknowledged that I didn't really know what to think, and the idea that we might be making the Earth fundamentally uninhabitable scared me.

CLIMATE CLARITY

My greatest moments of clarity came whenever I discovered an author or speaker who, instead of giving his particular answer to the question of global warming, would *try to clarify the questions*. For example: "What exactly does it mean to believe in 'global warming'?" Some warming or a lot? Little deal or big deal? A little man-made or a lot man-made? Accelerating or decelerating?

Having a background in philosophy, I recognized that most discussion of global warming would not stand up to fifteen seconds of scrutiny by Socrates, who alienated fellow Athenians by asking them to define what they meant when they used terms vaguely. I think Socrates would have been all over anyone who spoke vaguely of global warming or climate change without making clear which *version* of that theory they meant: mild warming or catastrophic warming.

A huge source of confusion in our public discussion is the separation of people (including scientists) into "climate change believers" and "climate change deniers"—the latter a not-so-subtle comparison to Holocaust deniers. "Deniers" are ridiculed for denying the existence of the greenhouse effect, an effect by which certain molecules, including CO_2, take infrared light waves that the Earth reflects back toward space and then reflect them back toward the Earth, creating a warming effect. But this is a straw man. Every "climate change denier" I know of recognizes the existence of the greenhouse effect, and many if not most think man has had some noticeable impact on climate. What they deny is that there is evidence of a *catastrophic* impact from CO_2's warming effect. That is, they are expressing a different opinion about how fossil fuels affect climate—particularly about the nature and magnitude of their impact.

Once I was clear on how unclear the questions we were asking were, I could ask better questions and get better answers. And once I got clearer on how to use experts as advisers, not authorities, and how to always keep in mind the big picture, I had a much better chance of getting the right answers to the right questions.

Here's how I put the right questions now, from a human standard of value.

The first is: How does fossil fuel use affect *climate livability*? When we burn fossil fuels, what are all the climate-related risks *and all the benefits* that result?

Given that our standard is human life—we want the climate we live in to be as livable as possible—there are two types of impacts we need to study and weigh. The first is the impact of CO_2 on climate itself. CO_2 affects climate in at least two ways: as a greenhouse gas with a warming impact, but also as plant food with a fertilizing impact (plants are a major part of the climate system as well as a benefit of a livable climate). I'll refer to these as the greenhouse effect and the fertilizer effect. The second impact of CO_2, which is rarely mentioned, is the tendency of cheap, plentiful, reliable energy from fossil fuels to amplify our *ability to adapt to climate*—to maximize the benefits we get from good weather and ample rainfall and minimize the risks from heat waves, cold snaps, and droughts. I'll refer to this as the energy effect.

Discussion of climate change often assumes that any man-made climate change is large if not catastrophic and that our ability to adapt is not all that important. This is unacceptable. It is prejudicial to assume that anything is big or small, positive or negative, before we see the evidence. We have to actually investigate the facts. It might be that the greenhouse effect leads to a tiny, beneficial amount of warming or that having or not having fossil fuels to build sturdy infrastructure is the difference between two hundred and two hundred thousand people dying in a hurricane.

Granted, acquiring evidence is often hard because of so many conflicting reports, which is why it's so important to get experts to explain what they know *and what they don't know* clearly and precisely.

The bottom line: For the three major climate impacts of fossil fuels—the greenhouse, fertilizer, and energy effects—we want to know how they work and how they affect us, all the while asking, "How do we know?"

CLIMATE LIVABILITY 101

To understand how each climate-related effect of fossil fuels works, we need to be clear on what exactly we're talking about when we talk about climate and climate livability. And a good place to begin is with the atmosphere.

The atmosphere is the mixture of gases around the Earth (held by its gravitational field) that makes life possible with oxygen (that humans breathe), carbon dioxide (that plants breathe), nitrogen (that plants eat), et cetera. It is a fascinating, fluid system that causes the heat of the sun and the water of the oceans and the plant life on the Earth's surface to lead to all kinds of local weather conditions around the globe.

Weather refers to present, near-term atmospheric conditions, especially temperatures and precipitation. At any given time on Earth, there exists a huge range of colder and warmer climates with different weather patterns that have different benefits and risks for human life. *Climate* is the longer-term (usually measured in thirty-year increments) weather trends in a given region: how hot and cold it gets, how much precipitation there is, what kind of storms pop up, et cetera. The global climate system is the sum of atmospheric conditions around the globe over time.

Talk about "the climate" tends to misrepresent how climate works. It makes climate seem like something uniform and unchanging rather than one part of a diverse, ever-changing system.

Climate change is a change in the general weather patterns on a local level. Global climate change, often equated with climate change per se or man-made climate change, is change in the overall climate system and its diverse subclimates. There are many factors that affect local and global climate, including changes in the sun's intensity, and changes in plant life that alter the concentration of different elements of the atmosphere and thereby change, for example, the amount of water vapor in the air. Locally, human activity can have major impacts. In Phoenix, for example, temperatures in the center of the city are up to 10 degrees Fahrenheit higher than in the rural areas.[2]

How can climate and climate change affect us? One crucial truth is that climate is naturally volatile and dangerous. Absent a modern, developed civilization, any climate will frequently overwhelm human beings with climate-related risks—extreme heat, extreme cold, storms, floods—or underwhelm human beings with climate-related benefits (insufficient rainfall, insufficient warmth). Primitive peoples prayed so fervently to climate gods because they were almost totally at the mercy of the naturally volatile, dangerous climate system.

In any era, it's easy to think that volatile, dangerous weather is unique to our era and must prove some dramatic climate change, whether natural or man-made. Every year, the news is full of headlines about dramatic, often tragic climate-related events—headlines like these:

- "20,000 Killed by Earthquake: Toll Is Growing, Bodies Float Down Ganges to the Sea"[3]
- "100 Are Injured, Property Damage Exceeds $1,000,000: Tornado Strikes Three States, Bitter Cold in North Area"[4]
- "Death's Toll Mounts to 60 in U.S. Storms"[5]
- "1,500 Japanese Die in Hakodate Fire; 200,000 Homeless: Largest City North of Tokyo Is in Ruins and Mayor Says It Is 'a Living Hell'"[6]
- "Where Tidal Wave Ruined Norway Fishing Towns"[7]
- "Antarctic Heat Wave: Explorers Puzzled but Pleased"[8]
- "7 Lives Lost as Tropical Storm Whips Louisiana: Hurricane Moves Far Inland Before Blowing Out Its Wrath in Squalls"[9]
- "Widely Separated Regions of the Globe Feel Heavy Quake"[10]
- "Earth Growing Warmer: What Swiss Glaciers Reveal"[11]
- "Death, Suffering over Wide Area in China Drouth [Drought]"[12]
- "Toll of Flood at High Figure: Over 100 Bodies Recovered and 500 Persons Missing in

Southern Poland"[13]

- "Cuban Malaria Increases: Thousands Become Ill in Usual Seasonal Spread of Disease"[14]
- "Mid-West Hopes for Relief from Heat; 602 Killed"[15]
- "Famine Faces 5,000,000 in Drouth [Drought] Area"[16]
- "Rumanians Are Alarmed by Epidemic of Cholera"[17]

While these headlines read like they're straight out of today's news, they are actually from 1934—before significant CO_2 emissions began. Climate is always volatile, climate is always dangerous.

Or take the issue of sea levels. We are taught to think of sea level rises as an evil inflicted on nature by human CO_2 emissions. We will explore today's sea level trends, and the role of fossil fuels in them, later in this chapter, but it is almost universally conceded that any sea level rise today is tiny compared with the enormous, rapid sea level rises that have occurred over the last ten thousand years.

Thus, climate change, extreme weather, volatility, and danger are all *inherent in climate whether or not we affect it with CO2 emissions.*

Thus, when we think about how fossil fuel use impacts climate livability, we are not asking: Are we taking a stable, safe climate and making it dangerous? But: Are we making our volatile, dangerous climate safer or more dangerous?

We'll start with the potential source of risk: the greenhouse effect.

THE GREENHOUSE FEAR

The greenhouse effect is the centerpiece of the prediction of catastrophic climate change. There are basically three parts to the prediction. (1) Man-made greenhouse gases emitted by fossil fuel combustion will cause dramatic warming of the global climate system. (2) Dramatic global warming will cause a dramatic, harmful change in the global climate system. (3) Those changes will overwhelm human beings' capacity for adaptation, rendering the planet far less livable.

Those are the steps that lead numerous scientists, environmental leaders, and political leaders to make statements like that of James Hansen, probably the world's most politically prominent climate scientist: "CEOs of fossil energy companies know what they are doing [by emitting CO_2] and are aware of long-term consequences of continued business as usual. In my opinion, these CEOs should be tried for high crimes against humanity and nature."[18]

If any element of the greenhouse fear turns out to be false—if CO_2 emissions don't cause dramatic warming, if dramatic warming doesn't cause harmful climate change, or if human beings can adapt well, then CO_2 emissions are not catastrophic.

In investigating whether they are or not, we'll start with the foundation: the amount of warming caused by the greenhouse effect from adding more CO_2 to the atmosphere.

WHAT EXACTLY IS THE GREENHOUSE EFFECT?

The greenhouse effect is a warming effect that certain molecules, including water and carbon dioxide, have when they are in the atmosphere. When infrared radiation from the sun reflects off the planet and heads toward space, these molecules, called infrared absorbers, reflect some of it back, causing heat.[19] The impact of these gases in the atmosphere is analogized, in its warming impact, to the glass in a greenhouse that helps keep plants warm.

Thanks to the greenhouse effect, the surface of Earth is many degrees warmer than it would otherwise be. Many scientists say that without it, the planet would be some 33 degrees Celsius (59 degrees Fahrenheit) colder—an ultra–Ice Age.[20]

When fossil fuels—hydrocarbons—are burned, or *oxidized,* the hydrogen becomes H_2O and the carbon becomes CO_2.

It's worth noting that every part of this process has climate impacts. The H_2O introduces new water vapor into the climate system and the burning of fossil fuels adds heat to the system—but both of these impacts are too small to make a noticeable difference. Much more significant, the human activities powered by fossil fuels are perfectly capable of affecting local climates. In cities, the bricks, pavement, and buildings impede the flow of ventilating winds, raising temperatures, especially nighttime lows, making heat waves more frequent. This man-made local warming is often far greater than the global warming trend over the last 150 years, which is .8 degree Celsius (1.44 degrees Fahrenheit), a quantity that cannot be perceived without instruments).[21]

Now let's look at CO_2. It's a greenhouse gas that exists in trace quantities in the atmosphere—just under .03 percent (270 parts per million, or ppm) before the industrial revolution, a level that we have increased to .04 percent (396 ppm).[22]

How do we know about the greenhouse effect of CO_2? The best way: it can be studied in a laboratory. The temperature difference between a box with a glass ceiling and normal atmospheric gas concentrations and one with additional CO_2 is measured when sunlight shines into it.

As with any effect, a crucial question is: What is its magnitude—including, at what rate does additional CO_2 change the effect? Some phenomena are linear, which would mean that every molecule of CO_2 you add to the system will add a unit of heat the same size as the last one. In some phenomena, the effect is constantly increasing or accelerating; in this case, every molecule of CO_2 you add to the system would be more potent than the last (this is the sense that we get from most popular treatments of the greenhouse effect). Then there are diminishing or decelerating phenomena—every molecule of CO_2 you add to the system would be less potent than the last.

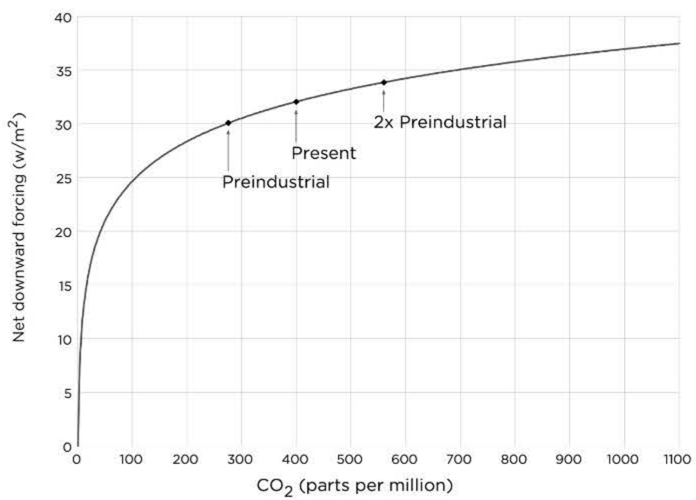
Anyone discussing this issue should know what kind of function the greenhouse effect follows. While I've met thousands of students who think the greenhouse effect of CO_2 is a mortal threat, I can't think of ten who could tell me what kind of effect it is. Even "experts" often don't know, particularly those of us who focus on the human-impact side of things. One internationally renowned scholar I spoke to recently was telling me about how disastrous the greenhouse effect was, and I asked her what kind of function it was. She didn't know. What I told her didn't give her pause, but I think it should have.

As the following illustration shows, the greenhouse effect of CO_2 is an *extreme diminishing effect*—a *logarithmically* decreasing effect.[23] This is how the function looks when measured in a laboratory.

Notice that we are just before 400 ppm (which means CO_2 is .04 percent of the atmosphere), where the effect really starts tapering off; the warming effect of each new molecule is not much.

This means that the initial parts per million of CO_2 do the vast majority of the warming of our atmosphere. The image below shows how, all things being equal, the heating effect of each additional increment of CO_2 is smaller and smaller.

Figure 4.1: The Decelerating, Logarithmic Greenhouse Effect



Source: Myhre et al. (1998)

So why do we have the idea that the greenhouse effect means rapid global warming? Because the proven greenhouse effect is *falsely equated* with the *related but speculative* theory that the greenhouse effect of CO_2 is dramatically *amplified* by other effects in the atmosphere, leading to rapid warming instead of the otherwise expected decelerating warming.

Some predictions of dramatic global warming (and ultimately catastrophic climate change) posit that the greenhouse effect of CO_2 in the atmosphere will greatly amplify water vapor creation in the atmosphere, which could cause much more warming than CO_2 acting alone would. This kind of reinforcing interaction is called a *positive feedback loop*.

What is the evidence for these predictions compared to the greenhouse effect?

To listen to most cultural discussion, predictions of dramatic global warming and associated catastrophic climate change are absolutely certain.

Secretary of State John Kerry said "absolutely certain" in a landmark speech discouraging the people of Indonesia from using fossil fuels, after they have experienced a major increase in prosperity due to increasing use of fossil fuels:

> The science of climate change is leaping out at us like a scene from a 3D movie. It's warning us; it's compelling us to act. And let there be no doubt in anybody's mind that the science is absolutely certain. It's something that we understand with absolute assurance of the veracity of that science. . . . Well, 97 percent of climate scientists have confirmed that climate change is happening and that human activity is responsible. These scientists agree on the causes of these changes and they agree on the potential effects . . . they agree that, if we continue to go down the same path that we are going down today, the world as we know it will change—and it will change dramatically for the worse.[24]

We'll get back to the 97 percent number in a minute, but if you press any climate scientist for an *explanation,* he will explain (or admit) to you that there is nothing resembling absolute certainty about these large positive feedback loops and the predictions associated with them. This is called the problem of determining *climate sensitivity;* how much warming, in practice, in the full complexity of the atmosphere, does *x* amount of CO_2 cause? How strong a *driver* of climate is CO_2?

Those who speculate that CO_2 is a major driver of climate have, to their credit, made predictions based on computer models that reflect their view of how the climate works. But fatally, those models have failed to make accurate predictions—not just a little, but completely.

While everyone acknowledges that the climate is too complex to predict perfectly, the idea behind catastrophic climate change is that CO_2 is an overwhelming *driver* of the global climate system and thus that its warming impact is predictable over time—in the same way that knowing the climate factors where I live, in Southern California, allows you to predict that it will be mostly dry, even though you can't predict exactly when it will rain.

Climate scientists who believe CO_2 is such a powerful driver feel confident in making *models*—simplifications—of the global climate system that predict its future based on CO_2 emissions.

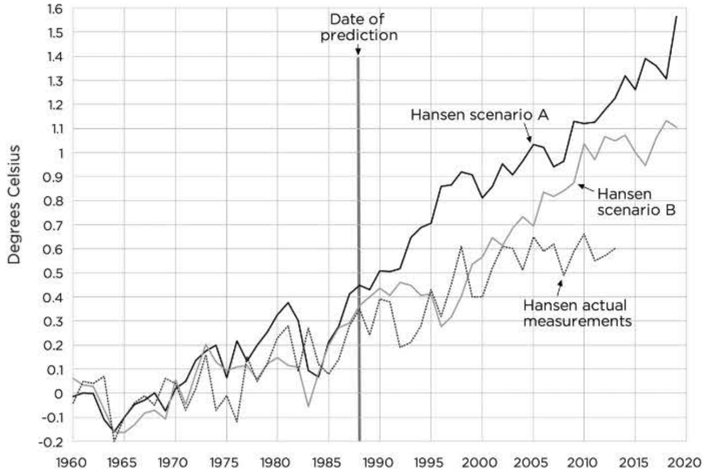
Just about every prediction or prescription you hear about the issue of climate change is based on models. If a politician talks about "the social cost of carbon," that's based on model predictions. If an economist talks about "pricing fossil fuels' negative externalities," that's based on model predictions. If we hear dire forecasts of drought going forward, that's based on model predictions. Which means if the models fall, they are invalid. Therefore we need to ask the experts advising us an obvious and essential question: How good are the models at predicting warming or the changes in climate that are supposed to follow from warming?

One pitfall in asking this question is that we have to make sure we have evidence of models *predicting climate in advance*. Why do I say "in advance"? Because part of climate models involve "hindcasting" or "postdicting"—that is, coming up with a computer program that "predicts," after the fact, what happened. There are reasons to do this—namely, it's important to see if your model could have accounted for the past. *But a model is not valid until it makes real, forward predictions.* It's a truism in any field of math that if you are allowed enough complexity, you can engage in "curve fitting" for any pattern of data with an elaborate equation or program that will "postdict" exactly what happened in the past—but in no way does that mean it will predict the future. (Many investors lose money doing this sort of thing.)

The best way to test a model is to see whether it can make accurate and meaningful predictions about the future. In the last thirty years, the climate science community has had the opportunity to do that. Many experts in modeling and in statistics thought this was an extremely dubious enterprise, given how complex the climate is—at least as complex as the economic system, where failed computer models helped promote policies that led to our recent Great Recession.

Consider perhaps the most famous model in the history of climate science, the 1988 model by James Hansen, who has a reputation in the media as the world's leading climate scientist. At twenty-four years old, the model has been given ample time to show its predictive accuracy. In the graph below, we can see how Hansen's prediction compares with the actual temperature measurements Hansen subsequently reported; he dramatically overpredicted warming.

Figure 4.2: The NASA/Hansen Climate Model Predictions vs. Reality

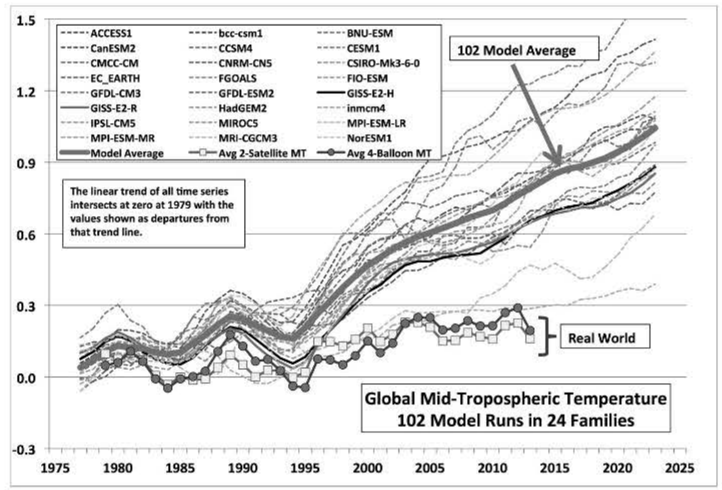


Sources: Hansen et al. (1988); RSS; Met Office Hadley Centre HadCRUT4 dataset; RSS Lower troposphere data

Note in particular that since the late 1990s, there has been no increase in average temperatures. Hansen and every other believer in catastrophic global warming expected that there would be, for the simple reason that we have used record, accelerating amounts of CO_2. But as the official government data show, these CO_2 increases have not driven major temperature increases; as CO_2 has increased dramatically, there have been relatively mild periods of warming, cooling, and now flattening. Thus, not just Hansen's model but every climate model based on CO_2 as a major climate driver has been a failure.

Here is a graph of 102 prominent, modern climate models put together by John Christy of the University of Alabama at Huntsville, who collects satellite measurements of temperature. Even though the modern models have the benefit of hindsight and "hindcasting," reality is so inconsistent with the theory that they can't come up with a plausible model. And note how radically different all the predictions are; this illustrates that the field of predicting climate is in its infancy.

Figure 4.3: Climate Prediction Models That Can't Predict Climate



Source: Christy, Climate Model Output from KNMI, Climate Explorer (2014)

Here's the summary of what has actually happened—a summary that nearly every climate scientist would have to agree with. Since the industrial revolution, we've increased CO_2 in the atmosphere from .03 percent to .04 percent, and temperatures have gone up less than a degree Celsius, a rate of increase that has occurred at many points in history.[25] Few deny that during the last fifteen-plus years, the time of record and accelerating emissions, there has been little to no warming—and the models failed to predict that.[26] By contrast, if one assumed that CO_2 in the atmosphere had no major positive feedbacks, and just warmed the atmosphere in accordance with the greenhouse effect, this mild warming is pretty much what one would get.

Thus every prediction of drastic future consequences is based on *speculative models* that have failed to predict the climate trend so far and that *speculate a radically different trend than what has actually happened in the last thirty to eighty years of emitting substantial amounts of* CO_2. And we have not even explored the complete failure to make accurate predictions about climate changes in specific regions, which is what really matters in assessing and adapting to any climate-related threats.

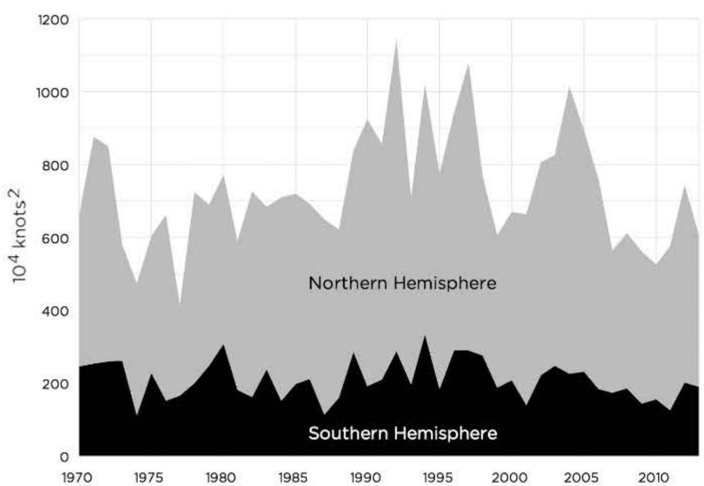
If a climate prediction model can't predict climate, it is not a valid model—and predictions made on the basis of such a model are not scientific. Those whose models fail but still believe their core hypothesis right still need to acknowledge their failure. If they believe that their hypothesis is right and that complete lack of dramatic warming is just the calm before the storm, they should state all the evidence pro and con.

Unfortunately, many of the scientists, scientific bodies, and especially public intellectuals and media members have not been honest with the public about the failure of their predictions. Like all too many who are attached to a theory that ends up contradicting reality, they have tried to pretend that reality is different from what it is, to the point of extreme and extremely dangerous dishonesty.

CLIMATE DISHONESTY: EXTREME MISREPRESENTATION ABOUT EXTREME WEATHER

As predictions of extreme global warming have completely failed to materialize, there has been more of an emphasis on extreme weather as a reason to oppose fossil fuels. But this is misleading. The prediction of catastrophic climate change is based on the idea that *warming* will cause extreme weather.

Figure 4.4: Storm Energy Is Normal



Source: Maue (2011, updated June 2014)

And the data bear this out. As might be expected, given that there has been little warming, there has been little change in the trends of various types of storms. For example, here are the most up-to-date data as of mid-2014 on "Accumulated Cyclone Energy," which is what would need to increase if the frequency and/or intensity of storms were to increase. As the data show, this is, like most things in climate, a dynamic variable—one that shows no dramatic changes recently. There is theoretical debate about how this would change if it had been warming dramatically—but it hasn't been warming dramatically.

Unfortunately, because people have been led to believe that CO_2 somehow causes climate change *in addition to,* not as a consequence of, global warming, it seems plausible to blame individual hurricanes on CO_2, even though the temperatures haven't increased. It is disingenuous for climate activists to blame every storm on climate change when there has been so little warming so far and when storm trends are so unremarkable. Remember, climate is always volatile, climate is always dangerous.

Or take the issue of sea levels, which we hear are rapidly rising. Al Gore's movie *An Inconvenient Truth* terrified many with claims of likely twenty-foot rises in sea levels.[27] Given the temperature trends, however, we wouldn't expect warming to have a dramatic effect on sea levels. And, in fact, it hasn't.

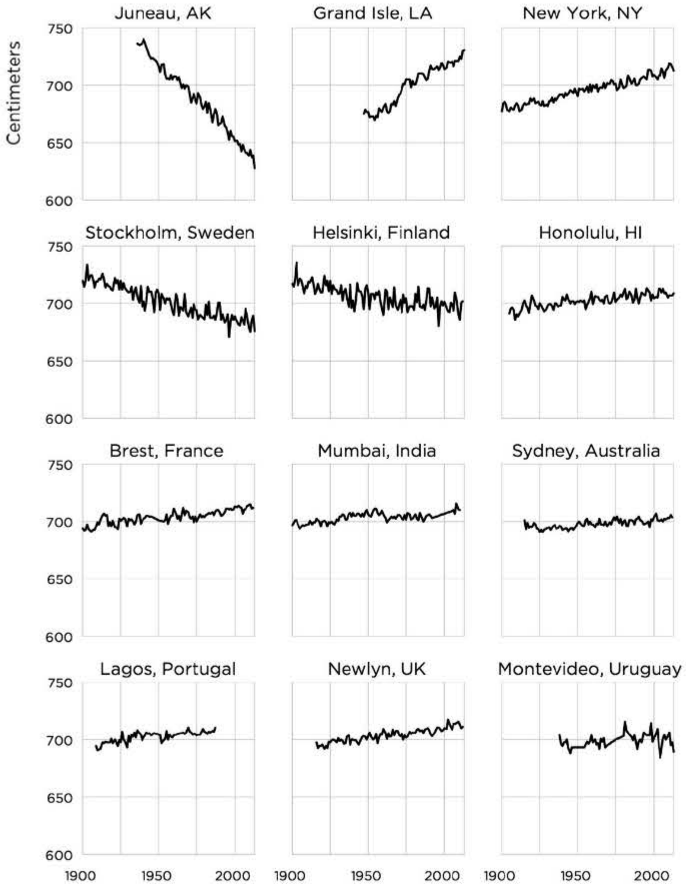
Figure 4.5 shows sea level trends from locations throughout the world. Note how smooth the trends are —and also notice how several of them are downward. This points to a truth about sea level and climate. It is affected by many factors, often factors that are much more important than any change in the global climate system.

But what about all those extreme scenarios of future sea level rise? They are not based on real trends or proven science; they are based on climate-prediction models that can't predict climate. And anyone who tries to equate science and speculation is being unethical. Which is, unfortunately, rampant.

CLIMATE DISHONESTY: EQUATING THE GREENHOUSE EFFECT WITH CATASTROPHIC CLIMATE CHANGE

The entire modern enterprise of catastrophic climate change predictions, the enterprise that threatens our energy supply, is based on equating a *demonstrated scientific truth,* the greenhouse effect, with extremely speculative projections made by invalidated models.

Figure 4.5: What Sea Level Rise Actually Looks Like



Source: Tide Gauge Data, Permanent Service for Mean Sea Level (2014)

In 1989, Bill McKibben pioneered this tactic in *The End of Nature,* wherein he called catastrophic climate change "the greenhouse effect." That would have been news to one of the discoverers of the greenhouse effect, Svante Arrhenius, who regarded increased CO_2 emissions as a very positive phenomenon. In 1896 he said: "By the influence of the increasing percentage of carbonic acid in the atmosphere, we may hope to enjoy ages with more equable and better climates, especially as regards the colder regions of the earth, ages when the earth will bring forth much more abundant crops than at present, for the benefit of rapidly propagating mankind."[28] (Remember this when we get to the fertilizer effect section below.)

Yet McKibben and others equate the greenhouse effect, dramatic global warming, and catastrophic global warming as it suits their political goals. By this kind of trickery, those who dispute catastrophic global warming are accused of denying the greenhouse effect and global warming. I experienced this in 2013 when I woke up to find myself named to *Rolling Stone*'s Top 10 list of "Global Warming's Denier Elite"[29]—in which they cited three articles of mine, each of which explained that CO_2 has a warming effect!

Here's what we know. There is a greenhouse effect. It's logarithmic. The temperature has increased very mildly and leveled off completely in recent years. The climate-prediction models are failures, especially models based on CO_2 as the major climate driver, reflecting a failed attempt to sufficiently comprehend and predict an enormously complex system.

But many professional organizations, scientists, and journalists have deliberately tried to manipulate us into equating the greenhouse effect with the predictions of invalid computer models based on their demonstrably faulty understanding of how CO_2 actually affects climate.

THE 97 PERCENT FABRICATION

This brings us to the oft-cited comment that 97 percent of climate scientists agree that there is global warming and that human beings are the main cause.[30]

First of all, this statement itself, even if it were true, is deliberately manipulative. The reason we care about recent global warming or climate change is not simply that human beings are allegedly the main cause. It's the allegation that man-made warming will be *extremely harmful to human life.* The 97 percent claim *says nothing whatsoever about magnitude or catastrophe*. If we're the main cause of the mild warming of the last century or so, that does not begin to resemble anything that would justify taking away our machine food.

But note how when I quoted John Kerry earlier, he went from "97 percent of climate scientists have confirmed that climate change is happening and that human activity is responsible" to "they agree that, if we continue to go down the same path that we are going down today, the world as we know it will change—and it will change dramatically for the worse."[31] Even in the 97 percent studies, which we'll look at in a moment, there is nothing resembling "97 percent of climate scientists have confirmed that . . . the world as we know it will change . . . dramatically for the worse." Kerry is pulling a bait and switch—using alleged agreement about a noncatastrophic prediction about climate to gain false authority for his catastrophic prediction about climate—and the anti–fossil fuel policies he wants to pass at home and abroad.

Unfortunately, this is very common. On his Twitter account, President Obama tweeted. "Ninety-seven percent of scientists agree: #climate change is real, man-made and dangerous."[32] There was no "dangerous" in the alleged agreement—and it wasn't "scientists," it was "climate scientists." This sloppy use of "science" as an authority, practiced by politicians of all parties, guarantees that we make bad, unscientific decisions.

On top of that, it turns out that the relatively mild "agreement" of the 97 percent is also a complete fabrication—which almost no one knows, because we're taught to obey authorities rather than have them advise us with clear explanations.

One of the main papers behind the 97 percent claim is authored by John Cook, who runs the popular Web site SkepticalScience.com, a virtual encyclopedia of arguments trying to defend predictions of catastrophic climate change from all challenges.

Here is Cook's summary of his paper: "Cook et al. (2013) found that over 97 percent [of papers he surveyed] endorsed the view that the Earth is warming up and human emissions of greenhouse gases are the main cause."[33]

This is a fairly clear statement—97 percent of the papers surveyed endorsed the view that man-made greenhouse gases were the main cause—*main* in common usage meaning more than 50 percent.

But even a quick scan of the paper reveals that this is not the case.

Cook is able to demonstrate only that a relative handful endorse "the view that the Earth is warming up and human emissions of greenhouse gases are the main cause." Cook calls this "explicit endorsement with quantification" (quantification meaning 50 percent or more). The problem is, only a small percentage of the papers fall into this category; Cook does not say what percentage, but when the study was publicly challenged by economist David Friedman, one observer calculated that only *1.6 percent* explicitly stated that man-made greenhouse gases caused at least 50 percent of global warming.[34]

Where did most of the 97 percent come from, then? Cook had created a category called "explicit endorsement without quantification"—that is, papers in which the author, by Cook's admission, did not say whether 1 percent or 50 percent or 100 percent of the warming was caused by man.[35] He had also created a category called "implicit endorsement," for papers that imply (but don't say) that there is some man-made global warming and don't quantify it.[36] In other words, he created two categories that he labeled as endorsing a view that they most certainly didn't.

The 97 percent claim is a deliberate misrepresentation designed to intimidate the public—and numerous scientists whose papers were classified by Cook protested:

- "Cook survey included 10 of my 122 eligible papers. 5/10 were rated incorrectly. 4/5 were rated as endorse rather than neutral."

—Dr. Richard Tol[37]

- "That is not an accurate representation of my paper . . ."

—Dr. Craig Idso[38]

- "Nope . . . it is not an accurate representation."

—Dr. Nir Shaviv[39]

- "Cook et al. (2013) is based on a strawman argument . . ."

—Dr. Nicola Scafetta[40]

Think about how many times you hear that 97 percent or some similar figure thrown around. It's based on crude manipulation propagated by people whose ideological agenda it serves. It is a license to intimidate.

CLIMATE ETHICS

The state of climate communication is a disgrace. Speaking from personal experience, it is incredibly difficult to get a straight answer about what is and isn't known in the field, because so much of it is catastrophic speculation by people who seem more focused on a political goal than on clear, honest, big-picture communication.

In 1996, Stanford climate scientist Stephen Schneider wrote an influential paper about the ethics of exaggerating the evidence for catastrophic climate change.

> On the one hand, as scientists we are ethically bound to the scientific method, in effect promising to tell the truth, the whole truth, and nothing but—which means that we must include all the doubts, the caveats, the ifs, ands, and buts. On the other hand, we are not just scientists but human beings as well. And like most people we'd like to see the world a better place, which in this context translates into our working to reduce the risk of potentially disastrous climate change. To do that we need to get some broad based support, to capture the public's imagination. That, of course, entails getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have. This "double ethical bind" we frequently find ourselves in cannot be solved by any formula. Each of us has to decide what the right balance is between being effective and being honest. I hope that means being both.[41]

I disagree entirely that this is a double ethical bind. It is doubly unethical. It requires deliberately misleading the public, which inevitably leads to uninformed, dangerous decision making.

We live in a society that has risen via the division of labor, by each of us specializing in, even mastering, some relatively small sliver of the ingredients of human survival and flourishing, so that in the aggregate we might create a world with an amazing sum of knowledge, technological achievement, and progress.

Specialization implies a sacred obligation. The specialist must never misrepresent what he knows and doesn't know, what he can do or can't do. The incompetent mechanic who claims that he can fix your complex engine problem, capitalizing on the fact that you know even less about engines than he does, is immoral.

In intellectual endeavors, in every field, there is an immense range of knowledge and opinion, from the decisively demonstrated to the wildly speculative. This is a good thing: Human knowledge builds on established knowledge, and each next step takes time to reach and establish. But specialists within the field have an obligation to explain precisely what they know and don't know—and also to welcome critical questioning and debate.

It can literally be deadly for a scientist to spread a hypothesis as fact. Take the realm of nutrition. For years, the government spread the gospel, treated as nutritionally proved, that a low-fat diet was healthy—

a campaign that coincided with record obesity. I'm not going to claim that I know the perfect diet. The point is that, at this stage, no one appears to—and when scientists with speculative theories feel licensed to disseminate them as fact, it is the most irresponsible scientists who will often garner the most praise.

One such scientist is Paul Ehrlich, who writes: "Scientists need to be direct and succinct when dealing with the electronic media. One could talk for hours about the uncertainties associated with global warming. But a statement like 'Pumping greenhouse gases into the atmosphere could lead to large-scale food shortages' is entirely accurate scientifically and will catch the public's attention."[42] Is such a statement "entirely accurate scientifically"? What about the fact that were it not for the industry that necessarily emits greenhouse gases and were it not for the fact that Ehrlich's proposals to dismantle it were not followed, millions or billions would have died of starvation?

Imagine if we actually had a very serious problem from CO_2 emissions. These leaders would be doing everyone a disservice by exaggerating the evidence and leading many disillusioned followers to conclude that there was none.

If there was a true threat, they would win credibility by giving an honest, big-picture explanation to the effect of: We thought we didn't have to worry about CO_2 emissions from fossil fuels, but now we think there's strong evidence they could lead to something very dramatic and bad. Here's the evidence, and here are our answers to the counterarguments. We understand that there are other considerations, such as the crucial importance of fossil fuel energy in modern life, and we don't know enough about the big picture to say what policy should be, but we do think there's a major risk and we want to have a public discussion about it.

The lack of this kind of honest explanation and the conspicuous lack of concern about proposals to drain our energy suggest that they are not using human life as their standard of value. As does the fact that they do not publicize a significant positive impact of CO_2 emissions: global greening.

THE FERTILIZER EFFECT AND GLOBAL GREENING

Climate scientist Craig Idso is an anomaly. The son of climate scientist Sherwood Idso, he followed in his father's footsteps and did research on the most scientifically established—yet least discussed—aspect of CO_2's climate impact—the fertilizing effect of giving more CO_2 to plants.

Here's the situation from a plant perspective. Fossil fuels are superconcentrated ancient dead plants. When we burn/oxidize them, we increase the amount of CO_2, plant food, in the atmosphere. Thus, on top of getting energy, we should get a lot more plant growth—including growth of the most important plants to us, such as food crops.

Idso and others, conducting thousands of experiments in controlled conditions—where everything is held constant except CO_2—have convincingly demonstrated that more CO_2 means more plant growth.[43]

Figure 4.6 documents what happens to the four plants, identical and all grown at the same time, except with different levels of CO_2.

Again, the results are dramatic. If we are "green" in the sense of liking plant life, rather than in the sense of not affecting anything, shouldn't we be excited?

Figure 4.6: More CO_2, More Plant Growth

Photograph courtesy of Craig Idso, Center for the Study of Carbon Dioxide and Global Change

Worldwide increases in plant growth are nontrivial—indeed, Idso and others attribute significant portions of modern agricultural yields to increased atmospheric CO_2.[44] And there is a lot of evidence for this; observe the increases in crop yield when the following crucial crops were exposed to 300 ppm more CO_2 than is in the atmosphere.

Figure 4.7: More CO_2, More Crop Growth

Trees	Mean % Increase	Number of Studies
Black Cottonwood	124.0%	5
Red Maple	44.2%	13
Northern Red Oak	53.3%	7
Loblolly Pine	61.9%	65
Average	70.8%	

Fruits	Mean % Increase	Number of Studies
Cantaloupe	4.7%	3
Sweet Cherries	59.8%	8
Strawberries	42.8%	4
Tomatoes	31.9%	35
Average	32.8%	

Vegetables	Mean % Increase	Number of Studies
Green Beans	64.3%	17
Soy Beans	47.6%	162
White Potatoes	29.5%	33
Sweet Potatoes	33.7%	6
Corn	21.3%	20
Carrots	77.8%	5
Average	45.7%	

Grains	Mean % Increase	Number of Studies
Barley	41.5%	15
Rice	34.3%	137
Wheat	33.0%	214
Average	36.3%	

Source: Idso, Plant Growth Database (2014)

All of this follows from basic chemistry and biology. Below 120 to 150 ppm CO_2, most plants die, which means human beings would die. All things being equal, in terms of plant growth, agriculture, et cetera, more CO_2 is better. Today's climate gives us far less CO_2 than we would like from a plant-growth perspective. We would prefer the thousands of ppm CO_2 that, say, the Cretaceous period had.[45]

What's most important about all this is not that it proves that there will be overwhelmingly positive climatological effects from *increasing* CO_2—though I think that's a possibility. The climate system is complex, and if no one among the specialists can predict it well, I certainly can't.

What's most striking is that these extremely positive plant effects of CO_2 are *scientifically uncontroversial* yet *practically never mentioned,* even by the climate-science community. This is a dereliction of duty. It is our responsibility to look at the big picture, all positives and negatives, without prejudice. If they think the plant positives are outweighed, they can give their reasons. But to ignore the fertilizer effect and to fail to include it when discussing the impacts of CO_2 is dishonest. It is meant to advance an agenda by not muddying it with "inconvenient" facts.

Occasionally the fertilizer effect will be mentioned as a trivial impact, not worthy of discussion, because the greenhouse effect will allegedly outweigh it so much with "too much" heat. This is dubious, given the observable increase in plant growth under conditions of increased CO_2 and given that the heat predictions are failures.

What's also striking is how, even though we all know that plants live on CO_2, almost no one in the culture thinks of potential positive impacts when he thinks about his "carbon footprint." This is prejudice—the belief that man-made impacts on our environment are necessarily bad, that the standard of value is nonimpact, and that there's no possibility of improving on Mother Nature.

Given that the climate naturally changes and human beings have generally thrived the warmer it has been, it is quite possible that a higher global temperature with higher CO_2 levels would be a great boon. It makes no sense to believe that the unchanged climate is the ideal.

My reading of the evidence is that there is a mild greenhouse effect in the direction human beings have always wanted—warmer—and a significant fertilizer effect in the direction human beings have always wanted—more plant life. I believe that the public discussion is prejudiced by an assumption that human impacts are bad, which causes us to fear and disapprove of the idea of affecting climate, even though climate is an inherently changing phenomenon that has no naturally perfect state.

But with both of these, particularly the greenhouse effect, I think it's important to be open to new evidence and new developments. And the only way to do that properly is for the community discussing this, including the scientific community, to drop its prejudice against man-made impacts, stop thinking about being "effective," and think only about being honest.

6

IMPROVING OUR ENVIRONMENT

ENVIRONMENTAL IMPROVEMENT

Try this thought experiment: Imagine that we transported someone from three hundred years ago, from essentially a fossil fuel–free environment, to today's world, which has fundamentally been shaped by coal, oil, and natural gas, and then took him on a tour of the modern world, good and bad, clean and dirty. What would he think about our environment overall?

I'll call our visitor Thomas, in honor of Thomas Newcomen, one of the pioneers of the steam engine, which was invented in 1712, almost exactly three hundred years ago.

Thomas's reaction would be disbelief that such a clean, healthy environment was possible.

"How is this possible?" he would ask. "The air is so clean. Where I come from, we're breathing in smoke all day from the fire we need to burn in our furnace."

"And the water. Everywhere I go, there's this water that tastes so good, and it's all safe to drink. On my farm, we get our water from a brook we share with animals, and my kids are always getting sick."

"And then the weather. I mean, the weather isn't that much different, but you're so much safer in it; you can move a knob and make it cool when it's hot and warm when it's cold."

"And you have to tell me, what happened to all the disease? Where I'm from, we have insects all over the place giving us disease—my neighbor's son died of malaria—and you don't seem to have any of that here. What's your secret?"

I'd tell him that the secret was his invention: a method of transforming a concentrated, stored, plentiful energy source into cheap, plentiful, reliable energy so we could *use machines to transform our hazardous natural environment into a far healthier human environment*.

Just as every region of the world, in its undeveloped state, is full of climate dangers (excessive cold, excessive heat, lack of rainfall, too much rainfall), so every region of the world is full of other environmental dangers to our health, such as disease-carrying insects, lack of waste-disposal technology, disease-carrying animals, disease-carrying crops, bacteria-filled water, earthquakes, and tsunamis. Nature doesn't even really give us clean air—because to live we have always needed some sort of fire, and for most of history, we had to breathe in smoke from outdoor fires or, once we got the benefit of true shelter, indoor fires, where the smoke was even worse, but the warmth was worth it.

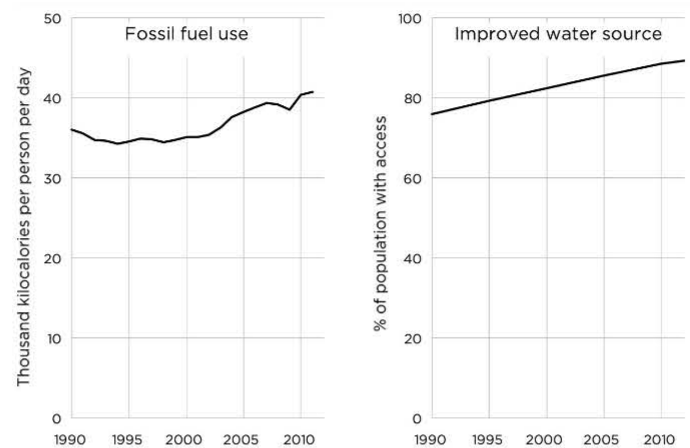
To conquer these environmental hazards we need to *develop* a far more sanitary and durable environment. Development is the transformation of a nonhuman environment into a human-friendly environment using high-energy machines. Development means water-purification systems, irrigation, synthetic fertilizers and pesticides, genetically improved crops, dams, seawalls, heating, air-conditioning, sturdy homes, drained swamps, central power stations, vaccination, pharmaceuticals, and so on.

Of course, as I address in the next chapter, development and the fossil fuel energy that powers it carries risks and creates by-products, such as coal smog, that we need to understand and minimize, but these need to be viewed in the context of fossil fuels' overall benefits, including their environmental benefits. And it turns out that those benefits far, far outweigh the negatives—and technology is getting ever better at minimizing and neutralizing those risks.

How much of a positive difference does fossil fuel energy make to environmental quality? Let's look at modern trends in four key areas of environmental quality: water, disease, sanitation, and air.

Here's water quality—measured by the percentage of world population with "access to improved water sources."

Figure 6.1: 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

Fossil fuel energy was essential to this improvement. It enabled us to transform once unusable water into usable water.

Most of Earth's surface is covered with water. The problem is that most of it is naturally in a chemical state unusable for our high standards and purposes. Most of the water is saltwater in the oceans. Most of the fresh water is trapped in massive ice sheets in places like Antarctica or Greenland. Some is part of a large water cycle of clouds and precipitation. Some portion is naturally "poisoned" brackish water of low quality in soil layers deep below the surface, containing too much salt and too many metals and other chemicals to be of any use without energy-intensive treatment. Nature does not deliberately or consistently produce "drinking water" able to meet a rigorous set of human health specifications.[1]

We need to transform naturally dangerous or unusable water into usable water—by moving usable water, purifying unusable water, or desalinating seawater. And that takes affordable energy.

If you were to turn on your faucet right now, in all likelihood you could fill a glass with water that you would have no fear of drinking. Consider how that water got to you: It traveled to your home through a complex network of plastic (oil) or copper pipes originating from a massive storage tank made of metal and plastic. Before it ever even got to the distribution tank, your water went through a massive, high-energy treatment plant where it was treated with complex synthetic chemicals to remove toxic substances like arsenic or lead or mercury. Before that, the water would have been disinfected using chlorine, ozone, or ultraviolet light to kill off any potentially harmful biological organisms. And to make all these steps work efficiently, the pH level of the water has to be adjusted, using chemicals like lime or sodium hydroxide.[2]

Natural water is rarely so usable. Most of the undeveloped world has to make do with natural water, and the results are horrifying. Billions of people have to get by using water that might contain high concentrations of heavy metals, dissolved hydrogen sulfide gas (which produces a rotten-egg smell), and countless numbers of waterborne pathogens that still claim millions of lives each year.[3] It's a major victory for any person who gains access to the kind of water we take for granted every day—a victory that fossil fuels deserve a major part of the credit for.

ERADICATING DISEASE

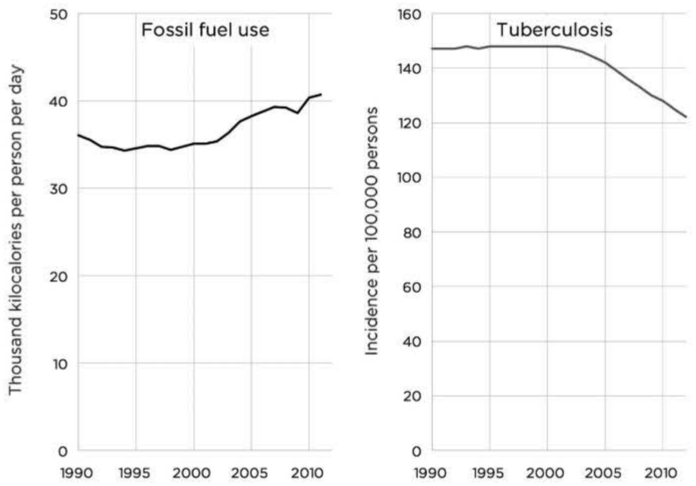
Potentially the worst, deadliest force in an environment is disease—the greatest predator of man. Some estimates have put the total number of human deaths caused by the bubonic plague, smallpox, and malaria alone at around one billion people.[4] While in the modern world we are taught to focus on any little particle emitted into the air by a power plant, we are not taught to appreciate the incomparably worse *diseases* those power plants have helped us get out of our air or made us safe from through mass production of pharmaceuticals and vaccinations.

Disease is on the decline—in large part because of the increased wealth that exists in the world and the increased *time* for scientific research—both products of cheap, plentiful, reliable energy. For example, Figure 6.2 illustrates the worldwide trend for tuberculosis, a major killer and one of the few diseases that is reported with any kind of consistency.

The tuberculosis trend just begins to indicate what is possible. Developed countries can use energy and technology to transform their environment to be totally rid of diseases that ravage underdeveloped countries today and that once ravaged all countries when they were underdeveloped.

While all infectious diseases can be traced back to some sort of pathogenic living organism, or germ, many of them require another animal to be transmitted: bugs. Mosquitoes transmit malaria and yellow fever, fleas transmit the bubonic plague, and lice transmit typhus. Once we understood this and had powerful machines to amplify our physical abilities *and our time to engage in scientific inquiry*, we declared war on the bugs that spread disease. We drained the wetlands where the bugs can lay their eggs, we introduced natural predators for the larval and adult forms of the bugs, we developed different chemicals that could kill the eggs, larvae, or adults, and we made it impossible for the bugs to encounter humans without encountering pesticide.

Figure 6.2: More Fossil Fuel Use, Less Tuberculosis



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

Notice how we discuss diseases like malaria as if they just happen to be in underdeveloped countries? Malaria existed in developed countries—they just developed their way out of it. Professor Paul Reiter, a malaria expert who has publicly criticized the IPCC for blaming malaria on global warming, gave a memorable explanation of the history of malaria in front of the House of Lords:

I wonder how many of your Lordships are aware of the historical significance of the Palace of Westminster? I refer to the history of malaria, not the evolution of government. Are you aware that the entire area now occupied by the Houses of Parliament was once a notoriously malarious swamp? And that until the beginning of the 20th century, "ague" (the original English word for malaria) was a cause of high morbidity and mortality in parts of the British Isles, particularly in tidal marshes such as those at Westminster? And that George Washington followed British Parliamentary precedent by also siting his government buildings in a malarious swamp! I mention this to dispel any misconception you may have that malaria is a "tropical" disease.[5]

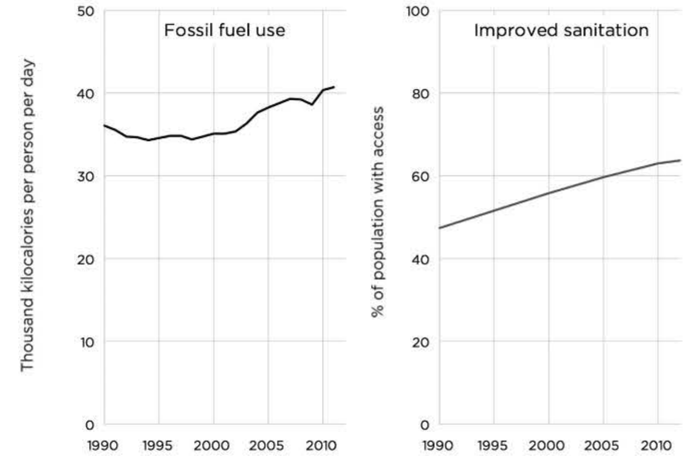
Want an increasingly disease-free population around the globe? We need more cheap, reliable energy from fossil fuels.

SANITIZING OUR ENVIRONMENT

Historically, the inability to effectively deal with our own bodily waste has been one of the largest threats to human health. To this day it takes an enormous toll on human life throughout the world. For example, cholera is a bacterial disease that is transmitted through the ingestion of food or water contaminated by human fecal matter. The toxin that these bacteria produce inhibits the body's ability to absorb food and water, which can very quickly cause death through dehydration. Worldwide, over a hundred thousand people get sick from cholera annually. (Think about that when you hear environmentalists talk about "harmony with nature"—i.e., harmony with all our predators, their waste, and our waste.) But cholera has been all but eradicated in the industrialized world.[6]

Here's the big picture of sanitation—the percent of our world population with access to improved sanitation facilities, according to the World Bank.

Figure 6.3: More Fossil Fuel Use, More Access to Sanitation



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

Note that as recently as 1990, under half the world had "improved sanitation facilities." The increase to two thirds in only a few decades is a wonderful accomplishment, but a lot more development is necessary to make sure everyone has a decent, sanitary environment.

Part of the way we have solved sanitation problems is through the industrialized world's ability to thoroughly sanitize any water human beings might consume using high-energy machines. Just as important, we have created entirely separate water systems to deal with sewage. Historically, a person's sewer tended to be connected, at least in part, to his drinking water. This was rarely intentional, and early civilizations did construct sewer systems to isolate human waste, but natural, unrestricted water flows usually lead to a certain amount of mixing between the human waste and the nearest freshwater source—particularly as more and more people group together.

Today, sewage is not only kept separate from clean water sources, but it is also extensively treated to render its most dangerous elements harmless so that it can be disposed of safely, in some cases used as a fertilizer or even, thanks to the latest technology, turned into drinking water.[7] The technology of sewage treatment is another advance made possible by industrialization, and it is yet another energy-intensive process for transforming our environment.

Want a more sanitary environment for people around the globe? We need more cheap, reliable energy from fossil fuels.

CLEANING THE AIR

Most of us have had the experience of sitting around a campfire when the wind changes direction and blows the smoke into our faces right as we take a breath. The resulting experience is unpleasant: a few sharp coughs, along with some stinging of the eyes and throat. For us, it's a temporary annoyance. For billions of people around the world, it is an everyday experience.

Imagine if the only way you could avoid the danger of cold—historically, cold is a far bigger killer than warmth—was to light a fire in your house every day of the year. You could do things to reduce the amount of smoke you breathed in by using a chimney and opening windows (though at the expense of letting cold in), but the fact remains that you would be breathing in an enormous amount of smoke every day. For many people today, that's the choice: breathing in smoky air or cold.

Today the idea of using a fire to routinely heat our dwellings is foreign to most of us. Modern homes are heated with advanced furnaces that heat air within a machine and then send the warm air to various locations in the house. The heating is usually done either via clean-burning natural gas, in which case the furnace has an exhaust system to remove any waste from the combustion, or with electrical heating elements powered by mostly faraway smokestacks (which themselves minimize air pollution by diluting and dispersing particulates higher in the air).

The combination of sophisticated machines and cheap, reliable energy has made the heating of homes such a trivial issue that most of us have never considered its connection to cleaning up the air we breathe every day. And yet natural-gas furnaces enable us to enjoy all the benefits of having a warm place to live with none of the downsides of smoky, toxic air that our ancestors would have endured for the same privilege.

All of these benefits apply, not just in heating our homes, but in cooking our food. Indoor pollution from primitive cooking methods is a major global problem, and using fossil fuels can help solve it.

We need to consider all these air-cleaning benefits when we consider the air pollution *risks* of fossil fuels. Which is our next task.

7

REDUCING RISKS AND SIDE EFFECTS

THE POLLUTION CHALLENGE

Let's recap where we are. We use cheap, plentiful, reliable energy from fossil fuels to transform our environment to meet our needs. This leads to a far longer, more opportunity-filled life—and, it turns out, far greater safety from, even mastery of, climate. And the same holds true for environmental quality in general. We don't take a safe environment and make it dangerous; we take a dangerous environment and make it far safer.

But at the same time, we *do* create risks and side effects that can be deadly, and we need to understand them in order to set policies that will maximize benefits while minimizing risks. Like all technologies, fossil fuels have risks and side effects. When we transform those ancient dead plants into energy, bad things can happen.

Every time we use energy from fossil fuels (and from any other form of energy) we are engaging in a process that is filled with risk and that, if not managed properly, can become deadly. The process of producing energy can involve all manner of hazardous materials. For example, hydrofluoric acid, a vital material in certain kinds of oil drilling (and many kinds of mining) can literally travel through your skin and melt your bones.[1] The process of producing energy, because it involves something that can generate enormous amounts of power, always carries the risk of the power going out of control: explosions, electrocutions, fires. And then the process of producing fossil fuels involves by-products that can be hazardous to our health.

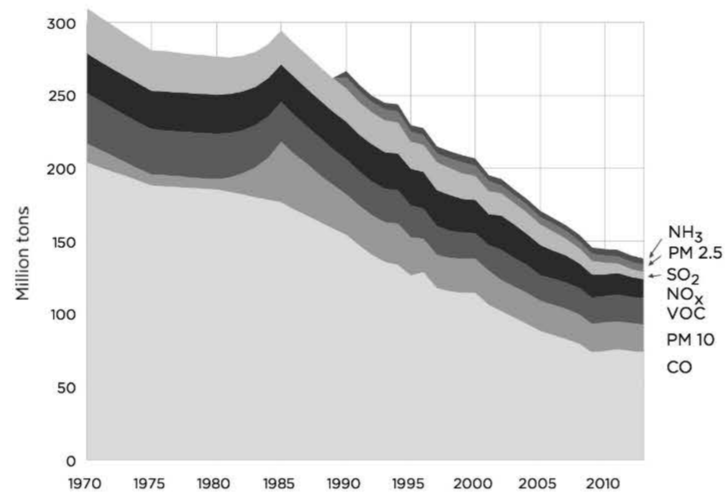
Take coal, the fossil fuel with the most potentially harmful by-products. Energy journalist Robert Bryce describes our "intense love-hate relationship" with "the black fuel."

> Coal heated people's homes and fueled the Industrial Revolution in England, but it also made parts of the country, particularly the smog-ruined cities, nearly uninhabitable. In 1812, in London, a combination of coal smoke and fog became so dense that according to one report, "for the greater part of the day it was impossible to read or write at a window without artificial light. Persons in the streets could scarcely be seen in the forenoon at two yards distance." Today, two hundred years later, some of the very same problems are plaguing China. In Datong, known as the "City of Coal," the air pollution on some winter days is so bad that "even during the daytime, people drive with their lights on."[2]

Stories of rampant smog in Chinese cities bring fears that the situation will inevitably get worse there and in any other country that industrializes. Fortunately, our experience in the United States illustrates that things can progressively get better.

Here again is a graph of the air pollution trends in the United States over the last half century. In the image are total emissions of what the EPA classifies as six major pollutants that can come from fossil fuels. Notice the dramatic downward trend in emissions—even though we were using more fossil fuel than ever.

Figure 7.1: Decline in U.S. Air Pollution



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

How was this achieved? Above all, by using antipollution *technology* to get as many of the positive effects of fossil fuels and as few of the negative effects as possible.

I like to think about risks and side effects this way. When we are using a technology, we are transforming our environment to meet our needs, to achieve a positive effect. But that transformation can accidentally or inevitably lead to an undesired effect—a power plant exploding or some type of molecule that, in high enough concentration, fouls up the air. The way to deal with it is to use technology to transform risks and by-products into smaller risks and smaller by-products.

To see how this works, let's take the fossil fuel that has historically and today been associated with the most environmental hazards: coal.

MANAGING BY-PRODUCTS AND RISKS—A UNIVERSAL CHALLENGE

Much of present-day energy discussion proceeds as if certain types of energy (fossil fuel, nuclear) are inherently dirty and dangerous and others (wind, solar) are clean and safe. But there is no limit to how much cleaner and safer fossil fuel use can be. For example, someday it might be possible to completely purify coal so that it generates no air pollutants and the materials that would have become air pollutants—nitrogen, sulfur, heavy metals—become valuable commodities. To a great extent, this is what we do with oil. What was once oil pollution dumped into a lake is now the basis for the plastic keyboard I am typing on.

At the same time, there is also no getting around the fact that *every* form of energy has risks—and every industry is responsible for managing them.

Consider the following story about the health and safety hazards of producing wind power. We think of wind as "clean" because there is no smoke coming out of the windmill. But in looking at any energy technology, we must remember that it's a process, starting with mining the materials necessary for the machines all the way to disposing of them. And wind turbines require far more toxic materials than fossil fuels do—materials called rare-earth elements. These elements are "rare," not in the sense that there are few of them, but in the sense that they exist in low concentrations in the Earth: it takes a lot of mining and a lot of separating of the desired metals from other elements using hazardous substances like hydrofluoric acid in order to get usable rare earth elements.

Here's what this process looks like in a major facility in China—where most rare earths for wind power are mined. This dispatch is from reporter Simon Parry, who visited to experience a rare earth mine firsthand. As you read his account, ask yourself: Does this mean that wind power is dirty and immoral?

> On the outskirts of one of China's most polluted cities, an old farmer stares despairingly out across an immense lake of bubbling toxic waste covered in black dust. He remembers it as fields of wheat and corn.
>
> ---
>
> Hidden out of sight behind smoke-shrouded factory complexes in the city of Baotou, and patrolled by platoons of security guards, lies a five-mile-wide "tailing" lake. It has killed farmland for miles around, made thousands of people ill and put one of China's key waterways in jeopardy.
>
> This vast, hissing cauldron of chemicals is the dumping ground for seven million tons a year of mined rare earth after it has been doused in acid and chemicals and processed through red-hot furnaces to extract its components.
>
> . . . When we finally break through the cordon and climb sand dunes to reach its brim, an apocalyptic sight greets us: a giant, secret toxic dump . . .
>
> The lake instantly assaults your senses. Stand on the black crust for just seconds and your eyes water and a powerful, acrid stench fills your lungs.
>
> For hours after our visit, my stomach lurched and my head throbbed. We were there for only one hour, but those who live in Mr. Yan's village of Dalahai, and other villages around, breathe in the same poison every day.
>
> ---
>
> People too began to suffer. Dalahai villagers say their teeth began to fall out, their hair turned white at unusually young ages, and they suffered from severe skin and respiratory diseases. Children were born with soft bones and cancer rates rocketed.[3]

Does this mean the energy source this process makes possible is dirty and immoral? When I speak at colleges and students tell me that fossil fuels are "dirty," I sometimes ask them that question without first telling them what kind of energy the story is talking about. Inevitably they say it should be banned. When I reveal it's wind power, they protest, "No, just because something has problems doesn't mean we ban it. Otherwise we would ban everything. We should look at the big picture and try to solve the problem."

Exactly, I say. And we need to take the same approach with fossil fuels.

USING TECHNOLOGY TO MINIMIZE, NEUTRALIZE, AND REVERSE POLLUTION

Coal as a fuel has many advantages: Modern coal technology can harness coal energy extremely cheaply, and it is available in enormous quantities in many regions of the world. One of its disadvantages lies in its natural properties. As a solid fuel of condensed biological origin, it includes a lot of materials that were part of the natural environment long ago and that are potentially harmful to human health, such as sulfur, nitrogen, and heavy metals.

Fortunately, thanks to technology, coal has been getting healthier and cleaner since the 1800s, and today places that are home to coal plants, such as North Dakota, also have some of the world's cleanest air.

In the 1800s, coal was a major provider of energy for private households in Western countries, heating the stoves that were at the center of every home to cook and to keep the deadly cold outside. But it had a major direct health impact: the constant coal smoke indoors, which is almost always worse than any outdoor air pollution (although the coal stoves also led to plenty of outdoor air pollution). Urban areas were particularly affected, as they were the centers of industrial activity and at the same time densely populated. Pollution was visible as the smoke dampened the sunlight in the cities, darkened the laundry hanging to dry, and even blackened the trees with soot. Still, the energy from coal was so valuable that these side effects were more than tolerated. In many cases they were embraced.

Take Manchester, England, a major industrial city full of coal waste. There was no movement against air pollution in Manchester—even though its pollution makes China's air today seem pristine.

Why not? Because, as one commentator put it, the smoke was an "inevitable and innocuous accompaniment of the meritorious act of manufacturing."[4] No coal meant poverty and starvation—something to consider when we tell poor countries to adopt impractical technologies instead of coal.

In Manchester, the smoking chimneys were considered "the barometer of economic success and social progress."[5] That is not to say that living in smoke is the goal. Manchester did not want and would not need to live in coal smoke forever, and neither will the poor countries now striving for energy, thanks to enormous advances in coal plant technology.

In 1882 Thomas Edison revolutionized the use of coal, both from the production side and from the pollution side, when he built the first commercial, *centralized* coal-fired electric power plant for New York residents, starting what is the primary use for coal today: the production of electricity.

The power plant, being centralized, away from most people's homes, provided in-home power *without burning the coal in the house.* People went from burning coal in their home to getting power, almost by magic, from electricity that didn't pollute at all. (One negative side effect of centralized power is that we are not taught to think about what's "behind the plug"; many don't realize that it's "dirty" fossil fuels that make it possible for them to have clean electricity.)

Power plants also became progressively better at getting more energy from less coal, meaning less pollution (and lower energy costs).

One of the biggest problems coal can cause, particularly when paired with unfavorable weather conditions, is smog. As late as 1952, London experienced a massive air-pollution problem from a temperature inversion—a phenomenon that prevents particles from dissipating throughout the atmosphere and keeps them in dangerous, concentrated form. The particularly tragic 1952 inversion increased sulfur dioxide and soot concentrations all over the city, with a death toll estimated between four thousand and twelve thousand in a matter of weeks.[6]

Thankfully, technology has evolved greatly since then. Modern coal technology has many different means of reducing pollutants. There are filters like ceramics or fabric filtration systems to prevent undesirable substances from getting into the air; there are ingenious processes that use certain chemical agents, such as limestone, to bind pollutants and prevent them from escaping; there are mechanical devices like wet or dry scrubbers to separate out unwanted constituents; and there are many others.

Over time, these technological advances, as they became economical, became mandated by law. There is a whole controversial literature about which laws (federal or state) get credit, how much was industry's profit-motivated pursuit of efficiency, and to what extent the laws *overregulated* pollution at the expense of access to energy. For our purposes the important thing is this: It's clearly possible to increase fossil fuel use while decreasing pollution. And what applies to the most challenging fossil fuel, coal, also applies to oil and natural gas. This is a lesson that China can learn—and as it adopts more sophisticated modern coal plants, is starting to learn.

MINIMIZING DANGER

So far, we have discussed the challenge we face from the negative by-products that come from producing and using fossil fuels. But there is another category of risk: the danger of the energy itself going out of control.

On Deepwater Horizon—the oil rig that exploded in 2010, killing eleven workers and causing the BP oil spill—the energy went out of control.[7] In creating massive amounts of power, there's always the risk that we'll lose control of the power. This can mean a nuclear meltdown, a massive fire at an LNG terminal, an explosion in a coal mine, a downed live power line, or even a flying windmill.

When energy goes out of control, you can both lose the energy (sometimes permanently) and often lose lives. Obviously we want to avoid this as much as possible. Fortunately, modern technology has made energy production much, much safer. For comparison, in the 1870s, according to Daniel Yergin's *The Prize,* some *five thousand* people died annually in kerosene explosions from the lamps in their homes.[8] Gasoline is *more* volatile than kerosene, yet we drive our cars without any fear of explosion.

One consequence of the improvements in safety is far lower fatality rates for workers. According to the Bureau of Labor Statistics, someone in oil and gas extraction is one third as likely to get into a fatal accident as someone in logging and one fourth as likely as someone in fishing and hunting. And this might surprise you: The fatality rate in coal mining is, thanks to a concerted effort to radically improve safety over time, even lower than that of oil and gas extraction. If trends continue, both industries will become safer still over time.[9]

In 2013, having read some of my writing, the vice president of a coal company in Kentucky invited me to go underground in one of the mines. I eagerly accepted. When I got there, I was struck by how proud the workers were of their safety practices and how worried they were that *I* would be afraid to be underground. I reassured them that I was well aware of the statistics and that "the most dangerous part of a trip to a coal mine is the drive there." Statistically, that's absolutely right.

Every mining accident is a tragedy, but it should not be exploited to misrepresent the truth that coal is becoming safer and safer.

THE ROLE OF GOVERNMENT

The history of pollution laws consists of competing approaches to a challenging problem: how to protect the individual's right to be protected against pollution while simultaneously recognizing his right to pursue a modern, industrial life along with the energy that life requires.

My view of the right approach is: Respect individual rights, including property rights. You have a right to your person and property, including the air and water around you. Past a certain point, it is illegal for anyone to affect you or your property. But—and here's where things get tricky—it's not obvious what that point is. Let's look at two extremes.

One policy would be: People can pollute or endanger other individuals at will so long as they are viewed as benefiting "the common good." This policy, encouraged by some businesses in the nineteenth century, is immoral. It says that some individuals should be sacrificed for the business and its customers.

Here's another bad policy: *Any* amount of impact on air, water, and land should be illegal. This is simply impossible by the nature of reality—for example, consider that perhaps our most dangerous emission, contagious disease, can often be transmitted through the air or other life forms in ways we cannot detect or prevent.

At any given stage of development, some amount of potentially harmful waste cannot be prevented. For example, the man who invented fire could not protect himself or his neighbors from smoke. Should he be prohibited from using fire? Obviously not, because the *right* to be protected from pollution exists in a *context,* which is the right to the pursuit of life more broadly. Fire was far more helpful to human health than it was harmful, and so it was the right, healthy choice to use it.

Energy is so valuable that throughout history people have been willing to tolerate what we would consider intolerable pollution because the energy impact was so positive. Fortunately, over time, technology makes it possible to create less and less harmful waste and to better deal with the waste still created. As we have more wealth, energy, and knowledge, we can have stricter pollution standards and even more minimization of harmful waste.

The role of government is to pass laws based on individual rights and standards set according to science and the current state of technological evolution. The job of industry is to continue that evolution.

If the government does its job, it achieves two great results: the *liberation and growth of energy production* and the *progressive reduction of pollution and danger.* Historically, that is the trend—and with better laws and technologies here and abroad, we can do much better.

Unfortunately, we are taught the opposite.

It is a common practice to attack fossil fuels by misrepresenting them as fundamentally or uniquely dangerous. This is what's behind the current attack on fracking—hydraulic fracturing, part of the shale energy revolution I discussed in chapter 3.

There are at least four common fallacies used to discourage big-picture thinking and breed opposition to fossil fuels: the abuse-use fallacy, the false-attribution fallacy, the no-threshold fallacy, and the "artificial" fallacy.

These are things to be on the lookout for when you follow the cultural debate; they are everywhere, and all four are used to attack what might be the most important technology of our generation.

THE ABUSE-USE FALLACY

The largest fossil fuel controversy today, besides the broader climate change issue, is fracking—shorthand for hydraulic fracturing—one of several key technologies for getting oil and gas out of dense shale rock, resources that exist in enormous quantities but had previously been inaccessible at low cost.

Fracking has gotten attention, not primarily because of the productivity revolution it has created, but because of concerns about groundwater contamination. The leading source of this view is celebrity filmmaker Josh Fox's *Gasland* (so-called) documentaries on HBO.[10] Looking at how these movies have affected public opinion is an instructive exercise.

Both *Gasland* movies follow a similar three-part formula. First, Fox tells a sad story about a family undergoing a problem, usually with their drinking water. "When we turn on the tap, the water reeks of hydrocarbons and chemicals," says John Fenton of Pavillion, Wyoming. Then Fox blames it on the oil and gas industry's use of fracking—without exploring any alternative explanations, such as the fact that methane and other substances often naturally seep into groundwater. This is the false-attribution fallacy, which I'll discuss in a minute.

Even if Fox's examples were true, it would be illegitimate of him to conclude what he concludes today and what "fracktivists" demand—that fracking, and really all oil and gas drilling, should be illegal, as if any technology that can be misused should be outlawed.

Any technology can be abused. As we have seen, people are dying right now because of bad practices in the wind turbine production chain. It is irrational to say that because a technology or practice can be abused, it ought not be used.

I call this the abuse-use fallacy. It is a blueprint for opposing any technology. For example, Fox could make *Carland,* which could show car crashes and then blame all of them on "Big Auto." Then he could argue that because car crashes are possible, we don't need cars. In fact, Fox could make a far more alarming movie than *Gasland* based on supposedly risk-free solar and wind technology. Imagine a scene at a rare-earth mine in a movie called *Wasteland.*

Defenders of fracking often point out that the "abusers" Fox cities are false attributions—the next fallacy we'll discuss. But the pattern of argument would be wrong even if Fox wasn't fabricating particular abuses; individual abuses do not prove that an entire technology should not be used—they prove it should not be abused.

The abuse-use fallacy is deadly because it can be used to attack anything a group opposes. As citizens, we hate to see even one coal mine accident, one spill of hazardous liquids, one example of industry corruption, but we must use that feeling to advocate for proper laws and best practices, not to drive us to outlaw crucial technologies.

THE FALSE-ATTRIBUTION FALLACY

False attribution is claiming that one event causes another, devoid of proof. For example, in *Gasland,* Josh Fox famously showed people lighting their water on fire—a phenomenon that, unknown to many, is a frequent natural occurrence almost always stemming from the natural presence of methane (natural gas) in the water.[11] But it gets falsely attributed to fracking, as do many groundwater problems that are actually due to natural contamination of standard water wells.

A U.S. Geological Survey study conducted between 1991 and 2004 examined the quality of water from domestic wells and found: "More than one in five (23 percent) of the sampled wells contained one or more contaminants at a concentration greater than a human-health benchmark. . . . Contaminants most often found at concentrations greater than human-health benchmarks were inorganic chemicals, with all but nitrate derived primarily from natural sources."[12] In other words, more than one in five wells are naturally contaminated according to our government's standards. Yet we are taught to treat "natural" water as clean and blame all dirty water on industry, especially the fossil fuel industry.

Attributing water issues to fracking is almost always disingenuous. Here's the truth about groundwater. Every technology uses raw materials that must be mined from the ground, and anytime we drill or mine or dig underground, groundwater can be compromised. Of all the things you can do underground, fracking is the least likely to affect groundwater, because it takes place thousands of feet away from it. As President Obama's former EPA administrator Lisa Jackson acknowledged, there is no "proven case where the fracking process itself has affected water. . . ."[13]

If an oil company causes contamination at a fracked oil or gas well, it almost certainly has nothing to do with the fracking element of the process, but rather something near the groundwater, such as a surface spill of oil or some other liquid. So why single out fracking? Because attacks on fossil fuels thrive on technophobia—the fear of new technology—which is exploited by using unfamiliar, unknown terms like fracking. If Fox had opposed drilling, he wouldn't have gotten very far, because the public knows that, while accidents can happen while drilling, drilling itself is a vital human activity.

A more sophisticated version of false attribution uses prestigious studies based on speculative models. Just as climate discussions today are governed by speculative models whose (in)validity is rarely specified, so are pollution discussions. Regulators often use models that assert unprovable relationships between tiny amounts of particulate emissions and health problems.

The evidence is brought to us via "studies," cited by news media eager to run dramatic, "if it bleeds it leads" headlines. The main thing to watch out for here is a statement like "X causes Y"—e.g., "coal causes asthma." That's usually an oversimplification at best; often it's completely bogus. It's hard to prove cause and effect. Here's a good question to ask when you encounter these kinds of claims: "Could you explain how you prove that—how you know that coal *in particular* caused asthma instead of everything else that might have caused it?" Usually the answer is no.

Let's look briefly at the claim that coal causes asthma problems through power plants' emission of particulate matter (PM).

Asthma or chronic respiratory disease has become more prevalent in Western countries.[14] That has triggered a variety of theories about the causes.[15] Claims about decreasing air quality or increasing exposure to toxins do not stand up, *as the increase in prevalence seems to be strongest in countries with much improved environmental quality;* for example, wealthier, cleaner West Germany had more asthma problems than poorer, dirtier East Germany.[16]

To put it in reverse, *countries with higher pollution levels have systematically shown lower rates of chronic respiratory diseases like asthma.* Something like asthma is a complex issue, and to use it to attack coal is to attack the health of everyone.

Or take mercury. Here's a summary of the typical argument about coal and mercury: Coal naturally contains mercury, a neurotoxin that can damage the nervous system, the brain, and other organs. When we burn coal, that mercury gets released into the atmosphere and ultimately rains down into bodies of water. This leads to higher mercury levels in fish, which lead to higher mercury levels in our bodies when we eat fish. Those levels are dangerous, particularly to the fetuses of pregnant women, whose children can experience developmental problems and learning disabilities. Therefore, coal is a massive threat to public health.

But here's the full context.

Mercury, a metal element, exists naturally throughout the world, most notably in the oceans, which contain an estimated 40 million to 200 million tons of mercury, as well as in most forms of plant and animal life. Mercury is released into the air by volcanoes, wildfires, and in far lesser quantities, the burning of coal. Natural causes of mercury are why the region of the United States with the highest mercury levels is the Southwest, whereas there are much lower levels in coal-heavy West Virginia and Kentucky.[17]

Mercury, like any substance, is toxic in certain forms and doses and harmless in others. The form of mercury that is of particular concern to human health is called methylmercury (or monomethylmercury), a combination of mercury, carbon, and hydrogen. Discussions of "mercury poisoning" are misleading, because mercury becomes methylmercury only under certain conditions, and methylmercury can be absorbed by human beings in relevant quantities only under certain conditions (for example, the element selenium seems to prevent the absorption of methylmercury).[18]

To be sure, negative cause-and-effect relationships do exist between fossil fuel emissions and human health—in certain concentrations and in certain contexts—but this doesn't appear to be one of them. Which brings us to the no-threshold fallacy.

THE NO-THRESHOLD FALLACY

> *All things are poison and nothing [is] without poison; only the dosage determines that something is not a poison.*
>
> —Paracelsus, sixteenth century[19]

The world around us and our own bodies consist of chemicals. All of them, without a single exception, can be poisonous to us if we are exposed to them in a certain concentration (which can be too high or too low) or in a certain form.

A simple example of this is medication. In the right concentration, a given hormone, heavy metal, or complex organic molecule can be lifesaving or can treat some nasty symptoms of a disease. Antibiotics are essentially poisons to microorganisms inside our bodies. If we take too much of certain drugs, we will die immediately.

The same is true for all substances in our bodies. Inside our bone tissue, for instance, there is a radioactive potassium isotope in a low concentration. Even pure water, which is the main constituent of our bodies, is a potential threat to our health. Drinking too much distilled water is dangerous because mineral-poor water entering our metabolism causes a mineral imbalance on the cellular level. On the other hand, pouring distilled, mineral-poor water on our skin is no threat.

A poison or pollutant is always a *combination* of substance and dose. If someone mentions just a substance to scare you, independent of the context or the dose, he has given you meaningless, misleading information. He is assuming or expecting you to assume that if a substance is dangerous in *some dosage,* it is dangerous in *all dosages*. One variant of this argument used to attack shale energy is the claim that fracking causes earthquakes.[20] This assertion is true in that fracking causes some amount of underground, earth-moving activity, but in almost all cases, it is completely inconsequential and not even discernible at the surface. A typical tremor that can be caused by hydraulic fracturing is −2 on the Richter scale, a "quake" that is not felt at the surface, causes no damage, and can be measured only deep underground. Such quakes are occurring continuously throughout the Earth, fracking or no fracking.[21]

What about a worst-case scenario? Many say that it's between 3 and 4 on the Richter scale, which means you can feel the quake but it's unlikely strong enough to cause damage.[22] And this is an incredibly unlikely scenario. For this we are supposed to ban all fracking?

Even if fracking in a certain place had a high risk of a truly dangerous earthquake—say, because it is near some seismically vulnerable area—that is an argument against fracking in that particular place, not an argument against fracking as such.[23]

When one treats something as poisonous regardless of dosage, he is denying the existence of a *threshold* at which a substance goes from being benign to harmful. If you deny a threshold, you can make a case for banning anything.

The no-threshold fallacy was used particularly insidiously in opposing nuclear power. People said we should have zero tolerance for radiation—not knowing, apparently, that the potassium in their bone tissue emits radiation, enough so that sleeping with a spouse gives you almost as much radiation as standing right outside a nuclear power plant. Both activities are nowhere near harmful.

"No-threshold" plus "false-attribution" is a dangerous combination in the hands of activists and regulators. They can keep claiming that nothing is clean enough and keep passing laws that regulate vital technologies, such as coal, out of existence. As always, whether we are talking about a natural substance or a man-made substance, our standard needs to be human life. *That* determines the threshold of danger.

THE "ARTIFICIAL" FALLACY

One of the big accusations against fracking is that it "uses chemicals." This is a funny way of putting it. Everything in our world uses chemicals, because our world is *made* of chemical elements.

The accusation is implying that fracking uses "artificial" or *man-made* chemicals, and the accusation assumes, and expects us to assume, that man-made means dangerous.

But it is simply untrue that "natural" is safe and man-made is unsafe. For example, fossil fuels are natural, organic, plant-based fuels whose pollution challenges stem from natural ingredients like sulfur and nitrogen and heavy metals. Arsenic and cyanide are natural substances, and many natural plants are poisonous.

The fact that we *didn't* make something shouldn't make us feel safe. And the fact that something is made in a laboratory shouldn't make us afraid. With every substance, we need to look at its nature and dosage in the context of human life.

One additional note: It *especially* doesn't make sense to be biased against man-made things, because they are *deliberately* made by a human mind, usually to promote human life. While man-made things can be bad, it is perverse to single out the man-made as bad per se. To be against the man-made as such is to have a bias against the *mind-made,* which is to be against the human mind, whose very purpose is to figure out how to transform our environment to meet our needs.

A HUMAN-CENTERED VIEW OF ENVIRONMENT

Fossil-fueled development is the greatest benefactor our environment has ever known. This needs to be mentioned in our environmental discussions, and so-called environmental groups need to be taken to task for omitting it. The only way fossil fuels are a net minus for "the environment" is if by "the environment" you mean our surroundings not from our perspective, but from a *nonhuman* perspective. From the perspective of organisms we need to kill or use to survive, such as the parasite, the malarial mosquito, the dangerous animal, or the trees we clear to build a road, *we* are a negative for the environment. (At the same time, we are positive for many other species. But as far as *our* environment goes, there is no environmental quality without development. And there is no global development without fossil fuel energy.

As we have seen, in using fossil fuels to improve our lives, including our environment, we create new environmental problems to solve—far fewer than those of undeveloped nature but real and important nonetheless. It's a fact of life that new technologies will bring problems that, by definition, would not exist if the technology didn't exist. There were no computer problems before computers. And just as we use computers to help solve computer problems, so we can use fossil fuels to help solve fossil fuel problems—to transform waste from a more dangerous form to a less dangerous form, or even to a benefit, by using energy and ingenuity. The energy we get from fossil fuels enables us to improve our environment—including mitigating or negating our own negative contributions.

This point belongs front and center in every discussion of fossil fuels and environment. All discussions of environmental issues need to recognize the phenomenon of *environmental improvement through* *development.*

Unfortunately, development has become one of the leading *targets* of environmental attacks. While any given instance of development can be bad—for example, if someone tramples on your property for his own project—the basic *purpose* of development is to improve our *human* environment.

That includes enjoying nature. Only with a society developed to the point of prosperity—including transportation systems crisscrossing the land, water, and air around the globe—can we enjoy the most beautiful parts of nature and the most fascinating parts of civilization.

The general opposition to development as antienvironment reflects a view that equates environment with *wilderness,* i.e., a nonhuman view of environment, which leads to an environment that is harmful for human beings because it does not sufficiently protect against natural threats or produce the resources necessary to overcome natural poverty. Here's the truth: The more development that happens, especially in underdeveloped countries, using fossil fuels, the more we can expect a *skyrocketing* of environmental quality around the world.

To be antipollution has nothing whatsoever to do with being antidevelopment. In fact, the two are incompatible; we need mass development to overcome nature's deadly pollution. And being prodevelopment, pro–fossil fuels, is completely consistent with another value that has been appropriated by the opponents of fossil fuels: appreciating nature.

PRESERVING NATURE TO BENEFIT HUMAN LIFE

In part because many anti–fossil fuel groups, such as the Sierra Club, celebrate the joys of spending time in less inhabited parts of nature, it is often believed that to advocate fossil fuel energy and the fossil fuel industry is to somehow oppose enjoying nature. (Terminology point: I consider human civilization just as natural as any other animal habitat, but I'll use *nature* in this context to mean "nonhuman nature.")

It's valuable to think of the ability to enjoy nature as a resource, something that we potentially have but don't automatically have. If we think that way, we see that like any resource, it is expanded by energy.

I'll use my own experience to illustrate. I have been fortunate enough to experience a wide variety of scenic, beautiful locations in my life. Some of my favorite moments are alone in nature. Snowboarding at the end of the day when I am the only one I can see on the mountain. Walking over lava on the Big Island of Hawaii. Standing under secluded waterfalls in the Grand Canyon. Like most people, sometimes I want to get away from everything, including all the complex machines.

And that's great, so long as I don't forget what got me there: complex machines.

Just as we are taught to think of nature as safe and clean, so we are taught to think of it as scenic. But it becomes scenic to us only if we have *access* to a variety of beautiful scenes.

There are more such scenes, but for most of history, no one got to enjoy many of them because they lacked the ultimate tool for enjoying nature—mobility. They also lacked the other crucial tool: adaptability, including medicine. Now we think of camping as a fun adventure. In the past, it was a deadly adventure.

If we view nature as another resource for us to enjoy and something to preserve when it is particularly beautiful or significant to us, then we will embrace fossil fuels. Fossil fuel energy gives us the *mobility* to get to it, the *adaptability* to be safe in it, and the *time* to enjoy it.

When we talk about resources, we have to remember that the only resource that can't be re-created, the real resource to guard jealously, is time—it is irreplaceable and unrepeatable. We can make more plastic, but we can't get back our time. And time is what enables us to enjoy nature. The more productive we are, the more time we have for leisure pursuits. (Whether people choose to take advantage of that is another issue.)

Furthermore, because fossil fuel energy is so dense and requires very little land and no live plants, it gives us both the wealth and the physical ability to preserve pretty much any piece of nature we want. And even in cases where one person's irreplaceable beauty is another person's needed energy source, we are talking about an installation that, if need be, has a finite lifetime and then can be transformed into a lush forest. Which is not to say that oil rigs are ugly—I think we should consider industrial civilization beautiful, too.

Look at the parts of the world where the "rain forest" (jungle) gets mowed down in seemingly shortsighted ways. Are they rich places? No, they are poor places with primitive agriculture and industry.

The now-developed world was once like that in preindustrial times. While we are taught to think that the country was once lush landscape, in fact, before coal, oil, and natural energy, our country and others survived by developing the landscape. As geographer Pierre Desrochers writes:

> Carbon fuels made this expansion of the forest cover possible in various ways. With the development of more sophisticated combustion technologies, coal, heavy oil and natural gas proved vastly superior alternatives to firewood and charcoal. Through their role as long-distance land and maritime transportation fuels, coal and later petroleum-based fuels (diesel and marine bunker fuel) encouraged agricultural specialization in the most productive zones of the planet, in the process making much marginal agricultural land superfluous.[24]

If you love enjoying nature, you should love fossil fuels.

The same basic logic applies to more abstract concerns about "biodiversity" and species extinction. There are huge debates in the ecology literature about what is happening or not happening to what species, and I have not studied them enough to take sides, but I can say that from an energy perspective, to the extent it makes sense to preserve a given species or biological arrangement—and such decisions should be made according to a human standard of value, not a nonhuman one—cheap, plentiful, reliable energy gives us the means to do so just as we can preserve a desirable forest or park. It is only when we are truly living off the rest of nature that we must gobble up whatever we can.

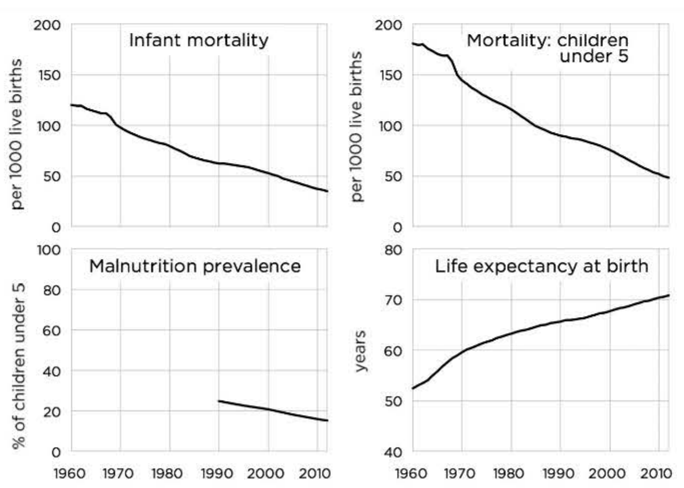
Whether to actively preserve a species or not should be made with reference to a human standard of value. Much of the ecology field holds to the nonimpact standard, which treats another species' extinction as intrinsically wrong. But human beings are right to favor some species over others. For example, pigs, cattle, and chickens are in no danger of extinction because their human-centered benefits are immediately visible, so we make them some of the most abundant life-forms on Earth. On the other hand, wolves and bears and disease-carrying insects have been threats that we destroyed in many regions. There is no inherent reason to think that the extinction of any given plant or animal is bad for humans. We should focus on maximizing our benefits. That can be the removal of a direct threat, such as making bears nonexistent where our kids go to school, or the preservation of species that we want to survive, such as the panda, even if we do not strictly need it for our own survival.

THE BIG PICTURE

So far we have seen that the overall impact of fossil fuels on our environment is tremendously positive. But let's step back and ask this: Why are we concerned about our environment? Why are we concerned, say, about pollution? Of course, most fundamentally we desire human flourishing but in particular we desire human *health.* Therefore, in looking at fossil fuels and environmental quality, it's important to look at not just how they help us transform our environment for the better, but also how they help us transform *ourselves* for the better through health technology.

Let's look at the trends: infant mortality, mortality under five, malnutrition, and life expectancy.

Figure 7.2: Health Trends Improving Across the Board and Around the World



Source: World Bank, World Development Indicators (WDI) Online Data, April 2014

Every one of these graphs represents a collection of real people, many of whom have been recently empowered by energy and many of whom who are suffering every day for lack of it.

World life expectancy at birth has gone up from sixty-three in 1980 to seventy in 2012. The child mortality rate on the planet went down from 115 to 47 per 1,000 live births. Infant mortality declined from 80 to 35 per 1,000 live births in the same time period.[25] The incidence of tuberculosis, an infectious disease that particularly threatens poor people with little access to modern medicine, has declined from 147 per 100,000 population in 1990, when the World Bank's record begins, to 122 in 2012.[26] Malnutrition, defined by the percentage of children under five with significantly below average weight or height for their age, has been constantly decreasing at a significant rate since 1990.[27] Access to electricity and improved water sources, which are basic indicators for human well-being, hygiene, and health in general, went up as well.[28]

Developing countries in the sub-Saharan and East Asian region have been particularly impressive; East Asian developing countries now have an average life expectancy at birth of seventy-three years.There is much credit to be given to industrial-scale energy, primarily, as we have seen in previous chapters, from fossil fuels. Without a large amount of affordable energy, the vast majority of the people whose lives were drastically improved in recent decades would still sit in the dark mourning their dead children and friends, if they were ever born in the first place.

Many energy-intensive technologies influence our overall health in a positive way. Food production, modern medicine, and sanitation require cheap, plentiful, reliable energy to make them available and affordable to as many people as possible.

All of this is part of the big picture of fossil fuels' impact on our lives, health, and environment.

To summarize, fossil fuels improve our environment by, among other things, empowering us to fight the otherwise overwhelming health hazards of nature. Like all forms of energy, they have risks and by-products, but they also give us the energy and resources to minimize, neutralize, or even reverse those harms. More broadly, if health is our concern, fossil fuels underlie the food and medical care systems that have created the longest life expectancy in history.

Once again, we see that an alleged negative of fossil fuels, its impact on environmental quality, is in fact a tremendous positive.

We have a choice to make. Will we use fossil fuels to maximize human well-being in all areas of life, including our environment? Or will we continue to see fossil fuels only through negative glasses, blind to the tremendous benefits that have come so far, and the tremendous ones that can come in the future?