POWER METAL

THE RACE FOR THE RESOURCES THAT WILL SHAPE THE FUTURE

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For Edith and Elaine
And Jed and Jane.

Greatly admired
Deeply missed.

INTRODUCTION

There's No Such Thing as Clean Energy

I bought my first all-electric car in 2018, back in what felt like the pioneer days of renewable energy, and, man, did I feel virtuous. There I was, with my unglamorous but morally exemplary used Nissan Leaf, doing my part to save the Earth.

At the time, I lived with my family in Los Angeles. Ours was a fairly typical setup—two parents, two kids, cat, dog, and, of course, two cars. How else could we have gotten around in a city like LA? But I was also very concerned about climate change, which was already afflicting life in our area with increasingly frequent and potent water shortages, wildfires, and heat waves. So, when our old Mazda hatchback finally gave out, I made the leap from gas to electric. At last, I thought, I was on the right side of history! No longer was I supporting any planet-plundering oil companies. My car emitted not a single ounce of carbon, no matter how far I drove. It ran on a battery I charged from a regular electrical outlet, just like my laptop and iPhone. In fact, I was pleased to learn, my car's battery, made mainly of lithium, cobalt, and nickel, was basically just a bigger version of the batteries in my digital devices.

True, the electricity to power those batteries came mostly from fossil-fueled power plants. But I expected that those carbon-spewing behemoths would soon be replaced by renewable sources, like solar and wind farms. Once that energy transition was accomplished, I figured, I would be leading

an environmentally blameless, climate-friendly life. My car would run silently on invisible electricity. I'd work and communicate with people wirelessly. The energy for it all would be drawn from sunlight and thin air. The image I had of my digitally enabled, renewably powered future life had a wonderfully weightless, dematerialized, untethered feeling of freedom to it.

Unfortunately, it was also utterly wrong.

As a journalist, it's my job to be inquisitive, to ask questions. I was curious about where the lithium, cobalt, nickel, and other raw materials for all those batteries in my machines came from. I started doing some research and quickly came to realize that the electric car I was so proud of, the digital devices I use every day and the renewable energy I was counting on to power them, are together spawning massive environmental damage, political upheaval, mayhem, and murder. To get the raw materials required to build cell phones, electric cars, and wind turbines, rainforests are being cut to the ground. Rivers are being poisoned. Children are being put to work in mines. Warlords and a billionaire crony of Vladimir Putin are getting rich. And untold numbers of people are getting killed.

The human race is facing a paradox: We must do everything we can to stave off the catastrophes of climate change, but, in doing so, we may create a whole other set of catastrophes. This book is an attempt to make clear the extent of the damage that process is already inflicting on people and the planet, the many ways in which it might get worse—and how we can do better. To build a sustainable world run on the digital technology we already take for granted and the carbon-free power we absolutely require, we need a whole new approach.

CHAPTER 1

The Electro-Digital Age

We are moving into a new era, a new phase in humanity's economic and social development. The twenty-first century is being shaped by forces that are changing how we communicate with each other, how we travel from place to place, how we heat and cool our homes, how we live our lives on an increasingly stressed planet. There are three major, interconnected drivers of this era: digital technology and the internet; renewable energy; and electric vehicles. Call it the Electro-Digital Age.

Digital tech, of course, is already deeply embedded in our lives and only growing more essential to almost everything we do. The other two drivers—renewable energy and electric vehicles—are coming on fast. In many ways, all of that is good news. The energy transition from fossil fuels to renewables is a crucial part of the cure for climate change. But it's a cure with brutal side effects. Taken together, the three pillars of the Electro-Digital Age are inflicting tremendous but largely overlooked harm all around the planet, including environmental catastrophes, child labor, slavery, robbery, and murder. They are also altering the balance of geopolitical power, mostly to the benefit of authoritarian regimes not especially friendly to the West. All of which is largely because the three pillars of this new, high-tech era depend on a set of ancient, natural materials: metals.

In our deeply digital, relentlessly online modern world, it's easy to forget, or ignore, or fail to appreciate the extent to which our lives depend on the extraction, transportation, and processing of titanic quantities of physical

materials. Millions of us, myself included, make our living dealing only with dematerialized abstractions, intellectual "products" that exist mainly on computers—articles, analyses, marketing plans, software, videos, podcasts. We process financial data, we build websites, we run social media campaigns, we develop business plans—products that have no physicality, no corporeality to them, beyond perhaps a hard copy version printed on paper. Information streams into our offices, we process it into other forms of information, and it streams back out again.

But all of that is made possible by machines—computers, phones, wireless routers, internet cables, data centers packed with computer servers—all of them drawing energy from enormous power plants. Just as most of us are disconnected from the processes by which our food is produced, we are disconnected from the processes by which our machines are manufactured. The raw materials from which those machines are built make our lives possible. And they come at enormous expense.

Laptops, tablets, and cell phones are made from a kaleidoscopic array of materials, from everyday metals to far more exotic and obscure substances. Mobile phones can contain as many as two thirds of all the elements in the periodic table, including dozens of different metals. Some of those metals are familiar: There's gold in the typical phone's circuitry, tin in its circuit board, nickel in its microphone. Some are not. Tiny flecks of indium in the screen make it sensitive to the touch of your finger. Europium enhances the colors you see on that screen. Neodymium, dysprosium, and terbium are used to build the tiny mechanism that makes your phone vibrate.

The batteries that power cell phones—probably the components to which we give the most thought—are made with lithium, cobalt, and nickel. Similar batteries energize your rechargeable drill, Roomba, electric toothbrush, and countless other cordless electric devices. That includes most electric vehicles, from e-scooters to Tesla SUVs. Electric cars are battery cars, but their batteries are *big*. Just one Tesla Model S can contain as much lithium as ten thousand mobile phones.

All of those batteries need to be charged, and charged again and again, with electricity. The more batteries there are, the more electric power we must generate to feed them. The millions of new electric vehicles hitting the world's roads each year come with a monstrous appetite for power. Driving those electric cars doesn't create carbon emissions, but generating the electricity that powers them often does. Today, the world's biggest source of electrical energy is still coal-fired power plants. The catastrophic impacts of our reliance on such carbon-intensive fuels are well-known. To keep those impacts to a minimum, we need to switch not only to electric cars but also to carbon-neutral renewable-energy sources, especially solar and wind, to power them.

Sunlight and air, beloved elements of the natural world, seem like wonderfully benign energy sources. So much more appealing than filthy coal or gooey petroleum. Solar and wind power are often described as free energy, since they literally fall from the sky. But they entail a Faustian bargain. To capture energy from the sun and wind, transmit it, and use it, we need machines. We need wind turbines, solar panels, switching stations, power lines, batteries.

Picture what's involved in the process of generating, transmitting, and using renewable energy. Los Angeles, for instance, gets a little more than 4 percent of all its electricity from the Red Cloud wind farm southeast of Albuquerque, New Mexico. The farm's dozens of towering turbines are made out of steel reinforced with a rare metal called niobium. Wind hits a turbine's blades, making them rotate. Inside the turbine, special magnets made with neodymium, another metal, convert that movement into electric power. Cables made with thousands of pounds of aluminum and copper then carry that electricity from the turbine into the New Mexico power grid. The electricity flows along hundreds more miles of copper cables to a switching station in Arizona and on from there to thousands of homes, garages, and offices in Los Angeles.

Thanks to those cables delivering the juice to my house, I can plug in my Leaf and electricity will flow into its battery. That battery is made with

approximately one hundred pounds of nickel, cobalt, and lithium, and nearly as much copper. When I step on the accelerator, hundreds of yards of coiled wires, made out of more copper, activate neodymium-based magnets, similar to the ones in the wind turbines, to convert the electricity back into movement, turning the car's wheels.

All of those machines, cables, wires, and batteries are made with metals. Metals don't fall from the sky. They are ripped from the Earth.

The Electro-Digital Age demands a terrifying amount of such ripping. To manufacture all the digital tech we demand and all the electric cars, wind turbines, cables, magnets, and other gear we require for the transition to renewable energy, we're going to need titanic quantities of what are variously called battery metals, technology metals, transition metals, or the term I prefer, "critical metals." In all of human history, we've mined about seven hundred million tons of copper. We'll need to mine the same amount again in the next twenty-odd years. By 2050, the International Energy Agency estimates, demand for cobalt from electric vehicle makers alone will surge to nearly five times what it was in 2022; nickel demand will be ten times higher; and for lithium, fifteen times higher, the annual total soaring from just under seventy thousand tons to over one million. The surge is well underway. The market size for copper, cobalt, and rare earths nearly doubled between 2017 and 2022, tripled for nickel, and septupled for lithium, reaching a total of $320 billion.

"Energy transition minerals, which used to be a small segment of the market, are now moving to center stage in the mining and metals industry," declared a 2023 IEA report. The market for critical metals is set to continue rising in the coming years—assuming the world can produce them. "The prospect of a rapid increase in demand for critical minerals—well above anything seen previously in most cases—raises huge questions about the availability and reliability of supply," warns the IEA.

All over the world today, governments, corporations, entrepreneurs, activists, and researchers are racing to figure out how to meet that mushrooming demand. Those millions of tons of metals have to come from

somewhere. Today, one industry provides the overwhelming majority of them. Our high-tech, carbon-free future depends on one of humanity's oldest and dirtiest endeavors: mining.

Mining is a rough business. Metals are natural resources, products of the Earth, but the Earth doesn't give them up willingly or easily. Digging up metals typically involves destroying the Earth in the most literal sense. The whole object is to tear up trees or grasslands or deserts, blast apart the underlying rock and earth with explosives, and rip out the remains. And it doesn't stop there. The metal-bearing ore clawed out of the ground has to be processed, smelted, and refined with enormous, energy-guzzling, pollution-spewing industrial equipment and oceans of chemicals.

"Mining done wrong can leave centuries of harm," says Aimee Boulanger, a former antimining activist who now heads the Initiative for Responsible Mining Assurance, a group that works with mining companies to develop sustainable practices.

The range and extent of damage inflicted by mining is staggering. Metal mining is America's leading toxic polluter and has sullied the watersheds of almost half of all the rivers in the American West. Chemical leaks and runoff often foul the air and water around metal mines. Mines also generate enormous piles of poisonous waste, which are stored behind dams that have a terrifying tendency to fail. Torrents of toxic sludge pouring through collapsed tailings dams have poisoned rivers and lakes from Canada to Brazil and killed hundreds of people. Those casualties are on top of the hundreds, possibly thousands, of miners who die in workplace accidents each year.

Chemical leaks and dam failures are unintended consequences. But even when everything is going as it's supposed to, mines inevitably inflict damage. They devour resources and excrete waste on a titanic scale. A study from the Vienna University of Economics and Business found that industrial mines have wiped out more than one thousand square miles of forests since 2000. Valuable metals typically make up only a tiny fraction of all the rock and earth that has to be dug up to get them. To get just one ton of nickel, an average of two hundred fifty tons of ore and waste rock must be processed.

For copper, it's twice that much. Seventy-five pounds of ore have to be wrested out of the Earth to build a single four-and-a-half-ounce iPhone. That ore has to be crushed and the metals separated from the waste rock around them, industrial processes that belch out as much as one hundred pounds of carbon per phone.

Mines also suck up huge quantities of water, a major point of conflict in arid regions such as northern Chile, which is home to some of the world's most immense copper and lithium operations. And the mines require fleets of drill rigs, trucks, diggers, and other heavy machinery, energy hogs that eruct megatons of greenhouse gases—as much as 7 percent of the world's annual total.

None of this is exactly welcomed by whoever lives nearby. Irate local residents and Indigenous communities are fighting proposed critical-metal mines all across the United States, from North Carolina to Nevada, as are their counterparts in Canada, Serbia, Brazil, the Philippines, and many other countries. In some places, this kind of opposition can have lethal consequences. At least 320 antimining activists around the world have been murdered since 2012. And those are just the ones Western human rights groups know about.

To keep our technology-abetted lifestyles going and to kick our fossil-fuel dependence, we humans need to get our hands on more critical metals. But we also need to find cleaner, more humane, more sustainable ways of getting those metals. How can we do that? Can we do it soon enough? Can we make our way to a truly sustainable world without trashing the planet in the process?

Searching for answers to those questions took me to mines, protest sites, and research labs around the world. I visited a shipyard in Belgium, a desert in Chile, a junkyard in Canada, and the biggest garbage dump in West Africa. I met some of the wild array of wealthy investors, grassroots activists, scientists, politicians, manual laborers, and artificial-intelligence experts who are all players in the trillion-dollar global race for the metals we need for this new era.

It's a race unfolding across the planet—and even on the ocean floor, not to mention outer space. Some aspects of it are genuinely promising, some are smoke-and-mirrors schemes, and some are disturbingly dangerous. This race will not only reshape industries, it will also affect the destinies of entire countries and alter the global balance of power. And it will force us to question how we organize our cities, our societies, and our lives.

The digital revolution is by now part of the everyday lives of almost everyone in the Western world, and, increasingly, the lives of everyone on Earth. As of January 2024, an estimated 5.35 billion people—about two thirds of the world's population—were using the internet. Nearly as many own mobile phones. All told, there are more than fifteen billion mobile devices in use worldwide.

The shift toward renewable energy and electric vehicles is also happening much faster than most people realize. Humanity is on the cusp of a new energy era that could be as transformative as our shift from wood to coal, and from coal to oil. Today's children will inherit a world powered in ways fundamentally different from that of their parents or grandparents. The shape of power, in the literal sense, is changing profoundly.

In talking about renewables, I'm focusing mainly on wind and solar power, because, at this point, they are the most advanced and rapidly expanding new sources of renewable electricity. There are others, of course. Hydropower is clean and renewable, but we've already dammed about as many rivers as we can (or should). Worse, climate-change-induced droughts are drying up rivers and reservoirs around the world, imperiling the hydro-energy supply. Many people consider nuclear power a viable, carbon-neutral alternative to fossil fuels, but that's a deeply complicated issue beyond the scope of this book (plus, it's not really renewable). Hydrogen may become a major energy source someday, but that day is still a long way off.

Solar and wind, meanwhile, are exploding. At the start of the twenty-first century, wind and solar combined produced a fraction of a percent of all the world's electricity. Now, they provide more than 12 percent. In the United States, renewables now provide almost a quarter of the nation's electricity,

outstripping both coal and nuclear. The IEA expects America's solar and wind capacity to nearly double by 2027. As of 2022, wind and solar were generating more power than all the world's nuclear plants. The disruptions to Russian oil and gas exports brought on by the invasion of Ukraine in February of 2022 jolted many nations into redoubling their efforts to develop more dependable alternatives, sparking what the IEA calls "unprecedented momentum for renewables." In 2023, the world created enough new renewable energy to power all of Germany and Spain. By 2027, the IEA predicts renewables will be the single largest source of electricity worldwide.

The electric car market is growing even faster—so fast that it's reshaping the entire automobile industry. As recently as 2012, only 120,000 electric vehicles were sold worldwide each year. By 2022, customers were snapping up more than that number every *week*. Sales of new electric vehicles are expected to top 30 million by 2030. California, Washington, and Oregon have all declared they will ban the sale of new internal combustion vehicles by 2035, and at least twenty countries have announced similar future prohibitions.

Every major automaker is rolling out electric models, from Cadillacs to pickup trucks. Industry heavyweights, including General Motors and Volkswagen, have declared they aim to phase out petroleum-powered vehicles altogether in the coming years. Electric-car battery factories are opening all over the United States and around the world. To safeguard their supply chains, carmakers are deepening their involvement with the mining industry. GM, for instance, recently sank $650 million into a proposed lithium mine in Nevada.

The critical-metal mining boom is also shaking up geopolitics. That's natural. Think about the last major energy transition, when the world shifted from coal to oil. Back in the coal-powered days, Saudi Arabia was an afterthought in global affairs. But with the rise of the automobile, the world suddenly needed huge amounts of a substance that hadn't been in much demand before: oil. Almost overnight, Saudi Arabia became one of the

richest nations on the planet. (Having learned from their history, the desert kingdom is now also investing heavily in critical-metal production.)

Similarly, a handful of little-noticed nations from the Arctic to the South Pacific now have a chance to reap fortunes from their huge reserves of metals that practically nobody cared about until recently. Way out in the South Pacific, the tiny French territory of New Caledonia holds as much as a quarter of all the world's unmined nickel. In the high Arctic, Greenland has enormous quantities of rare earths. Bolivia, in the middle of South America, has the world's largest deposits of lithium. The Democratic Republic of the Congo, in the heart of Africa, holds almost half of the world's cobalt reserves. Afghanistan harbors enormous deposits of copper, cobalt, and other metals. Remember the niobium that reinforced those wind turbines? Brazil produces almost all of the world's supply.

In Southeast Asia, Indonesia and the Philippines are just starting to fully exploit their huge nickel reserves. For now, however, the world's top producer of high-grade nickel is Russia. It's also a huge exporter of copper and other metals. Fears that Russia's war in the Ukraine might affect its nickel production sent the metal's prices skyrocketing in the days after Vladimir Putin launched the invasion in February 2022. Turns out, traders need not have worried. Though most Russian exports were closed off by international sanctions, the world quietly decided that Moscow's nickel, copper, palladium, and other minerals were too important to shut off. For more than two years after the war began, Russia continued to export billions of dollars' worth of nickel to the West. In other words, to some extent, the switch to electric cars helped to fund Russia's invasion of Ukraine.

But when it comes to winners in the critical-metals race, one country is way out in front of all the others. No matter what material you're talking about, at least one and quite possibly *all* of the steps in the production chain, from mining to processing to refining to manufacturing the final product, will take place in China.

Leveraging its own natural resources, relatively lax environmental standards, diplomatic clout, and shrewd overseas investments, China has, in

recent decades, come to dominate the entire supply chain for critical metals. China has huge reserves of lithium and other metals, some of which it allegedly mines with forced labor. The homegrown resources it lacks, it buys abroad; Chinese companies own mines all around the world that produce raw cobalt, nickel, and many other metals.

Regardless of where critical metals are dug up, or by whom, most will end up sent to China for refining and processing. China has more than half the world's refining capacity for lithium, cobalt, and graphite (another key battery ingredient) and close to that much for nickel and copper. Other Chinese factories then take those refined metals and turn them into most of the world's solar panels, a hefty share of its wind turbines, nearly three quarters of all lithium-ion batteries, and a majority of all electric vehicles. All of which gives Beijing not only a commanding position in the emerging economy of the Electro-Digital Age but also enormous geopolitical leverage. China has already shown, in recent years, that it is willing to cut off world supplies of a particular set of critical metals to support its political goals. It could unsheathe the embargo weapon again at any time.

Western nations have belatedly awakened to this vulnerability and are scrambling to address it. The United States, Canada, Japan, and the European Union have all explicitly prioritized finding non-Chinese sources for critical metals and are pouring cash and resources into the quest. "The United States' mineral import dependency and the concentration of mineral supply from certain countries are broadly recognized as growing threats to economic growth, competitiveness, and national security," warned the US Senate's Committee on Energy and Natural Resources in 2019. In 2022, the US Congress enacted an infrastructure package that included $7 billion to expand the domestic supply chain for battery minerals. That same year, it passed the Inflation Reduction Act, which includes many more billions of dollars to subsidize batteries and electric vehicles made with domestically sourced metals.

The good news is that there are many ways the rest of the world can get its hands on the metals it needs without bolstering Beijing (or Moscow) or

devastating natural landscapes. Start in the most obvious place: the mining industry itself.

I knew practically nothing about mining when I started researching this book, but I assumed it was a dirty, destructive industry, disastrous for the environment and anyone living nearby. Historically, that has often been true. But, to my surprise, I learned that it's not as true now as it used to be. The industry and the context it operates in have changed a lot in recent years and continue to change, often for the better.

In decades past, mining companies in league with greedy governments could just pick a spot to dig, shove aside whoever and whatever was living there, gouge the metals out of the ground, and dump the waste wherever was handy. Today, that kind of rape-and-run approach is much more difficult to get away with. Stricter government regulations, higher environmental and social standards, and the industry's evolving perception of what's in their self-interest are doing a lot to change mining practices and minimize their damage. Much of that is because mining's chief opponents—environmentalists and the local communities and Indigenous people who bear the brunt of the industry's impacts—now have far more legal protection, political power, and social clout than they used to.

Fifty years ago, the environmental movement barely existed. Indigenous peoples and local communities had little recourse against mining companies that came looking for precious metals on their lands. The playing field was tipped wildly against them. Today, that field is still far from level, but it's not nearly as lopsided as it used to be. Groups like Greenpeace, Friends of the Earth, and the World Wildlife Fund have millions of members and operations in dozens of countries. A welter of international agreements and national regulations are on their side. And in a world in which almost everyone has a video camera in their pocket and the means to broadcast to the world, it's much harder to get away with the terrible practices for which the industry had become infamous. Even industry titans like Robert Friedland, a Canadian American mogul nicknamed "Toxic Bob," acknowledge this. "Every one of these hand phones is an NGO," he told a