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51 BILLION TO ZERO

There are two numbers you need to know about climate change. The first is 51 billion. The other is zero.

Fifty-one billion is how many tons of greenhouse gases the world typically adds to the atmosphere every year. Although the figure may go up or down a bit from year to year, it's generally increasing. This is *where we are today*.*

Zero is *what we need to aim for*. To stop the warming and avoid the worst effects of climate change—and these effects will be very bad—humans need to stop adding greenhouse gases to the atmosphere.

This sounds difficult, because it will be. The world has never done anything quite this big. Every country will need to change its ways. Virtually every activity in modern life—growing things, making things, getting around from place to place—involves releasing greenhouse gases, and as time goes on, more people will be living this modern lifestyle. That's good, because it means their lives are

* Fifty-one billion tons is based on the latest available data. Global emissions dropped a bit in 2020—probably by around 5 percent—because the COVID-19 pandemic slowed the economy so dramatically. But because we don't know the exact figure for 2020, I will use 51 billion tons as the total. We'll return to the subject of COVID-19 periodically throughout this book.

getting better. Yet if nothing else changes, the world will keep producing greenhouse gases, climate change will keep getting worse, and the impact on humans will in all likelihood be catastrophic.

But "if nothing else changes" is a big If. I believe that things *can* change. We already have some of the tools we need, and as for those we don't yet have, everything I've learned about climate and technology makes me optimistic that we can invent them, deploy them, and, if we act fast enough, avoid a climate catastrophe.

This book is about what it will take and why I think we can do it.

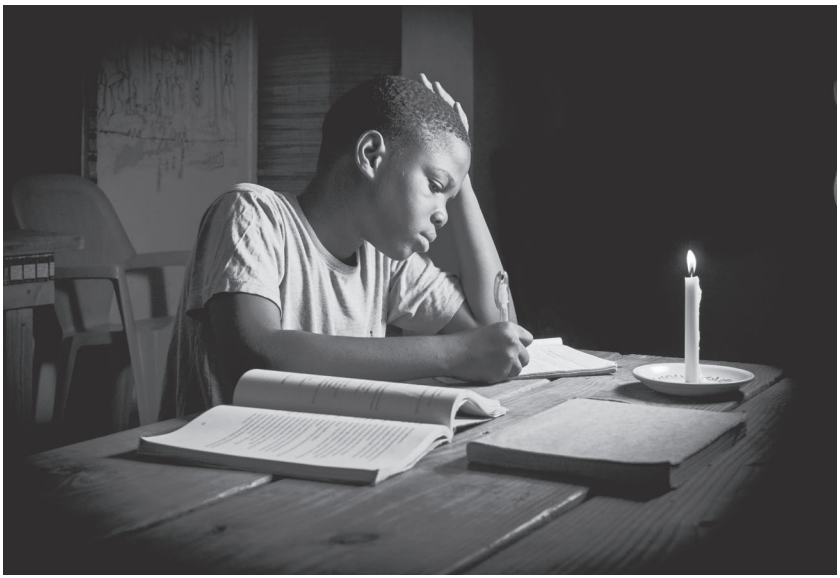
Two decades ago, I would never have predicted that one day I would be talking in public about climate change, much less writing a book about it. My background is in software, not climate science, and these days my full-time job is working with my wife, Melinda, at the Gates Foundation, where we are super-focused on global health, development, and U.S. education.

I came to focus on climate change in an indirect way—through the problem of energy poverty.

In the early 2000s, when our foundation was just starting out, I began traveling to low-income countries in sub-Saharan Africa and South Asia so I could learn more about child mortality, HIV, and the other big problems we were working on. But my mind was not always on diseases. I would fly into major cities, look out the window, and think, *Why is it so dark out there? Where are all the lights I'd see if this were New York, Paris, or Beijing?*

In Lagos, Nigeria, I traveled down unlit streets where people were huddling around fires they had built in old oil barrels. In remote villages, Melinda and I met women and girls who spent hours every day collecting firewood so they could cook over an open flame in their homes. We met kids who did their homework by candlelight because their homes didn't have electricity.

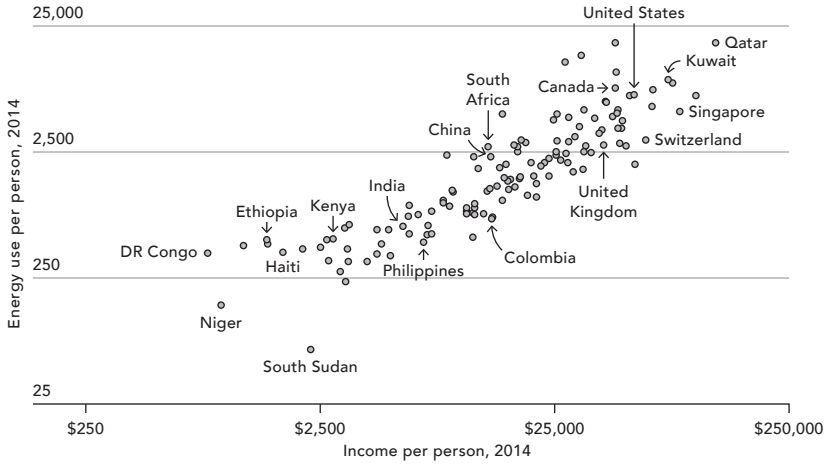
I learned that about a billion people didn't have reliable access to



Melinda and I often meet children like nine-year-old Ovulube Chinachi, who lives in Lagos, Nigeria, and does his homework by candlelight.

electricity and that half of them lived in sub-Saharan Africa. (The picture has improved a bit since then; today roughly 860 million people don't have electricity.) I thought about our foundation's motto—"Everyone deserves the chance to live a healthy and productive life"—and how it's hard to stay healthy if your local medical clinic can't keep vaccines cold because the refrigerators don't work. It's hard to be productive if you don't have lights to read by. And it's impossible to build an economy where everyone has job opportunities if you don't have massive amounts of reliable, affordable electricity for offices, factories, and call centers.

Around the same time, the late scientist David MacKay, a professor at Cambridge University, shared a graph with me that showed the relationship between income and energy use—a country's per capita income and the amount of electricity used by its people. The chart plotted various countries' per capita income on one axis and energy consumption on the other—and made it abundantly clear to me that the two go together:



Income and energy use go hand in hand. David MacKay showed me a chart like this one plotting energy consumption and income per person. The connection is unmistakable. (IEA; World Bank)

As all this information sank in, I began to think about how the world could make energy affordable and reliable for the poor. It didn't make sense for our foundation to take on this huge problem—we needed it to stay focused on its core mission—but I started kicking around ideas with some inventor friends of mine. I read more deeply on the subject, including several eye-opening books by the scientist and historian Vaclav Smil, who helped me understand just how critical energy is to modern civilization.

At the time, I didn't understand that we needed to get to zero. The rich countries that are responsible for most emissions were starting to pay attention to climate change, and I thought that would be enough. My contribution, I believed, would be to advocate for making reliable energy affordable for the poor.

For one thing, they have the most to gain from it. Cheaper energy would mean not only lights at night but also cheaper fertilizer for their fields and cement for their homes. And when it comes to climate change, the poor have the most to lose. The majority of them are farmers who already live on the edge and can't withstand more droughts and floods.

Things changed for me in late 2006 when I met with two former Microsoft colleagues who were starting nonprofits focused on energy and climate. They brought along two climate scientists who were well versed in the issues, and the four of them showed me the data connecting greenhouse gas emissions to climate change.

I knew that greenhouse gases were making the temperature rise, but I had assumed that there were cyclical variations or other factors that would naturally prevent a true climate disaster. And it was hard to accept that as long as humans kept emitting any amount of greenhouse gases, temperatures would keep going up.

I went back to the group several times with follow-up questions. Eventually it sank in. The world needs to provide more energy so the poorest can thrive, but we need to provide that energy without releasing any more greenhouse gases.

Now the problem seemed even harder. It wasn't enough to deliver cheap, reliable energy for the poor. It also had to be clean.

I kept learning everything I could about climate change. I met with experts on climate and energy, agriculture, oceans, sea levels, glaciers, power lines, and more. I read the reports issued by the Intergovernmental Panel on Climate Change (IPCC), the UN panel that establishes the scientific consensus on this subject. I watched *Earth's Changing Climate,* a series of fantastic video lectures by Professor Richard Wolfson available through the Great Courses series. I read *Weather for Dummies,* still one of the best books on weather that I've found.

One thing that became clear to me was that our current sources of renewable energy—wind and solar, mostly—could make a big dent in the problem, but we weren't doing enough to deploy them.*

* Hydropower—electricity created by water pouring through a dam—is another renewable source, in fact the biggest source of renewable energy in the United States. But we've already tapped most of the available hydropower. There's not a lot of room to grow there. Most of the additional clean energy we want will have to come from another source.

It also became clear why, on their own, they aren't enough to get us all the way to zero. The wind doesn't always blow and the sun doesn't always shine, and we don't have affordable batteries that can store city-sized amounts of energy for long enough. Besides, making electricity accounts for only 27 percent of all greenhouse gas emissions. Even if we had a huge breakthrough in batteries, we would still need to get rid of the other 73 percent.

Within a few years, I had become convinced of three things:

1. To avoid a climate disaster, we have to get to zero.
2. We need to deploy the tools we already have, like solar and wind, faster and smarter.
3. And we need to create and roll out breakthrough technologies that can take us the rest of the way.

The case for zero was, and is, rock solid. Unless we stop adding greenhouse gases to the atmosphere, the temperature will keep going up. Here's an analogy that's especially helpful: The climate is like a bathtub that's slowly filling up with water. Even if we slow the flow of water to a trickle, the tub will eventually fill up and water will come spilling out onto the floor. That's the disaster we have to prevent. Setting a goal to only reduce our emissions—but not eliminate them—won't do it. The only sensible goal is zero. (For more on zero, what I mean by it, and the impact of climate change, see chapter 1.)

But at the time I learned all this, I wasn't looking for another issue to take on. Melinda and I had picked global health and development and U.S. education as the two areas where we would learn a great deal, hire teams of experts, and spend our resources. I also saw that many well-known people were putting climate change on the agenda.

So although I got more involved, I didn't make it a top priority. When I could, I read and met with experts. I invested in some clean energy companies, and I put several hundred million dollars into starting a company to design a next-generation nuclear plant that

would generate clean electricity and very little nuclear waste. I gave a TED talk called "Innovating to Zero!" But mostly, I kept my attention on the Gates Foundation's work.

Then, in the spring of 2015, I decided that I needed to do more and speak out more. I had been seeing news reports about college students around the United States who were holding sit-ins to demand that their schools' endowments divest from fossil fuels. As part of that movement, the British newspaper *The Guardian* launched a campaign calling on our foundation to sell off the small fraction of its endowment that was invested in fossil-fuel companies. They made a video featuring people from around the world asking me to divest.

I understood why *The Guardian* had singled out our foundation and me. I also admired the activists' passion; I had seen students protesting the Vietnam War, and later the apartheid regime in South Africa, and I knew they had made a real difference. It was inspiring to see this kind of energy directed at climate change.

On the other hand, I kept thinking about what I had witnessed in my travels. India, for example, has a population of 1.4 billion people, many of them among the poorest in the world. I didn't think it was fair for anyone to tell Indians that their children couldn't have lights to study by, or that thousands of Indians should die in heat waves because installing air conditioners is bad for the environment. The only solution I could imagine was to make clean energy so cheap that every country would choose it over fossil fuels.

As much as I appreciated the protesters' passion, I didn't see how divesting alone would stop climate change or help people in poor countries. It was one thing to divest from companies to fight apartheid, a political institution that would (and did) respond to economic pressure. It's another thing to transform the world's energy system—an industry worth roughly $5 trillion a year and the basis for the modern economy—just by selling the stocks of fossil-fuel companies.

I still feel this way today. But I have come to realize that there are

other reasons for me not to own the stocks of fossil-fuel companies—namely, I don't want to profit if their stock prices go up because we don't develop zero-carbon alternatives. I'd feel bad if I benefited from a delay in getting to zero. So in 2019, I divested all my direct holdings in oil and gas companies, as did the trust that manages the Gates Foundation's endowment. (I hadn't had money in coal companies in several years.)

This is a personal choice, one that I'm fortunate to be able to make. But I'm well aware that it won't have a real impact on lowering emissions. Getting to zero requires a much broader approach: driving wholesale change using all the tools at our disposal, including government policies, current technology, new inventions, and the ability of private markets to deliver products to huge numbers of people.

Later in 2015 came an opportunity to make the case for innovation and new investments: the COP 21, a major climate change conference to be held by the United Nations in Paris that November and December. A few months before the conference, I met with François Hollande, who was the president of France at the time. Hollande was interested in getting private investors to join the conference, and I was interested in getting innovation on the agenda. We both saw an opportunity. He thought I could help bring investors to the table; I said that made sense, though it would be easier to do if governments also committed to spending more on energy research.

That was not necessarily going to be an easy sell. Even America's investment in energy research was (and still is) far lower than in other essential areas, like health and defense. Although some countries were modestly expanding their research efforts, the levels were still very low. And they were reluctant to do much more unless they knew that there would be enough money from the private sector to take their ideas out of the lab and turn them into products that actually helped their people.

But by 2015, private funding was drying up. Many of the venture

capital firms that had invested in green tech were pulling out of the industry because the returns were so low. They were used to investing in biotechnology and information technology, where success often comes quickly and there are fewer government regulations to deal with. Clean energy was a whole other ball game, and they were getting out.

Clearly, we needed to bring in new money and a different approach that was tailored specifically to clean energy. In September, two months before the Paris conference started, I emailed two dozen wealthy acquaintances, hoping to persuade them to commit venture funding to complement the governments' new money for research. Their investments would need to be long term—energy breakthroughs can take decades to develop—and they would have to tolerate a lot of risk. To avoid the potholes that the venture capitalists had run into, I committed to help build a focused team of experts who would vet the companies and help them navigate the complexities of the energy industry.

I was delighted by the response. The first investor said yes in less than four hours. By the time the Paris conference kicked off two months later, 26 more had joined, and we had named it the Breakthrough Energy Coalition. Today, the organization now known as Breakthrough Energy includes philanthropic programs, advocacy efforts, and private funds that have invested in more than 40 companies with promising ideas.

The governments came through too. Twenty heads of state got together in Paris and committed to doubling their funding for research. President Hollande, U.S. President Barack Obama, and Indian Prime Minister Narendra Modi had been instrumental in pulling it together; in fact, Prime Minister Modi came up with the name: Mission Innovation. Today Mission Innovation includes 24 countries and the European Commission and has unlocked $4.6 billion a year in new money for clean energy research, an increase of more than 50 percent in just a handful of years.

Launching Mission Innovation with world leaders at the 2015 UN climate conference in Paris. (See page 237 for the names of those photographed.)

The next turning point in this story will be grimly familiar to everyone reading this book.

In 2020, disaster struck when a novel coronavirus spread around the world. To anyone who knows the history of pandemics, the devastation caused by COVID-19 was not a surprise. I had been studying disease outbreaks for years as part of my interest in global health, and I had become deeply concerned that the world wasn't ready to handle a pandemic like the 1918 flu, which killed tens of millions of people. In 2015, I had given a TED talk and several interviews in which I made the case that we needed to create a system for detecting and responding to big disease outbreaks. Other people, including former U.S. president George W. Bush, had made similar arguments.

Unfortunately, the world did little to prepare, and when the novel coronavirus struck, it caused massive loss of life and economic pain such as we had not seen since the Great Depression. Although I kept up much of my work on climate change, Melinda and I made COVID-19 the top priority for the Gates Foundation and the main focus of our own work. Every day, I would talk to

scientists at universities and small companies, CEOs of pharmaceutical companies, or heads of government to see how the foundation could help accelerate the work on tests, treatments, and vaccines. By November 2020, we had committed more than $445 million in grants to fighting the disease, and hundreds of millions more via various financial investments to get vaccines, tests, and other critical products to lower-income countries faster.

Because economic activity has slowed down so much, the world will emit fewer greenhouse gases this year than last year. As I mentioned earlier, the reduction will probably be around 5 percent. In real terms, that means we will release the equivalent of 48 or 49 billion tons of carbon, instead of 51 billion.

That's a meaningful reduction, and we would be in great shape if we could continue that rate of decrease every year. Unfortunately, we can't.

Consider what it took to achieve this 5 percent reduction. A million people died, and tens of millions were put out of work. To put it mildly, this was not a situation that anyone would want to continue or repeat. And yet the world's greenhouse gas emissions probably dropped just 5 percent, and possibly less than that. What's remarkable to me is not how much emissions went down because of the pandemic, but how little.

This small decline in emissions is proof that we cannot get to zero emissions simply—or even mostly—by flying and driving less. Just as we needed new tests, treatments, and vaccines for the novel coronavirus, we need new tools for fighting climate change: zero-carbon ways to produce electricity, make things, grow food, keep our buildings cool and warm, and move people and goods around the world. And we need new seeds and other innovations to help the world's poorest people—many of whom are smallholder farmers—adapt to a warmer climate.

Of course, there are other hurdles too, and they don't have any-

thing to do with science or funding. In the United States especially, the conversation about climate change has been sidetracked by politics. Some days, it can seem as if we have little hope of getting anything done.

I think more like an engineer than a political scientist, and I don't have a solution to the politics of climate change. Instead, what I hope to do is focus the conversation on what getting to zero requires: We need to channel the world's passion and its scientific IQ into deploying the clean energy solutions we have now, and inventing new ones, so we stop adding greenhouse gases to the atmosphere.

I am aware that I'm an imperfect messenger on climate change. The world is not exactly lacking in rich men with big ideas about what other people should do, or who think technology can fix any problem. And I own big houses and fly in private planes—in fact, I took one to Paris for the climate conference—so who am I to lecture anyone on the environment?

I plead guilty to all three charges.

I can't deny being a rich guy with an opinion. I do believe, though, that it is an informed opinion, and I am always trying to learn more.

I'm also a technophile. Show me a problem, and I'll look for technology to fix it. When it comes to climate change, I know innovation isn't the only thing we need. But we cannot keep the earth livable without it. Techno-fixes are not sufficient, but they are necessary.

Finally, it's true that my carbon footprint is absurdly high. For a long time I have felt guilty about this. I've been aware of how high my emissions are, but working on this book has made me even more conscious of my responsibility to reduce them. Shrinking my carbon footprint is the least that can be expected of someone in my position who's worried about climate change and publicly calling for action.

In 2020, I started buying sustainable jet fuel and will fully offset my family's aviation emissions in 2021. For our non-aviation emissions, I'm buying offsets through a company that runs a facility that removes carbon dioxide from the air (for more on this technology, which is called direct air capture, see chapter 4, "How We Plug In"). I'm also supporting a nonprofit that installs clean energy upgrades in affordable housing units in Chicago. And I'll keep looking for other ways to reduce my personal footprint.

I'm also investing in zero-carbon technologies. I like to think of these as another kind of offset for my emissions. I've put more than $1 billion into approaches that I hope will help the world get to zero, including affordable and reliable clean energy and low-emissions cement, steel, meat, and more. And I'm not aware of anyone who's investing more in direct air capture technologies.

Of course, investing in companies doesn't make my carbon footprint smaller. But if I've picked any winners at all, they'll be responsible for removing much more carbon than I or my family is responsible for. Besides, the goal isn't simply for any one person to make up for his or her emissions; it's to avoid a climate disaster. So I'm supporting early-stage clean energy research, investing in promising clean energy companies, advocating for policies that will trigger breakthroughs throughout the world, and encouraging other people who have the resources to do the same.

Here's the key point: Although heavy emitters like me should use less energy, the world overall should be using *more* of the goods and services that energy provides. There is nothing wrong with using more energy as long as it's carbon-free. The key to addressing climate change is to make clean energy just as cheap and reliable as what we get from fossil fuels. I'm putting a lot of effort into what I think will get us to that point and make a meaningful difference in going from 51 billion tons a year to zero.

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This book suggests a way forward, a series of steps we can take to give ourselves the best chance to avoid a climate disaster. It breaks down into five parts:

Why zero? In chapter 1, I'll explain more about why we need to get to zero, including what we know (and what we don't) about how rising temperatures will affect people around the world.

The bad news: Getting to zero will be really hard. Because every plan to achieve anything starts with a realistic assessment of the barriers that stand in your way, in chapter 2 we'll take a moment to consider the challenges we're up against.

How to have an informed conversation about climate change. In chapter 3, I'll cut through some of the confusing statistics you might have heard and share the handful of questions I keep in mind in every conversation I have about climate change. They have kept me from going wrong more times than I can count, and I hope they will do the same for you.

The good news: We can do it. In chapters 4 through 9, I'll break down the areas where today's technology can help and where we need breakthroughs. This will be the longest part of the book, because there's so much to cover. We have some solutions we need to deploy in a big way now, and we also need a *lot* of innovations to be developed and spread around the world in the next few decades.

Although I'll introduce you to some of the technologies that I am especially excited about, I'm not going to name many specific companies. Partly that's because I'm investing in some of them, and I don't want to look as if I'm favoring companies that I have a financial interest in. But more important, I want the focus to be on the ideas and innovations, not on particular businesses. Some companies may go under in the coming years; that comes with the territory when you're doing cutting-edge work, though it's not necessarily a sign of failure. The key thing is to learn from the failure and incorporate the lessons into the next venture, just as we did at Microsoft and just as every other innovator I know does.

Steps we can take now. I wrote this book because I see not just the problem of climate change; I also see an opportunity to solve it. That's not pie-in-the-sky optimism. We already have two of the three things you need to accomplish any major undertaking. First, we have ambition, thanks to the passion of a growing global movement led by young people who are deeply concerned about climate change. Second, we have big goals for solving the problem as more national and local leaders around the world commit to doing their part.

Now we need the third component: a concrete plan to achieve our goals.

Just as our ambitions have been driven by an appreciation for climate science, any practical plan for reducing emissions has to be driven by other disciplines: physics, chemistry, biology, engineering, political science, economics, finance, and more. So in the final chapters of this book, I'll propose a plan based on guidance I've gotten from experts in all these disciplines. In chapters 10 and 11, I'll focus on policies that governments can adopt; in chapter 12, I'll suggest steps that each of us can take to help the world get to zero. Whether you're a government leader, an entrepreneur, or a voter with a busy life and too little free time (or all of the above), there are things you can do to help avoid a climate disaster.

That's it. Let's get started.

CHAPTER 1

WHY ZERO?

The reason we need to get to zero is simple. Greenhouse gases trap heat, causing the average surface temperature of the earth to go up. The more gases there are, the more the temperature rises. And once greenhouse gases are in the atmosphere, they stay there for a very long time; something like one-fifth of the carbon dioxide emitted today will still be there in 10,000 years.

There's no scenario in which we keep adding carbon to the atmosphere and the world stops getting hotter, and the hotter it gets, the harder it will be for humans to survive, much less thrive. We don't know exactly how much harm will be caused by a given rise in the temperature, but we have every reason to worry. And, because greenhouse gases remain in the atmosphere for so long, the planet will stay warm for a long time even after we get to zero.

Admittedly, I'm using "zero" imprecisely, and I should be clear about what I mean. In preindustrial times—before the mid-18th century or so—the earth's carbon cycle was probably roughly in balance; that is, plants and other things absorbed about as much carbon dioxide as was emitted.

But then we started burning fossil fuels. These fuels are made of carbon that's stored underground, thanks to plants that died eons