CHAPTER ONE

MAKING APPLE PIE FROM SCRATCH

If you want to understand what's wrong with energy in the United States today and how it might work better tomorrow, you need to start with the electric grid—that network of wires that ties electric generators to consumers and consumers to one another. Today, the electric grid stretches from coast to coast, linking subdivisions in Alabama with grocery stores in British Columbia. Here, there, and everywhere in between, our daily lives are dependent on this grid, from the moment the digital alarm clock buzzes us awake at dawn. But reliable, always available electricity service—the ability to flip on a light, anytime, anywhere, and know it will work—doesn't just happen.

A simple experiment can help explain the basics of generating electricity. Take a bar magnet and slide it quickly in and out of a coil of copper wire. Every time you do this, you'll produce a small electric current (and a large potential for immature jokes). The physical tango of a conductive metal moving through a magnetic field produces electricity. The interaction of magnets and metal doesn't actually "generate" something out of nothing. Instead, the magnetic field simply forces electrons to move. You know how an atom is set up—a central nucleus surrounded by a cloud of electrons. In conductive metals, the electrons aren't tied down to any one atom. Rather, they mingle, forming something akin to a river of electrons in which atomic nuclei float like buoys. The magnetic field makes the electron "river" flow along, from one buoy to another. What we call "electric service" is simply the movement of electrons around a closed loop of wire. On one end is the generator; at the other is your house.

That's the simplified version. In reality, the grid is vast and mighty. Yet it had a humble birth. In 1882, the first two permanent central electric plants in the world—within a month of each other—began to push electrons around some very short loops of wire.

These first experiments in grid building were very different from what we know today. None of the customers were farther than a short walk away from the power plants. Neither proto-grid operated during the day. At the time, there wasn't much you could *do* with electricity besides turn on light bulbs, so electric service started at sunset. Both systems were still little more than working prototypes, buggy and prone to mishap. However, the first plant, which opened on September 4, had a slight advantage over the second. Installed in a warehouse in what is now New York City's financial district, it was built and run by Thomas Alva Edison. The project was his baby, the result of countless hours of work. Earlier that same year, Edison and his hand-picked team had set up a temporary centralized electrical system in London, part of a larger Edison exhibit at London's Crystal Palace.[1] They were literally the only people in the world with practical experience in controlling a grid. What's more, they'd invented or improved nearly every part—from the coal-powered generators right on down to the very lightbulbs.

Twenty-six days later, the second permanent centralized electric system—and the first hydroelectric power plant in the world—began operations. It was in Appleton, Wisconsin. Yes, seriously. London, New York, Appleton, and the story gets a bit weirder from there. See, the Appleton system was only a licensee—the brainchild of a group of local businessmen who bought a couple of Edison generators and built a power plant around them. They had no experience with controlling electricity. In fact, the nearest electrical engineers of any quality were two hundred miles away, in Chicago. If Thomas Edison's New York system was an epic triumph of biblical proportions, then Appleton was more like *Waiting for Guffman*.

And yet it worked. Mostly. I could tell you about the successes of Edison, but there's no risk there. You, me, the nineteenth-century civic leaders of New York City—we all trust the Menlo Park boys a little too much. If you really want to understand how hard it was to build a functioning grid, you can't follow the exploits of the team of geniuses who could simply invent their way out of any problem. If you think the American public was optimistic about the electric grid or that it was an instant business success, then you need to see what was happening outside the confines of the Edison Electric Company. Appleton gives you a more rough-and-tumble view of history, unpolished by all of the mythology surrounding a great historical figure. To make sense of what's happening to our electric infrastructure today, you have to start in Wisconsin.

Appleton sits on the Fox River, a little south and west of Green Bay, part of a chain of small cities that ring Lake Winnebago. Back in 1882, that waterfront location wasn't only about great views or good fishing. The river and the lake themselves were vital parts of the infrastructure. In a time before reliably passable highways, water was the interstate. When energy meant hauling coal or felling trees, the Fox River was a cheap and easy power source that could run entire factories. The water made products. The water shipped those products, and Appleton got rich.

Or, at least, *some* people in Appleton got rich: H. J. Rogers, for instance. Rogers was a man of industry and action—a Gilded Era capitalist, with a fabulous, fluffy mustache to prove it. The *Appleton Post* and the *Appleton Chronicle* considered his dinner parties legitimate news. When his family took a jaunt to Chicago, it made both papers. So it wasn't terribly surprising when the local media printed a short announcement that Rogers had taken a fishing trip in July 1882, along with a salesman who was working for the Western Edison Light Company. The papers printed a longer article when he came back from that vacation, a proud Edison Electric licensee. Take it as hubris. Take it as evidence of why you should never go fishing with salesmen. But, despite owning the city's gas light company and without ever having so much as seen an electric light himself, Rogers decided that he was going to electrify Appleton, starting with his own house. Ever enthusiastic, the papers crowed about the coming success—and then promptly stopped discussing the plans surrounding Rogers's new venture for the rest of the summer.

You have to read between the lines to get at the local public sentiment. For instance, whenever the *Post* and the *Chronicle* made any mention of electric light after July 1882, it came with the solemn assurance that such lights were *perfectly* safe. Decades later, the *Wisconsin Magazine of History* would report that the lack of news during the summer of 1882 led to rumors that Rogers wasn't planning on building an electric system at all but had simply bought the rights in order to keep his gas company's monopoly on artificial light.[2] Meanwhile, even the personal letters of A. L. Smith, one of Rogers's business partners in Appleton's new electric lighting utility, imply that not everyone was entirely convinced that this "electric light" thing would pan out. A few months after Rogers and Smith *did* manage to get their system up and running, Smith wrote to his sister and asked, about her husband, "What does Walter think now about Edison?"[3]

There were good reasons to be skeptical. Gas lights, for instance, had been around since the 1790s and had proved to be somewhat flawed. The gas was delivered via wooden pipes, built like long, skinny links of pickle barrel. That design held liquid okay, but it tended to leak gas. When you added gas light to your home, you were making a trade—convenience in exchange for a weird, oppressive stench.[4]

Electric lights offered a tidier option, but dozens of researchers had been fiddling with the incandescent lamp for eighty years, and nobody had been able to translate that into real commercial success. Worse, Thomas Edison had sold some decentralized electric systems to rich first-adopters, and the results of those experiments weren't totally comforting. In the spring of 1882, Edison wired W. H. Vanderbilt's New York City mansion for electric light, powered by a generator installed in the Vanderbilts' basement. The wires had very little insulation. The wallpaper in the Vanderbilts' parlor was actual cloth, interwoven with bits of metallic tinsel. When Edison switched on the lights for the first time, the wall went up like a match. In the end, the house was saved but not the electrical system. Understandably freaked out, Mrs. Vanderbilt ordered it removed.[5]

It's a little mind-blowing to think about how much the way we use energy changed in a century and a half—and, at the same time, how *little* it changed. On the night of the Vanderbilts' parlor fire, Americans consumed about 5 quadrillion BTUs (British thermal units) of energy per year—not counting the energy from the sweat of their own brows or the muscles of their livestock. At this point, burning wood was still our number-one energy source. Back then, Americans used energy for heat, for light, and to turn water into the steam that powered trains and factories.[6]

Today, we consume a lot more energy than that, and we use it to accomplish different tasks. The most recent complete data is from 2009, when we used 94.6 quadrillion BTUs. Because of the "quadrillion" and the somewhat abstract unit of measurement, this number might not mean a lot to you. Let me put it another way: in 2009, Americans used enough energy to completely boil away the Great Salt Lake twice over.[7] Most of that energy use went into making electricity. We used 38.3 quadrillion BTUs—a full 41 percent of our total energy consumption—for that purpose. Of that, most(48 percent) came from coal, with a little help from nuclear power (22 percent) and natural gas (18 percent). Renewables, mainly hydroelectric power, accounted for 11 percent of electricity generation.[8] All of this would have left the Vanderbilts boggled.

Ditto for our second largest energy expenditure: transportation. In 2009, we used 27 quadrillion BTUs—or 29 percent of the total—on transportation. Mostly, we're talking about petroleum here, the gasoline for cars, the jet fuel that makes planes fly, and the diesel that moves semitrucks from coast to coast.

In contrast, the last two sectors of energy use would have been much more familiar to nineteenth-century Americans. Industry used 18.8 quadrillion BTUs—20 percent of the total. That sector burns natural gas or coal on-site at factories for heat or to make electricity that never enters the national grid. The industrial sector also used a lot of petroleum but not for transportation. Instead, industries turn petroleum into everyday chemicals and products. Finally, residential and commercial buildings consumed 10.6 quadrillion BTUs—11 percent of our national total—in the process of making buildings, food, and water warmer. Most of that was natural gas, which heats up your oven, keeps your morning shower cozy, and powers the radiators that make Wisconsin winters bearable.

Obviously, a lot has changed since the 1880s, but some key details remain the same. For instance, nineteenth-century Americans would have understood our reliance on fossil fuels. By 1885, coal had overtaken wood as America's main energy source. Since then, fossil fuels have ruled. No other energy source even comes close.

Yet even though a lot more Americans use electricity today than they did in 1882, most of us don't understand it any better than the Vanderbilts or the citizens of Appleton did back then. Case in point: most of the energy we put into electricity is wasted. We burn it and never get a benefit. Of the 38.3 quadrillion BTUs that go into electricity production, 66 percent never becomes usable electricity. Instead, it falls victim to conversion losses—turning into heat that warms up the air around a power plant, rather than actually producing electricity. Only 12.8 quadrillion BTUs make it to us through the grid.

Finally, electricity was and is primarily something we use in buildings. Back then, it was only for lightbulbs. Today, the uses of electricity have multiplied. Out of that 12.8 quadrillion BTUs' worth of electricity, 72 percent is used by houses, apartments, offices, stores—the places we live and work. That's the lights and the air conditioners, the electric heaters and the stoves. It's appliances, computers, cell phones, and all manner of plug-in gadgets. In 1882, few people imagined how much American lives would one day depend on the electric grid, but they could identify with the difficulties involved in keeping that grid up and running.

On September 23, 1882, the Appleton newspapers announced that the first of two electric generators had arrived. This generator had a squat, bulbous metal base that sprouted three pairs of tall copper cylinders, which were topped off with another thick block of metal. Metal prongs stuck out of the top, and wires connected to those prongs tied the generator to the power lines. The Edison K Dynamo is a complicated-looking piece of machinery, but how it works is really really fairly simple.[9] Electricity generation in 1882 and, for the most part, still today is based on the phenomenon I mentioned earlier—the movement of conductive metal through a magnetic field.[10] So the issue of where electricity should come from, one of the most contentious questions covered in this book, really boils down to, "How should we make that metal move?"

Today, we have a lot of different options. In 1882, there were only two. You could move the metal using steam produced by burning coal, or you could use the power of water. In Appleton, Rogers chose the latter, building the world's first hydroelectric power plant. It was installed at a riverfront paper mill, which was also owned by Rogers. There, the Fox River turned a water wheel that moved a system of gears, which spun a cylinder of conductive metal between the six tall magnets. That got the river of electrons flowing, and wires carried that river throughout the paper mill and to the power plant's only residential customer: Rogers himself. Or, at least, that was what was supposed to happen. On September 27, Rogers turned the generator on, but the lights at his house did nothing. A second attempt, on the morning of September 30, also failed. It wasn't until after dark—by which point, a sizable crowd had gathered near Rogers's hilltop mansion—that the electrical system worked as promised. Even at the birth of electrified life in America, how energy got from here to there was just as important as how it was made in the first place.

The success, however, was not unequivocal. "Two and a half months after [the salesman] had first talked to Rogers about it, the first hydroelectric central station in the world was in business," wrote Forrest McDonald in *Let There Be Light*, his 1957 book on the history of electric utilities in Wisconsin. "But this speed was accomplished partly by the omission of several of the safety and reliability features of the complete Edison system and partly by the use of makeshift equipment."[11]

There are several important lessons that you need to learn about the way energy works in the United States. This is the first: our current energy infrastructure isn't the same as an *ideal* energy infrastructure. These systems that we stake our lives and livelihoods on every day weren't designed so much as they evolved, the sum of lots of little decisions made to meet immediate needs or solve short-term problems. There are inefficiencies. There are kludgey temporary fixes that became long-term staples. If it looks as if we're making it up as we go, it's because, in a lot of ways, we're making it up as we go. The result serves our current needs—most of the time—but you shouldn't be surprised that the energy infrastructure will require a serious overhaul before it can meet the needs of future generations.

Appleton is a great example of how this happened. The infrastructure was built quickly and built to be cheap. Whether it could do the best job possible didn't factor into the equation. Even the very location of the generator turned out to be a bad decision. To save time and money, Rogers initially opted to have the generator be powered by the same water wheel that ran the pulp beaters on his paper mill. It was the mill's activity, however, not the electrical system, that determined how fast the wheel needed to turn. This meant, on a busy day at the factory, that the wheel would be set to go at top speed, with little regard for what the generator wanted to do—and that meant trouble.

Think back to our river of electrons. It can't simply flow from place to place randomly. It's not a wild force of nature that we can sit back and watch. We're not talking about some mountain stream or even the dammed and barricaded Mississippi. In reality, the electric grid has more in common with the lazy river at a water park. Imagine the grid as a channel of water running in a loop. This lazy river has to be just the right depth, an analogy that corresponds to what electrical engineers call *voltage*. It also has to move at a constant speed—what the engineers call *hertz*. Rogers didn't take either of those issues into account. To maintain the right balance of hertz and voltage, you have to produce just about exactly as much electricity as is being used at any given point in time. There's not much wiggle room. The water that's being dumped into the channel has to equal the amount of water being pumped out of it. Basically, Rogers's system left the spigots on at full force but without nearly enough drains. So the water backed up, the channel flooded and, in the Rogerses' home, electric lightbulbs burned out—bulbs that cost the equivalent of $35 a pop. Inadvertently, Rogers had stumbled onto an important rule about electricity, one that you'll soon find we're struggling with even to this day: having too much electricity is just as big a problem as having too little. Within two months, Rogers had arranged to move the generator to its own building, powered by its own water wheel.

I've peeked inside a replica of this power plant, constructed on the original site in the 1930s.[12] Really just a shack, it was smaller than my bedroom back home. At one end of the rectangular room, enthroned up on a little dais, sat the generator. At the other end was a chair, next to a bare electric lightbulb that dangled from the ceiling. Even after Rogers was forced to put the power plant in its own building, he still didn't learn his lesson about making the river run smoothly.

For years, that lightbulb was the closest thing Appleton had to a voltmeter. Staring at it was the only way anyone could tell whether the electron river was too deep, too shallow, or just about right. Edison had invented a meter to monitor the system more accurately, but Rogers and company didn't buy it. Instead, whoever was on duty simply watched the bulb, looking for signs that it was glowing a little too brightly or a little too dimly.[13]

The missteps didn't end at the generator itself. Today, electric wires are coated in thick layers of insulating plastic. In Appleton, if a wire was insulated at all, it was usually just wrapped in a thin coat of paper or silk. In that state, it was pretty easy for anything—a twig, a squirrel—to dam the electron river and short out the wire. When that happened, the entire grid had to be shut down. A. C. Langstadt, one of the early controllers who started working in Appleton after the system had picked up a few more customers, remembered regularly having to stop work, turn off the generator, and spend an hour—or even a full day—going from house to house looking for the shorted wire.

There wasn't even a good way to know how much electricity was being used. Again, Edison had invented an electric meter, but it would be years before that technology came to Appleton.[14] In the meantime, customers were simply charged a flat rate, per lightbulb, no matter how long they left the bulbs turned on. The generators didn't run at all during the day. The grid was activated in the evening and shut down again at daybreak. Because the price was the same, though, many customers simply left the lights on all night as a status symbol—their houses glowing long after everyone had gone to bed.

This brings me to the second fact you need to learn about energy in America today: we waste a lot of it. When you think about using less energy, you probably think about conservation, doing without something you want. This assumes, however, that we get something valuable out of all of the energy we use right now, and that's simply not true. Remember how much energy we burn through at power plants and how little electricity we get out of it? The same is true in our homes, our offices, and our cars. If we cut out the waste, we could use a lot less energy and still benefit from what energy does for us. That's called efficiency. Yet as in Appleton many years ago, we don't have a lot of good incentives out there today that lead us to be more efficient. In fact, the opposite is often true, particularly because getting efficiency right can be more complicated than it looks at first.

Without incentives, efficiency simply won't happen—and if efficiency doesn't happen, then we have a problem. In fact, a lack of efficiency also turned out to be a big problem for Rogers and his business partners. Back then, electricity was pretty cheap to make, but these men spent far more money building the infrastructure to run the grid than they made back from their customers. It wasn't just because of the poorly thought-out pricing scheme, either. Think of all of the ways you use electricity every day—all of the appliances and the gadgets that are plugged in 24/7. None of that existed in the early days. For decades, electricity was simply a tool to produce light and nothing more. Even after meters were installed, customers couldn't possibly use enough electricity for investors to make a return. In 1884, Rogers wrote of his accounts always being overdrawn. Within a few years, he de-invested from the utility and left Appleton entirely.

The utility company didn't fare much better. After the first three years, investors had plopped down the equivalent of more than $500,000 and found that they owned a business worth far less. They never got any dividends. By 1896, the Appleton utility was bankrupt—and it wasn't alone. Across the country, most of the companies that built the first grids failed. Edison made plenty of money from his patents, but very few people got rich off electricity itself. Today, we see electricity as a story of success, but that's with the benefit of long-term hindsight and big-picture thinking about what turned out to be good for you and me. For people such as H. J. Rogers, electricity was nothing but a dreadful, belly-up failure.

In that flop, you'll find two more lessons about energy in the United States. Energy is always about economics. When change happens—and when change *doesn't* happen—there are probably dollar signs behind it, and that's okay. As we pay attention to the symptoms of climate change, we can't ignore our wallets. Oil may be a limited resource, but so is money. Rogers made some big mistakes when he tried to build an energy system at the lowest possible cost, and we're facing our own consequences from that same sort of mentality today. Yet that doesn't mean the correct response is to spend as much as possible. We have to put some thought into this and get the changes we need at a price we can afford. Which brings me to another important lesson: "A price we can afford" is still going to be pretty damn high. We don't want to simply throw money at a problem without considering whether it's being spent wisely or whether we could get the same results for less cash. At the same time, however, we do have to accept that energy change will not be cheap. The biggest costs are always in infrastructure, which is why even "free" energy from the wind and the sun won't actually be free. The wires, the generators, the rights-of-way for transmission, and the controllers to make sure everything works—it all costs a lot of money. Even on the relatively small scale that Appleton was dealing with, infrastructure turned out to be far more expensive than most nineteenth-century businessmen would have realized.

"You had to put this enormous infrastructure in place before you could make a penny," says Gregory Summers, an associate professor of history at the University of Wisconsin-Steven's Point. "And it broke down all the time. Companies failed all the time. Utilities, railroads, lots of nineteenth-century businesses had this issue with fixed costs."

Summers studies the history of industrialization, technology, and environmental politics. He says the dawn of twentieth-century living—the increase in convenience and comfort that was dependent on the construction of new, massive infrastructures for transportation and energy—represented a major shift in how businesses operated. Right up until the end of the 1800s, the relatively cheap cost of operations—making the widget—was the main problem companies worried about. "If there was a recession, you'd just shut down the factory and reopen later," Summers says. "Now, think about something like an airline today. If it temporarily shuts down, it would keep on losing billions every day, because it would keep losing money on the infrastructure. [People in the nineteenth century] weren't accustomed to running a business where the biggest expense was fixed costs, rather than operating costs."

That sort of blew my mind, but, then, I've only known a world where infrastructure already exists. For all I knew when I was a little kid, electricity poles grew with the trees. But the truth is that Americans today are using a system that took a century to build. Some of the investments in that system were public and some were private. Either way, building that infrastructure cost a lot of money. As late as the 1930s, Summers told me, electricity was still something of a luxury—expensive and available only in urban markets where the costs could be spread among a large number of customers, without the utility having to build an equally large grid.

Rural America didn't get electricity until the government stepped in and was able to spread the cost of constructing an infrastructure across the entire country. For infrastructures where that kind of national investment didn't happen, it took a very long time to catch all Americans up to the same level of modernization. Case in point, the telephone. My maternal grandparents lived on a farm about fifty-five miles northwest of Kansas City, Kansas. In the mid-1980s, they were still stuck using a party-line system. Essentially, multiple households shared the same phone line. I can remember my grandma having me pick up her phone to check whether the line was in use before she could make a call.

Today, electricity is relatively cheap, because the basic infrastructure already exists. Utility companies build new power plants here and replace a stretch of wire there, but that's really maintenance of the grid—not creation of it. It's been thirty years since anyone made major investments in the network of wires that feeds electricity around the country. One big reason the people who own coal-fired power plants are so keen on keeping those plants up and running is that their investments were paid off long ago. They only have to worry about covering the cost of operation, and they pass those savings on to you. In some ways, with electricity, we've almost come back around to a point where—like H. J. Rogers and his business partners in Appleton—we have a hard time figuring out how to run a business that has to build its own infrastructure.

This is important stuff to think about. The national grid was pieced together from a quilt of little grids, such as the one in Appleton, which were themselves built partly on know-how and partly on after-the-fact engineering. The grid is like a river, but it's also like an old house that's been heavily remodeled and expanded, at different times and by different owners. In its current form, the grid can't handle lots of electricity coming from sources as variable as wind and solar. To make renewable energy work, in the long run, we'll have to upgrade, and that will get expensive. Yet you have to put those costs in perspective. For one thing, there are some pretty big chunks of the grid that will need replacing in the near-term future, anyway. Take transmission lines—the wires that carry electricity over the long distances between cities and states—and distribution networks, the wires that move electricity around your town. Neither of these systems has had much work done since the late 1970s, especially transmission lines.

At this point, the complexity and cost of changing America's energy systems sounds pretty daunting. Maybe it even sounds like something to avoid. Unfortunately, that's not really possible. For all of the problems associated with changing the way we use energy, doing nothing is likely to be worse. Despite its flaws, our infrastructure is something we can't live without.