# 3

# A History of the Electric Power Industry

## 3.1 THREE INTERTWINED ASPECTS GREW SIMULTANEOUSLY

In the century from 1885 to 1985, the electric power industry grew from a series of fledgling "technology opportunists" – small companies that would be called "start-ups" today – into a cornerstone of our civilization. In its first three decades, the electric industry had tremendous hurdles to overcome. To begin with, homeowners and businessmen in the late 19th century had no way to *use* electricity. Houses and commercial buildings of the time lacked the internal wiring that is ubiquitous today. But beyond that, *there were no electric appliances available* in stores, so that even if homeowners, businessmen, and factory owners had access to electricity, they could do nothing with it. People did many things *manually* that are done today with electricity. They ironed clothes with heated irons, made coffee with percolators heated on stoves, and ran sewing machines and washers by hand. For light, they used the sun, kerosene lamps, or firelight. Finally, few people understood electricity, and even fewer trusted it.

But against these barriers to its use, electricity had several advantages. It was clean, odorless, flexible, and easily controlled. As a result, a market demand developed quickly. The electric utility industry began a process of intertwined growth in three mutually dependent aspects: electric power *usage,* electric power *technology,* and the electric power *business,* itself. Each was necessary for continued growth of the other two. For example, there would be no need for technology, and no business, if there were no demand for electricity. Similarly, despite growing demand and improving technology, without a sound business structure, the industry would not have flourished. This chapter will trace each of these three strands of electric utility history: usage, technology, and business.

## 3.2 GROWTH OF ELECTRICAL USAGE

The original and initially the *sole* use for electricity was lighting. Thomas Edison patented the incandescent light bulb on January 27, 1880. Electric lighting represented a staggeringly important breakthrough in the late 19th century. It provided bright and unwavering illumination, but required no fuel, had no flame, produced no odor or fumes, and presented no fire hazard. It could be controlled with the mere turn of a switch.[1]

There had been earlier forms of electric lighting. An inventor named Charles Brush, who was to compete against Edison briefly and unsuccessfully, had used arc-lights, and other types of “illuminating devices” several years earlier. Many other inventors had similarly tried to tackle the problem of practical electric lighting. But none mastered the requirements: making it small enough for room application (arc-lights were bigger than a team of horses), and making it reliable, easy to run, and inexpensive.

Edison’s incandescent lighting was so utterly superior to other forms of exterior and interior lighting that *lighting companies*, whose sole business was the sale of electric illumination, had no trouble establishing themselves as viable and growing businesses. These early companies sold lighting, not electricity. *They billed their customers according to the number of light fixtures*, *not on the basis of actual usage*.[2] The major barrier they faced was daunting. Homes and businesses had no internal wiring! Therefore, lighting companies not only had to build electric distribution systems, but install conduit, light sockets, fuses, and switches inside their customers’ homes and businesses. Still, they did a brisk business, because there was a great demand for their services. The unwavering glow of electric light through the window shades of one’s home at night was a sign of personal prosperity, and the telltale conduit for wires running along the baseboards and across the ceiling to a retrofitted light fixture inside one’s home were sought after signs of prestige by Victorian-era yuppies, much like a three-pointed star hood ornament would be a century later.

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[1] Early wall switches rotated on and off, much like the switches on table lamps, rather than flipping up or down as today’s wall switches do. Hence the phrase “*turn* on the lights.”

[2] How and why they billed this way will be discussed in a later section on the history of the business side of electricity.

## Moving Usage Beyond Lighting

For the first decade of the electric power industry, lighting represented virtually all electric usage. It still represents over 30%. Early electric companies realized that a big potential source of revenue was the sale of power to run large electric motors, which could be used for numerous industrial applications. Many of these first light companies quickly became more interested in large industrial sales than in retail sales of lighting to homeowners because of the higher revenues they could realize. They focused on selling both motors and electricity to factories, grain processing centers, water pumping plants, and the like. Electric motors were reliable, relatively quiet, needed no fuel, and did not require the plant to be located on a stream or river, as waterwheels did. More important, they were easy to operate and required relatively less maintenance than other power sources.

Another industrial application that fascinated Edison and George Westinghouse, as well as other early inventors and advocates of electric power, was electric railways. Electric-powered locomotives were particularly suited to urban use, for what is called "people movers" or "mass transit systems" today. Electric trains produced no clouds of dense smoke, soot and cinders, as did the coal-fired locomotives of the 1880s. They were quiet, controllable so they could start and stop quickly, and they accelerated much faster than coal-fired locomotives. *Electric railways and trolleys were an important element of early electrification.* Their widespread use continues to this day throughout Europe. Widely employed in the United States until eclipsed by the popularity of automobiles, they all but died out by the 1960s, but are enjoying a strong comeback in the 21st century, a modern, "low-impact" solution to urban commuting.

Although industrial usage soared to the point that many early electric utilities concentrated on it in the late 1880s and early 1890s, the residential and small business market was too big to ignore. Even before light companies began to set up shop, they recognized that electricity could perform other types of useful work besides providing light. Small electric motors could turn fans or replace the manual treadle of sewing machines, could power refrigerators, obviating the need for weekly ice deliveries, and they could also run washing machines, reducing the physical labor involved in all of these activities. Electricity could also produce heat, for toasters, clothes irons, and coffee percolators. In all such applications, it offered greater convenience and smaller appliance size than traditional methods, e.g., the alternative to a conventional oven being the far smaller electric toaster.

Not much imagination or engineering skill was needed to invent a plethora of electric appliances, like toasters or sewing machines, which basically just applied electricity to traditional needs. But it took time for manufacturers to set up shop to produce such items, and for retailers to begin marketing them. It took still more time for a few adventurous souls to buy them and discover that they worked well, and for word to spread that electricity was a superior way to get the job done. Thus, for the first quarter of the 20th century, electricity only spread slowly to other applications throughout households and businesses, where it was regarded as a *premium* means of doing work – more expensive but worth it for those who could afford it. For example, even as late as 1947, many families did not own a toaster, let alone a washing machine, the average cost of which was $240, or about $1,770 in today's dollars. Once a great luxury of the post-war era, these appliances became items that cost less today than a generation ago.

### The Radio and a Change in Attitude about Electricity

Of all electric devices ever invented, the radio had the greatest "psychological" impact on society, for it permanently altered the way people regarded electricity. Before the invention of radio, electricity was just a better way of doing things, a more convenient replacement for whale oil and kerosene (lighting), coal and wood (cooking, ironing, making coffee, making toast), waterwheels (industrial motors), and other power and energy needs. Everything electricity did could be done – had been done – by other means. Even a phonograph could be powered by a manual crank. But radio was different. It worked only with electricity, and it did something never done before. *Electricity could do things nothing else could.*

Although radio communication had been discovered in the 1890s, it took until the 1920s for reliable receivers to be available at prices affordable to large portions of the public. Radios exploded into the marketplace. Americans spent an impressive $60 million on radios in 1922 – representing roughly a million home units at an average price of about $60 each. Four years later, an incredible *half billion dollars* was spent on radios. Many Americans were buying their second or even third – keeping up with technological progress. Radios evolved as rapidly as cell phones and personal assistant and entertainment systems ("Blackberries," iPods) do today, with "new" models becoming obsolete within three years, during the 1920s.

During the 1920s and early 1930s, the public attitude about electricity gradually shifted, due mostly to widespread use of the radio. Now, electricity was not merely a more convenient means to accomplish useful things that had been done by traditional methods. It was apparently essential to "modern" technology and progress.

As a result, by the late 1930s, electricity was regarded by many people as a basic utility, like water and sewers. This was an opinion that grew and hardened until it was not disputed by any credible politician, as will be discussed under the history of electricity's business side, later in this chapter. By the 1940s, prevailing opinion held that everyone should have access to electric power, and that facilities for its distribution should be built into every home and business. Thus, in roughly a half-century, from 1890 to 1940, electricity grew from a useful, prestigious service into a basic utility that was considered a necessity by both the public and the major political sectors throughout the United States.

## Electricity Application Continues to Grow in Diversity

The growth of electric demand in the remainder of the 20th century was due to the broadening application of electricity, as shown in Figure 3.1. A diverse range of applications for home, office, and industry grew steadily. Although initial electricity usage was where electricity replaced traditional ways of accomplishing needed functions such as lighting, water heating, etc., most of its continued growth was driven by new applications, which, like the radio, had no non-electric counterpart (shaded area in Figure 3.1). The two most recent major new applications were the microwave oven (about 1970) and the home computer (about 1985), which by the year 2000 were in nearly 90% of US homes. While the rate of invention of new electrical applications has slowed, and for the time being focused on personal, portable applications (cell phones, etc.) there is no reason to believe it will not continue indefinitely.

Electric usage grew because electricity could perform many functions better than other energy sources, or could provide functions that could not be done by other means. Either way, usage increased because electricity offered high value.

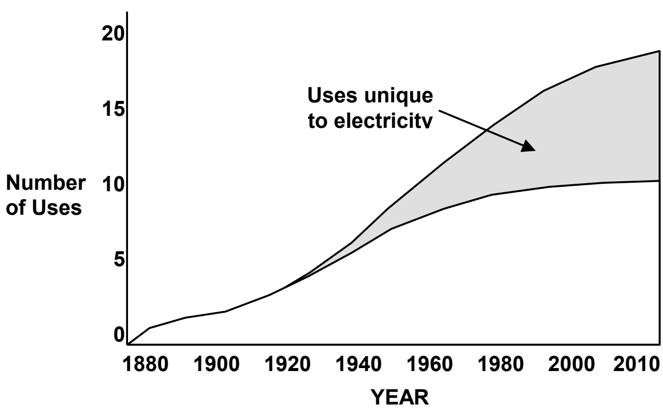


**Figure 3.1** The number of different types of electric applications in a typical home (e.g., lighting, dishwashing, TV) has grown almost steadily from 1882 to 1997. Initially, electricity's sole use was lighting. Gradually, it was used for other applications, such as cooking, ironing, etc. Widespread use of the radio, beginning in 1920, initiated an era of appliances and devices that operate *only* on electricity and that have no counterpart in non-electric applications (gray area). *Source: Energy Education Specialists.*

Nevertheless, while many of these new uses for electricity contributed great value to home and business, few consumed a lot of power. Televisions, whether the crude vacuum-tube affairs of the early 1950s or the biggest-screen models of today, consume only about as much power as a large table lamp. Washers and dryers consume a lot of power when running, but operate for just a few hours a week. Then as now, the fans, toasters, coffee pots, radios, sewing machines, washers, dryers, etc., of earlier eras use much less electric power than lighting.

## Air Conditioning Becomes a Major and Heavy Usage

Almost the sole exception to the trend of light electric usage among new electric applications was air conditioning. Cooling a home or office requires a lot of energy, even when the buildings are properly insulated and the air conditioning units are efficient. Although the basic principles were understood even before the advent of electric systems, air conditioning on an individual household basis really only became reliable, affordable, and practical in the early 1960s.

Increasing sales of electricity for air conditioning contributed greatly to the electric industry's continued growth in the 1950s through the 1970s. "Space cooling" increased the value that electricity could contribute to its users, and as a result it raised electric sales tremendously. Today, throughout many parts of the United States, air conditioning of one form or another accounts for up to *half* of residential electric usage. In most areas of the United States it is the only end-usage that exceeds lighting in overall amount of electricity consumed. It contributes a huge amount of revenues to electric utilities.

## Cost of Usage Decreased over Time

An important accompanying trend to the broadening *diversity* of electric usage was that the *cost* for it has dropped steadily since 1880. This is partly because over the long term, 1880 to 2000, the cost of electric power, if adjusted for the changing value of the dollar, *declined significantly*. Average electric rates dropped from over a dollar per kilowatt hour to less than ten cents.

However, the cost of electricity is only *one* element of total cost, and usually not the most important to consumers. Appliance costs usually outweigh the price of electricity, and they have dropped steadily for the past century. For example, in 1925 the purchase price of a basic clothes iron was $8, that for a basic radio $65, equivalent to about $60 and $400 in 2005 dollars. Eighty years later, a basic iron costs about $20, a radio only $25. A basic television – the late 20th century equivalent of that 1925 radio – costs about $200.

Such decreases in cost occur among new inventions, too. The home microwave oven dropped from $600 in 1972 (in 1972 dollars) to about $60 today (in 2005 dollars) – in fact it dropped by about 20% since the first edition of this book was published. The cost of electricity for typical microwave home usage has held fairly steady at roughly $100 (in 2005 dollars) over the

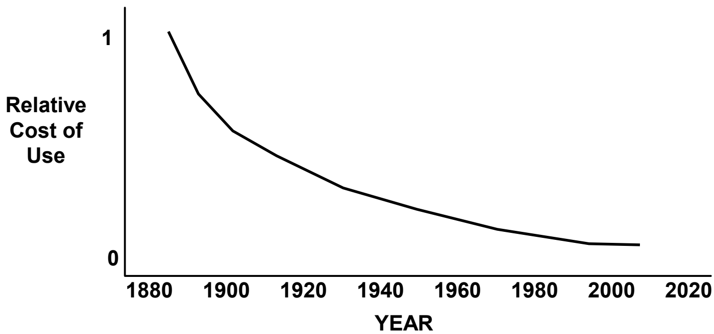


**Figure 3.2** Relative cost of providing light over the 12 decades of the electric era. While part of this trend has been due to a decreasing cost of electricity, the major driving force has been increasing efficiency along with decreasing prices for lighting equipment.

fairly steady at roughly $100 (in 2005 dollars) over the average 14-year microwave lifetime. Thus, overall cost dropped from about $50 per year ($600+$100 for the electricity, divided by 14 years) to about $14 a year ($100+$100 divided by 14 years), or a factor of three and one-half to one.

But perhaps lighting best illustrates long-term trends in cost of electric usage. In 1880, Edison had calculated that in order to succeed in the marketplace, the first light bulbs had to be priced no higher than 40¢ (roughly equivalent to five dollars today). Each would use about $20.00 worth of electricity at contemporary prices during its lifetime. (This disparity between the cost of the bulb and the electricity it used was the reason that Edison focused his business interests on selling electricity, rather than light bulbs, as will be described later.)

A century later, a 75-watt light bulb costs about one dollar (2005) but still uses about $20 worth of power during its lifetime, making it now, as in 1880, one of the few applications where the electricity costs *much more* than the device. Even more-expensive compact fluorescent devices, which reduce overall energy usage for lighting by large measures, are qualitatively similar. They cost about $12 and use about $25 worth of power in their (longer) lifetime.

Figure 3.2 shows the relative cost in constant dollars to provide 2,000 lumens, the typical output of two modern 60-watt incandescent light bulbs and sufficient for a typical room, from 1880 to the year 2005. Overall, electric usage grew throughout the 20th century in both number of customers and usage. In 1900, only a small minority of homes and businesses had electric power, and the average "electric" household used less than 600 kWhr per year. Today, over 99% of households in the United States have access to electric power on a routine basis. Average usage is about 1000 kWhr per month.

## 3.3 THE GROWTH OF ELECTRIC SYSTEMS TECHNOLOGY

### An Early Scientific Curiosity

The growth in electric usage would have been impossible were it not for the development of *machinery* that could produce electricity and distribute it to the millions who used it. Electricity was the source of experiments and curiosity among rich dilettantes as far back as the early 1600s. William Gilbert, the physician to Queen Elizabeth of England, coined the phrase *electrica* in 1600, from the Greek word *elektron* (amber, a material that could be used to produce static electricity, the only electricity known at that time). By the early 1700s, scientists throughout Europe, and a few in what was to become the United States, understood that *something* could be made to flow or jump (spark) between metal objects, and that somehow it was related to magnetism. But, the thing itself was poorly understood, and often described in different ways by different scientists. At the time, it was not believed to be capable of any practical application. Research into electricity was "basic research" – learning for learning's sake.

Many great scientists, justifiably famous today for their discoveries, helped develop mankind's understanding of electricity. Table 3.1 lists some of the most significant researchers or developers (the distinction was moot in the $18^{th}$-$19^{th}$ century) in electric technology. One who does not receive due credit as a scientist is Benjamin Franklin. Although often seen as a printer/politician/patriot who only dabbled in science, and whose only electric experiment involved a kite and a good deal of luck, he was, in fact, a serious experimental scientist who approached his research with intuition, careful organization, and tenacity. His contemporaries called him "the Newton of electricity," about the greatest accolade that could be bestowed at the time, and many modern scientists have labeled him "brilliantly analytical and objective."[3]

In 1747, Franklin took up the investigation of this poorly understood subject, with its competing theories and definitions. Many of the "prevailing truths" about electricity at the time were bunk, such as the widely held belief among scientists of the day that there were two types of electricity, called *resinous* and *vitreous*, which roughly corresponded to the two types of chemicals, bases and acids. Franklin knew that in order to build useful machines for electric application, mankind would have to understand electric theory correctly. However, his journals and notes indicate that he was mostly interested in understanding, rather than application. Unlike Edison and Westinghouse, and a host of engineers who came after him, and whose research was motivated by a

[3] Mitchell Wilson in *American Science and Invention,* Crown, New York, 1960.

**Table 3.1** Persons Who Contributed Significantly to the Early Development of Electricity, its Technologies, and the Electric Utility Industry

**Charles Brush** (1849 – 1929) was an American inventor/businessman who developed and successfully marketed an alternating current (AC) arc-light system for outdoor (street) in the 1880s, which made him a wealthy man. His AC system, similar to but different from Westinghouse's, was the basis for the creation of several early electric companies in which he had a large financial interest, including Cleveland Electric Illuminating. The possession of several key Tesla patents, and perhaps better salesmanship and access to financing, gave Westinghouse and his equipment standards an edge which eventually overshadowed Brush's contributions.

**Thomas Edison** (1847 – 1931), American, was an inventor more than a scientist. Famous in his own time for a series of inventions including the phonograph, the microphone, and the light bulb, he did early research into radio (patenting a basic concept in 1891) but did not make the key breakthrough (see Marconi). Perhaps more important, Edison can be said to have invented the corporate R&D lab: institutionalized commercial, invent-for-profit effort focused on with commercial potential. Edison's careful control of image tended to focus most public attention on himself, and although he was the key researcher he employed many who contributed a great deal, including for a while, Nikoli Tesla – far smarter if possessed of far less business acumen and ego.

**Benjamin Franklin** (1706 – 1790) contributed so much to American independence, folklore ("A penny saved is a penny earned," etc.), and myth that it tends to overshadow his role as a serious and committed scientist whose publications contributed greatly to understanding of electrical phenomena. Franklin carried on an orderly line of research into electricity for several decades in the mid $18^{th}$ century. Mostly interested in knowledge for knowledge's sake, he nonetheless was a prolific inventor, his most noteworthy electrical invention being the lightning rod and the concept of grounding facilities like buildings and signal towers.

**Guiglielmo Marconi** (1874 – 1937) was an Italian physicist who looked into "Hertzian waves" (radio waves) late in the $19^{th}$ century and received a patent for "improvements in transmitting electrical impulses and signals" in 1897. He began manufacturing the first radios for commercial sale in 1898, and by 1901 had successfully sent signals across the Atlantic. His early radios transmitted only Morse or similar codes, not voice, and his development and business were aimed at two-way communication for ship-to-shore and similar needs. Commercial radio broadcasting, which led to mass consumer sales of radios and changed the image of electricity forever (see text), took nearly two decades, and a host of new patents by many others, to develop.

**Nikoli Tesla** (1856 – 1943) was a Serbian American scientist who received over 700 patents during his lifetime, including three key patents for equipment used by all electric utilities today: an improved transformer which proved practical and efficient, multi-phase AC electrical power, and AC power transmission. He invented florescent lighting, largely to prove that he could invent a lighting system that did not infringe on Edison's patents. Tesla sold his early patents to George Westinghouse, which permitted Westinghouse to build his empire, and Tesla to set up his own research lab in New York.

**George Westinghouse** (1846 – 1914) was an American engineer businessman who was among the first, and certainly the most successful, of those to recognize that alternating current (AC) had substantial system advantages over DC in terms of business potential. He bought rather than invented his key patents but drove considerable innovative development including hiring, for a time, Nikoli Tesla.

desire to build practical machinery, Franklin was a scientist, who focused on obtaining knowledge, regardless of its usefulness.

Franklin created electrostatic generators, Leyden jars, an early form of condenser, or capacitor, and other devices to test each theory, and gradually evolved a coherent and demonstrable explanation for electricity. He created a simple but accurate theory of electricity that has lasted to this day. Along with that he devised much of the modern terminology*: battery, conductor, charge, discharge, armature, electrician, positive* and *negative* poles, and more.

### Practical Breakthroughs in the Victorian Era

Although Franklin was at heart a very practical man, ultimately he found no way to apply electricity to any useful purpose. Subsequent work by other scientists proceeded at a slow pace. Throughout the first part of the 19th century, electricity was considered an interesting curiosity, but nothing more. Three inventions changed that. The first, in 1867, was the "self-exciting" *dynamo*, or power generator, developed by Z. T. Gramme. Generators at the time were inefficient, requiring considerable mechanical power to produce just a small amount of electrical energy. Gramme's device used a portion of the electricity it produced to create and magnify the magnetic field inside itself, thereby dramatically increasing the electricity it created. *Useful amounts of electricity could be produced at affordable cost.* There was still little of practical value for the electricity to do, but there was now a reason for researchers to try.

The second development was the *light bulb*, mentioned earlier in the discussion of the history of usage. At the time of the light bulb's invention, electricity had been used to make light for several decades. But prior "illumination devices" were arc lights – huge, crackling, and smelly affairs that created an intense white light from the open discharge of an electric current. In the 1860s, several arc lights without any lens to focus their light into a narrow beam, as in lighthouses, were installed on eight-story-high lattice towers straddling major intersections in cities such as New York, Cleveland, and San Jose. At night they produced a "blinding light" that illuminated streets for several blocks around.

But such devices were unsuitable for interior use. They were as big as an average room, produced thousands of times more light than needed, and were noisy. Edison's light bulb changed that. As discussed earlier, it revolutionized interior lighting, providing something useful for electricity to do.

The third and final development that created the modern electric industry was the *transformer*, a device that can change the character of electric energy, taking power at low voltage and high current, and turning it into the same amount of power, but at high voltage with low current.[4] The transformer was

[4] *A transformer does not change the amount of power.* One might take ten amps at ten

based on a principle discovered in 1832 by Joseph Henry, an American who went on to head the Smithsonian Institution and the National Academy of Science. However, it was a Frenchman, Lucien Gaulard, with the financial backing of an English businessman, John Gibbs, who turned it into a useful gadget, obtaining a patent for a basic AC electric system in England in 1882.

Gaulard and Gibbs weren't entirely sure what to do with the device they had invented, which they called a *secondary generator.* It was an American engineer-businessman, George Westinghouse, who realized that it held the key to efficient distribution of electricity to thousands of potential customers. Westinghouse bought the American rights to the transformer in 1885, and built an empire on it.

Most uses of electric power (lighting, turning motors) require a lot of electric current, propelled by only a modest (low) voltage. That was in fact how Victorian-era dynamos – power generators – produced electricity. But in that form – high current and low voltage – electricity could not be moved over power lines more than two or three blocks. This limitation in "transmission distance" meant that a large, bulky, and noisy generator had to be built in every neighborhood, so that it would be close enough to the customers using the lighting it provided. Further, larger generators were efficient, but a really efficient generator, powerful enough to light ten thousand homes, was worthless if one could only move power to several dozen homes nearby.

Westinghouse understood that to move power efficiently over greater distances, one needed a low current propelled by a high voltage. A transformer could change high-current, low-voltage power at the generator site into this "easy to move" low-current, high-voltage form and move it *dozens of miles* if necessary. He had the vision to realize that this meant he could build large, cost-effective generators – big enough to power an entire city – and run the power through a large transformer at the generator site to raise voltage and reduce the current to make it readily movable. At this voltage, he could then route power on rather thin (and inexpensive) power lines throughout the city, locating small *step-down transformers* in every neighborhood to provide electricity to homes in that locale.

Thus was born the concept of the widespread *power system* – a coordinated set of generators, transformers, and high-voltage lines extending over a large region – with power produced at only a few locations, but distributed to many thousands of users. *Electricity could now be efficiently distributed to the mass market.*

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volts (one hundred watts) and transform it into one amp at one hundred volts (also one hundred watts). That transformer can be operated in reverse, too: if one amp at one hundred volts is run through it in the other direction, it emerges as ten amps at ten volts.

## Competing Electricity Formats: Direct vs. Alternating Current Technologies

Westinghouse's transformer-based power system required alternating current (AC), a form of electricity far different from direct current (DC – see Chapter 3) which is the type of power produced by batteries and early electric dynamos (see Chapter 4). Either form of electricity, AC or DC, can produce light or heat, power motors, or run radios, etc., but the two forms are incompatible. While a light bulb will give light if provided with either AC or DC power, most appliances like sewing machines, fans, and radios have to be designed to run on one or the other form of electricity.

In the late 19th century, a bitter business and technological rivalry developed between the two types of power, with Westinghouse championing AC power systems, and Edison promoting DC power.[5] Neither man was a scientist. Both were basically technology entrepreneurs, as were their counterparts in Europe – engineer/inventors with a successful track record of invention transformed into profitable business. Unlike Franklin, Henry, and others, they were interested in electricity for the money, and both were intent on parlaying their inventions and patents into a large, profitable empire. Edison invented the light bulb as the deliberate result of what would today be labeled a business plan. It envisioned creating a need for generators, too, which he intended to, and did, produce and sell. The plan worked, and for a while he sold fantastic quantities of both.

But by the turn of the century, Westinghouse's concept of a few big generators, narrow distribution lines built with thin wire, and many small transformers had established itself as the superior way to utilize electricity. Edison's DC system had advantages in certain circumstances, but to distribute power throughout a big city, it required a forest of thick overhead wires, both ugly and expensive. Thus, AC became the preferred public power system. By the dawn of the new century, AC had become the standard everywhere, adopted even by Edison's companies. However, Edison could laugh all the way to the bank. Every Westinghouse style system still had to use the light bulb he had invented!

Technological development thereafter merely built on Westinghouse's original concept, which remains unchanged a century later, although it has been greatly refined through innovation and invention. Throughout the twentieth century, power systems technology developed along several lines of progress, as outlined below.

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[5] There is substantial evidence that Edison knew AC power was more efficient, but he didn't own the patents on the essential element required for AC power, the transformer. Thus, he stayed with what would make him the most money, DC, as long as he could.

## More Efficient Generators

The cost for an electric utility to produce electric power dropped, from nearly a dollar per kilowatt hour in 1880 to less than two cents in 1997, both figures in 1997 dollars. This improvement was accomplished through better design and materials, but mostly through economy of scale: the bigger the generator, the less expensive the power produced. As a result of pursuing efficiency, even a small power station by today's standards – 100 MW – produces more power than was consumed worldwide in the first decade of the electric industry.

## More Efficient Voltage, Equipment, and Design

The use of increasingly higher voltages made power distribution ever more efficient, halving the cost of moving power in the first three decades of the 20th century. Progress continued – transformers built in the 1990s are less expensive and more efficient than those of the 1960s, which were themselves vastly superior to those of the 1930s. But beyond this, by the mid-1960s, the concept of hierarchical voltages – using a series of transformers and different voltages as needed in the power system, each optimized for its particular use had led to a further halving of cost. Cost of moving power (in real terms) dropped roughly six-fold from 1900 to 1990.

## Larger Power Systems

Edison originally promoted the use of neighborhood power systems. A small generator was equipped with power lines to run electricity to homes in only a small area of a city or town, where a high density of usage would justify expenses and provide a business profit. Westinghouse's AC systems could distribute power over increasingly wider areas, which led to entire towns, and small cities, where a single power system could provide electricity throughout. Yet in the early part of this century, nearly every city and town had a separate system.

Gradually, over most of the 20th century, as steadily higher voltages permitted power to be moved on transmission lines over ever greater distances, cities and towns were interconnected into increasingly larger *power pools*, or shared power grids. This was done mainly to make electric power more reliable. If one community's generator failed, it could "borrow" power over the grid from its neighbors until repairs were made (see Power Pools in the Glossary). Interconnection also led to lower costs. For one thing, it allowed cheap hydro power produced in the Rocky Mountains and New England to be moved to cities like Los Angeles and Portland.

Today, electric utility systems in the United States are connected into only three gigantic power grids. The Eastern grid extends roughly from Kansas and Nebraska, proceeding east to the Atlantic coast. The Western grid extends from

Colorado westward toward the Washington and California coasts. Texas, which is caught in the middle, operates its own grid with only “weak” interconnections to the other two. In each-interconnected system, equipment owned and operated by the different electric utilities there works in a synchronized manner. In a very real, if technically limited, sense, it is possible to route power produced in northern Maine to western Kansas, or vice versa.

### Energy Efficiency and Conservation

Viewed as a long-term trend, there has been a growing emphasis since the 1970s on energy efficiency and conservation, driven by a sense of social responsibility. Efficiency improvements throughout the early part of the century were driven by a desire to reduce cost, with a motive of actually increasing power usage –“if it costs less, people will buy more.”

However, since the late 1970s, while the move toward “energy responsibility” has waxed and waned several times, the long-term trend has been toward increasing awareness that even if power is cheap, it shouldn’t be wasted. By 2005, appliances such as refrigerators and air conditioners are more than twice as efficient as they were 30 years ago; doing the same job with half the power. Compact fluorescent light bulbs are increasingly used in place of incandescent bulbs, cutting power used for illumination. In a similar manner, technological progress will probably cut usage in half, for the same end result, over the period 2005 to 2055. However, if historical precedent continues, new applications for power, newly innovated, will develop to fill the gap, resulting in ever greater use of electricity overall.

### Distributed Generation

Edison’s original concept of “a generator for every neighborhood” had several advantages over even the most advanced evolution of Westinghouse’s big-system concept. But in many ways, the concept was too advanced. It was too difficult to get all those small generators to coordinate their operation with one another. It was only at the end of the 20th century that a host of messy, but important problems associated with that idea were solved. Fuel cells, absolutely silent and almost non-polluting, and MTGs – micro-turbine generators, almost silent, inexpensive, and virtually non-polluting – can both be built as small as a step-down transformer, and can produce electric power for anywhere from five to fifty homes. They eliminate the need for further construction of transmission and distribution lines, with their often-accepted but always unwanted esthetic clutter. Both fuel cells and MTGs require a natural gas line to be run underground to them, or fuel delivery to a nearby tank, and both are more expensive than traditional ways of producing power, but not enough to preclude their being viable alternatives in many cases.

### Automation and Power Electronics

A combination of modern computerization and high-power electronic devices can control electric power in ways that Edison and Westinghouse could not have foreseen. Electricity moves, literally, at lightning speed, fast enough to confound the quickest mechanical switches and control systems. The best circuit breakers and control relays and line switches that Edison, Westinghouse and three generations of engineers after them could devise were mechanical devices, which, while excellent in many ways, could not track and react to electric flows fast enough, and precisely enough, to handle many potential contingencies at full load. As a result, electric equipment throughout the first eight decades of the 20th century had to utilize conservative and often awkward designs − basically utilization levels far below actual capacity − in order to avoid these situations.

But fast as electricity is, modern computers and electronics can react fast enough to control, and even to anticipate and modify, the behavior of electricity on the power grid − a sort of "anti-lock braking system" for the electric grid, which can sense and shut down problems before power can outdistance control. This means that many power grids can have their capacities upgraded at relatively low cost, to the point where they operate safely and dependably at loading levels that would have been "at the brink of blackout" only a decade before.

## 3.4 THE RISE OF THE ELECTRICAL UTILITY INDUSTRY

In the United States, three technological entrepreneurs, Charles Brush, Thomas Edison, and George Westinghouse (see Table 3.1), all capitalized on their own inventions as well as patents they purchased or licensed from others (e.g., Nikoli Tesla) to largely create the electric power industry. Each created his own large commercial-industrial empire to manufacture electrical equipment and do further research. Eventually each also promoted, through funding and ownership, start- up financing, or sales of franchises, the development of electric utility companies – companies that sold electric lighting, power and appliances directly to homeowners and businesses. All three took this route largely because each saw that only a lively retail demand for electricity usage would create the large commercial opportunities for their inventions that would lead to business success.

All three were very much rivals, competing fiercely with tactics that would be considered quite "dirty" by modern standards. Initially, each of their companies sold not only electricity, but also everything required for its use, including light bulbs, light fixtures, switches, fuses, and internal wiring for homes. They really had no choice. Since there was no other supplier of these appliances and equipment, they had to provide them. But in addition, the sale of these items was profitable in itself. As a result, there were three competing "standards" or types of electric utility systems and appliances in use in the United States during the late 19th century.

Edison founded his Edison Electric Illuminating Company in 1880, along with several ancillary companies to manufacture switches and distribution equipment. Edison sold and was strongly committed to direct current (DC) technology and systems. Although he proclaimed widely a firm belief in DC and was quite vocal in pronouncing his rival's alternating current (AC) systems as dangerous, a good deal if not all of this was probably due to the fact that he had invented most of DC's technology and held few patents on AC equipment.

Charles Brush's company was founded about the same time as Edison's and initially marketed indoor and outdoor lighting. He had invented and patented a type of AC generator (dynamo) and had perfected a practical, low-maintenance arc light (a type of lighting device that uses an open electrical arc to produce light). His arc-light produced a brilliant light superb for outdoor street lighting, etc., but was not as convenient for indoor and small applications as light bulbs (arc lights make a continuous crackling and buzz). Nonetheless Brush was quite successful, branching out into other electric uses, and setting up a number of early utilities: Cleveland Electric Illuminating Company still does business under the same name as when founded by Charles Brush.

Westinghouse followed Edison and Brush by about five years in founding a large industrial electrical company (he had, however, had an earlier start, and great success, with Westinghouse Air Brake which made him a fortune in railroad locomotive brake systems). Westinghouse had a slightly different business approach than Edison or Brush, who both dominated and directly led in their company's research and development, and built businesses largely around their own inventions. Westinghouse bought patents and hired good scientists to work for him, and concentrated more on just "running the business" than his rivals. Westinghouse built his business around technologies that made the most business sense: If he didn't own the patents, he would buy them or a license for their use. Furthermore, he had what proved to be a far superior technology in alternating current (AC) compared to Edison's DC. And while Charles Brush also used AC, it was a slightly less efficient system, not as well aimed at fulfilling residential needs.

All three men sold electric distribution franchises and packaged power plants and distribution equipment along with license rights to their technology, each in intense competition with the other two. Each was interested in the sale of the electricity itself, because as mentioned earlier, it represented the major portion of the dollars involved in lighting. But all three were, by nature, mostly engineers and tinkerers who found the devices that produced and applied electricity much more fascinating than the actual business of selling power. (Westinghouse was a bit more disciplined and realistic in his approach, but even he let the "fun factor" distract him from the business at times.)

As early as 1890, the business structure of the industry began to split into "equipment manufacturers" and "electric utilities," the former building the machinery and equipment used by the latter. All three industrialists tried to stay involved with both parts, by diversifying their companies. For example, Edison founded more than a half dozen companies, including the Electric Light Company (light bulbs), Bergmann and Company (electric switchgear), Sprague Electric Railway, and the Edison Electric Illuminating Company. Westinghouse similarly diversified his activities. Both basically divided their companies into a series of regional sales (electric utility) companies, and equipment manufacturing companies.

To some extent, all three focused too much on maintaining control over the industry they had created, rather than on assuring sound finances for their various companies. All three, more engineer than businessman and more committed to invention than business management, demonstrated a lack of financial acumen which led to cash flow problems. When business difficulties forced them to sell off part of their enterprises or to seek additional investors, each chose to sell the electric business and keep the equipment manufacturing as his continued focus. That proved a poor choice, for electricity was where the low-risk profits were in the late 1890s. All three ultimately lost control of most of their companies, although none did particularly badly from the standpoint of personal wealth.

Edison's empire eventually became the General Electric Company, which survives under that name and is a major supplier of electrical equipment to this day. Westinghouse Electric was taken over by its investors and operated as a major equipment supplier into the early 1990s. It merged with a European conglomerate, ASEA Brown Boveri – itself the result of a merger of several large electric equipment firms – in the early 1990s, to form ABB Inc., now perhaps the largest global supplier of electric equipment and services.[6]

## The Birth of Electric Utilities

A host of electric companies, financed by the Victorian equivalent of venture capitalists, sprang up anywhere there was a city or town large enough to provide high density market for electricity. A few of these companies were owned directly by either Edison, Brush, or Westinghouse, but most were franchises that bought franchise rights, patent rights, and licenses, as required from one or more of the three. Both Edison and Westinghouse made many sales, gradually edging

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[6] Westinghouse, as a corporation, had by that time diversified into a variety of other businesses, such as broadcasting and defense. It sold only its electrical power businesses to ABB and continues under the name "Westinghouse" as a major player in many other markets.

out Brush and making the early three-way race into a two-man contest for dominance of the electric industry. With his AC technology, which provided lower operating costs as a utility grew, Westinghouse gradually pulled ahead. AC was so vastly superior to DC that he had nearly an unfair advantage in the long run. The two are basically equivalent if one wants to wire a single home, or a group of houses or offices that are very close together. But Westinghouse's system had an economy of scale as a utility grew: As it added more and more customers and gradually expanded its service over a wider area, cost per customer would actually decrease. By contrast, Edison's cost per customer stayed the same or even increased slightly as system size increased. Eventually, the AC approach won over DC. In 1889 Westinghouse sold 1,100 generators, only about 25% more than Edison. By 1900 he was selling more than twice as many. Except for some unusual niche markets,[7] all electric utilities had converted to a "Westinghouse" AC approach by 1920. And Edison's General Electric Company converted, too. It came to be a major competitive player in designing and building "Westinghouse" type equipment.

Many of these early electric companies – franchises purchased from Brush, Edison, or Westinghouse – were financed and run by businessmen who had no interest in the engineering and focused only on making a profit. One of the most successful was Charles Coffin, whose Troughton-Houston Company got its start with electric trolleys and railroads. He diversified where ever there was money to be made from electricity, and ultimately took control of General Electric from Edison as well as many elements of the former Brush Electric Company.

Whether they used AC or DC power, and regardless of who owned them, the earliest electric utilities thought of themselves as companies that sold lighting, not electric power. In fact, most early electric utilities billed their customers on a monthly basis according to how many light fixtures they had installed in their home, or in some cases on a "bulb evening" basis.[8] This early identification with being a *lighting* company as opposed to an electric utility persists: the term "light company" is still widely used as a synonym for "power company."

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[7] Early elevators worked much better with DC than with AC. As a result, many utilities continued to provide DC power to buildings in the downtown core of major cities, along with AC for everything but the elevators. In the late 1960s, one of the author's (Willis) worked on what was among the very last of these systems left (downtown Houston, Texas) and subsequently designed the AC replacement circuit when it was retired in the late 1970s.

[8] Edison invented the first practical electric meter, but for a decade or more such devices were expensive, costing much more than the power being monitored. As a result, many late 19th century electric companies had "meter readers" who walked the streets every night with a clipboard, noting how many rooms had lights on in each home. There was only one light fixture per room and usually only 3-5 lights per home. Customers were billed according to this count – basically per "light-bulb evening."

Brush, Edison, Westinghouse quickly developed a host of other appliances and machines to use electricity – fans, clothing irons, electric stoves and washers, and large motors for industry. They pursued this approach both because it was what they did best – developing and commercializing new products – and because the use of such devices would expand the demand for electricity. In the very early 20th century, applications for electricity, other than lighting, began to be more important, at least in the view of some utilities.

## Changes in the Focus of Utility Companies

Interestingly, the names of utility companies and the history of their names demonstrates the change in identity and focus that electric companies have undergone throughout the 20th century. Electric utilities founded in the 19th century called themselves "illuminating companies." Few of those names survived to the end of the 20th century, most being the victim of re-organizations and mergers somewhere along the line. One of the few remaining is the Cleveland Electric Illuminating Company – a part of First Energy Corporation today, but still operating under its original name.

Electric utilities founded or re-organized during the first half of the 20th century usually featured the word "power" in their names, with its prominence compared to the word "lighting" a sign of how late in the century they were organized. Early in the century they saw themselves mainly as *light* companies. Later, this view changed to *power* companies, whose main product was electric power, whether used for light or other activities.

Thus, companies established in the first few decades of the 20th century called themselves "Lighting and Power," for example, Houston Lighting and Power. Those established a bit later reversed the order of those words, as in Dallas Power and Light, and those founded later than about 1930 usually forgot light altogether, e.g., Empire District Electric, Nevada Power. After 1970, utilities merging or selecting a new name usually made no reference to power or light – Southern Company, PacifiCorp – or at best referred to "energy" instead, e.g., Entergy. These changes mirror the image companies had of their purpose. In the 21st century, electric utilities see themselves as service companies, and many have chosen names like Xcel Energy, or Progress Energy, etc., which subtly stress the quality of their service or commitment to a region.

## Utility Regulation

As described earlier, by the late 19th century, the companies founded by Edison (General Electric) and Westinghouse (Westinghouse Electric) bowed out of direct retail electric sales and concentrated instead on building and selling power production and distribution equipment to retail electric companies. They manufactured and sold generators, transformers, meters and "switch-gear" (the circuit breakers and other apparatus needed both to control power flow during normal operations and to protect against short circuits should equipment fail).

Without a doubt, a big reason for the move out of retail sales was that Edison and Westinghouse along with the engineers who staffed their companies were more comfortable with the equipment business and its engineering culture than retail electric sales and the transactional culture it demanded. But an important factor was that by the early 20th century, government regulation began to reduce profit levels from electric sales to reasonable if not outstanding levels. Both Edison and Westinghouse, as well as many other early pioneers attracted to the new industry, were by nature risk-takers intent on achieving high profits. Since regulated and guaranteed profits were simply not what they wanted, they went elsewhere and left electric sales to a different type of businessman.

Electric utility regulation began slowly, driven partly by the change in attitude toward electricity as it came to be regarded as a necessity and not a prestige item, and partly by the desire of utilities to reduce risk, as will be discussed below. Many city and county governments, in areas that already had electric companies as well as in areas still without power, began exercising control over the future of the lighting industry in their jurisdiction, by passing laws that gave the right to grant franchise rights for electric distribution. A particular company was guaranteed exclusive rights to be *the* local electric company, but only if it accepted certain terms. The most important was that it had to accept an *obligation to serve* every home and business that wanted electricity, not just those it thought would be most profitable. Second, the rates it could charge were limited, so that when the cost of serving all those customers was taken into account, it would make a reasonable, but not excessive, profit.

While regulation and franchise rights limited profit levels, they took much of the risk out of the retail electric business, and most early electric utility businessmen viewed it as a good compromise. In particular, the exclusive right to be the *only* electric retail company in an area eliminated a big risk that worried early electric companies: What if a competing electric company, using a newer and superior technology, enters the local market. With its newer technology it could under-cut price and take over the market. With the guarantee of sole franchise rights, the utility could be certain that the investment it made to serve every home and business would pay off – maybe not with exorbitant profit levels, but at a profit nonetheless.

## Expansion of the Urban and Suburban Utility Industry

In the first four decades of the electric era, from 1880 to 1920, over a thousand investor-owned utilities (IOUs) were formed to take advantage of the opportunities to make money through the retail sale of lighting and electric power. Most of these were "one-franchise" companies formed to serve a single city or town, often financed by local businessmen who had worked out a franchise agreement with local elected officials. In aggregate, these investor-owned utilities distribute power to over eighty percent of the population in the United States.

## Mergers: Bigger is better

The vast majority of the original small, local, investor-owned power companies disappeared by 1950, having merged with their neighbors into larger utilities. Size conveys many advantages to an electric utility: the potential for slightly more efficiency, and the ability to operate at less risk from storms and unexpected emergencies. As a result, various investor-owned utilities have been merging with one another for more than a century. Today there are far fewer, but far larger, electric utilities than there were a century ago, or merely a few decades ago, for that matter.

Many people unfamiliar with the power industry's lengthy history believe that mergers among electric utilities are a recent trend caused by de-regulation and performance-based rate pressures, but in fact *mergers and acquisitions among investor-owned utilities have been a continuous part of the electric business for more than a century.* Merger activity was actually highest during the first half of the 20$^{th}$ century. There were originally over one thousand investor-owned electric companies in the United States. By 1980 there were only 238. Ten years later there were only 206, and a decade later that had dropped to less than 190.

Almost all modern IOUs are the product of many mergers over many decades. For example, the areas in New York state and New England served at present by National Grid USA were at one time broken into more than forty small IOU service territories. Modern investor-owned electric companies are quite large. Most serve well over a million customers each, and the largest at the time of this writing, Exelon, delivers power to seven million customers. The number of IOUs is also likely to continue to drop. In a manner similar to what happened in the airline industry, investor-owned electric utilities that cannot compete will cease to exist: the equivalent of those airline "routes," i.e., service franchise rights, lines, facilities, and franchise rights, will go to the successful companies who bid the most for them.

## Municipally Financed Utilities

By the early 20$^{th}$ century, local electrification was a sign of prestige for a community, a business advantage for local industry, and a sought-after convenience for homeowners. It quickly came to be viewed as a civic necessity by many local governments – a city or town could not afford to be without "electrification" or it might be left behind as the 20th century progressed. Communities too small, or otherwise unable to make a satisfactory franchise arrangement with an electric company, often took matters into their own hands and built their own municipal electric system. They had constructed and managed their own roads, water, and sewer lines for years; they would do the same with power. A few counties did likewise, forming county utilities or Public Utility Districts (PUDs) along similar lines. Slightly less than 2,000 such municipal or public power district utilities still exist in the United States today, distributing power to about 14% of all electric consumers.

Similarly, during this period, cities and towns throughout Europe were converted to "full electric service" in much the way that North America converted. A mixture of state-owned, municipal, and investor-owned corporations focused mostly on cities and towns, where the high density of customers made electrification affordable. Slightly different standards for electric system design and operation evolved in Europe than in America, but both used a "Westinghouse" AC approach. To this day both the system frequency and nominal voltage level are different, but otherwise the electric systems are incredibly alike.

### Rural Electrification

By 1930, fifty years after electric power had first been commercially viable, most cities and towns in the United States had electric power, but most rural areas still lacked it. It was a matter of business economics. In the large cities there were enough customers per mile to cover all the costs of lines and equipment at a price low enough to be affordable to nearly everyone. In small towns and the suburbs of large cities the situation was not quite as good, but retail electric sales were marginally profitable and still quite popular.

But rural electrification was a losing business proposition, even in 1930. There were too few customers in rural areas to pay for too many miles of needed line. Even if someone did provide funds for the investment in lines and equipment, recovering that investment over two or three decades would make the resulting electricity prohibitively expensive. The Europeans did not face this problem to the same degree: rural areas in Europe were packed compared to the sparse populations of rural Tennessee or western Kansas, to say nothing of North Dakota, west Texas, or New Mexico. Rural electrification in Europe proceeded slowly, but made enough business sense that government and private companies took on the task directly. In America, the countryside had remained dark at night for the first quarter of the new century.

The U.S. government realized that rural electrification would have advantages beyond those of immediate benefit to people living in remote areas. It would increase farm productivity, and it would reduce the flight of people from the countryside to the cities; while a certain amount was an acceptable sign of a growing industrial economy, too much of it would leave the "breadbasket" of the United States empty and abandoned. The nation's manifest destiny required that agrarian areas compete with the cities on equal terms.

Thus, in 1935, as part of President Roosevelt's New Deal, the United States government created the Rural Electrification Administration (REA) to bankroll rural utility companies. Boiled down to its basics, its cooperative concept for agrarian "utilities" worked much like the shared community grain elevators in many farming communities:

(1) The government would lend money to the farmers and villagers in a region to finance creation of a local electric company, and construction of a power system feeding their homes and businesses.

(2) Jointly, they would be co-owners of this local utility, called an electric membership cooperative (EMC). The cooperative was the official borrower of the money – farms and homes were not at jeopardy if the deal fell through. That was unlikely to happen, though, because the loan had a very low interest rate and a very long payoff period.

(3) Everyone would buy electricity at rates the REA set according to a formula that was aimed at paying off the loan eventually, but not quickly. These rates were perhaps twice as high as those in the cities, but still much less than one would have expected had an IOU, or even a municipal utility, been involved.

Nearly 1,000 utilities were formed in this way. Almost all of them exist to this day. (Government procedures, the financing methods used, and the EMC charters make it virtually impossible to arrange mergers or business re-structuring of these companies.) Rural membership electric cooperatives distribute power to about ten percent of Americans.

While the government helped finance rural electrification, American innovation helped remove another barrier in front of it. Traditional ways of building an electric power system (by this time the industry was nearly 50 years old and indeed had "traditional" ways) would have been too costly for many rural areas, even with government assistance. A new type of power system design, called *rural single-phase*, was invented and standardized through design guidelines established by the REA. A rural single-phase power system could not distribute very much power, but then these areas did not need a lot – there were usually only four to sixteen farmhouses per square mile. Rural single-phase power systems cost *much less* than they would have if they had been built along the lines of systems in the cities. Conveniently, even though these rural systems were different in design, they used the same types of utility lines and equipment (as manufactured by General Electric or Westinghouse or the other suppliers), and they could run the same types of appliances used in the cities.

## De-Regulation

As mentioned earlier, and as will be discussed more thoroughly in Chapter 10, utility regulation brought a lot of benefits to the early power industry. Viewed from the larger perspective, de-regulation, or "re-regulation" as it is more properly called, is occurring because regulation of the electric industry has served its larger purpose. In the early and mid $20^{th}$ century regulation assured that adequate investment in utility infrastructure would be made. Its promise of return-on-investment led to the achievement of a universal power grid reaching throughout all cities and towns and into all rural areas. It provided a stable industry and stable prices during times when technology, systems, and prices were expanding. It led to the growth of a healthy power industry. None of that would have happened without monopoly franchises, regulatory assurances of return on investment, and rate caps.

But by the early 1990s, the technology, customer bases, and usage levels in the power industry had been fully developed and reasonably stable for decades. The original investment required to build the "universal electric system" had been recovered decades earlier.[9] Most of the reasons that originally prompted utility regulation no longer exist to the same degree that they did at the beginning and middle of the 20th century.

Meanwhile, regulation and a complete lack of competition had led to a type of stagnation. Despite a minor facade of applied R&D and progress, regulated vertical electric utilities had little incentive to do anything other than what they have done in the past: Regulation made them afraid to take business risks, and there were no rewards for bold new ideas.

Very clearly, the electric utility industry did not keep pace with the progress of society and technology as a whole in the last half of the $20^{th}$ century. Certainly, there was some progress and change, but not nearly enough. In 1995, the year de-regulation began, the electric utility industry was offering essentially the same products, services, and billing options that it had been providing to its customers in 1945. Had a similar lack of innovation occurred in the airline industry, jet planes and computer technologies would have been used by the airlines to offer passengers the type of service given in 1945: top speeds limited to 200 mph, only short hops between adjacent cities, with transcontinental travel requiring many frequent stops, low altitude operations that make flights bumpy and cause frequent delays due to storms, and prices affordable only for the wealthy or businesses in dire need of "fast" travel.

In 1997, only two years after de-regulation's start, the range of products and services, and pricing options for consumers began increasing rapidly, with no

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[9] At least for IOUs and many municipal utilities. Many REAs are hopelessly in debt, but that is as much due to poor government policy as it is to poor management.

end in sight. Competition promotes innovation, wider choice, and lower prices. It will reward those power companies that think and do better, and remove from the marketplace those who cannot keep up. A controlled form of competition is what is being sought, from what is really "re-regulation" – a change in the rules. (See Chapters 2 and 10 for more details.)

## Downsizing: One trend of the '90s

Proof that utilities can do better is evident in the downsizing trend that swept the industry in the early and mid-1990s and that continues at a slower pace today (as utilities asymptotically approach the best they can do). As de-regulation began to be a possibility, utilities prepared by cutting staff and capital spending. They did so partly to reduce cost, so that they would become more competitive. They also knew that all of them – regulated and unregulated – would face increasing investor expectations to improve their bottom line, as any and all companies in any competitive, unregulated industry do. But a more important reason was that lowering employee count lessened their fixed costs, which reduced their business risk, a prudent move in times of uncertainty.[10]

Despite what naysayers had predicted, the lights stayed on. In fact, some utilities reduced their employee count by half, trimmed capital spending by 33%, and still managed to find a way to improve customer service levels. Basically what happened is that the drastic cuts forced utilities to re-examine traditional methods, to focus more on the basics (customer value) while foregoing other issues, and, most important, to innovate.

There might very well be another round of downsizing in the early 21st century. Some industry observers point out that compared to a TV cable company, an electric utility of equal size – as measured by miles of line, dollars of revenue or in some other way – has nearly twice as many employees. The TV cable industry is the only "utility industry" born in the modern era. With no tradition or historical precedent, it organized itself to take maximum advantage of modern technology and practices, and has roughly half the employee count of equivalent electric utilities. Certainly, it is difficult to compare one type of industry to another, but most such comparisons, when they can be done, usually show that many downsized electric utilities are still not "lean" enough.

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[10] One way to reduce business risk is to reduce the fixed portion of the business's costs. This can make sense even if the company's variable costs rise, as they would, for example, if an electric utility had to hire outside firms to do construction because it didn't keep enough full-time employees to do the work. While its overall costs might be higher, the company can react more quickly to changing conditions because it has a smaller portion of its costs that it cannot rapidly change.

## De-Regulation and Debacle

As stated in Chapter 2, electric industry de-regulation can work very well when implemented with soundly designed rules and in a framework that accommodates the dual nature of utility transmission flows (see Figure 2.9 and accompanying discussion on the difference between electrical and "money" flow in a power system). However, early de-regulation efforts in many nations were less than perfect, and in some, including the US, poorly thought out and just plain clumsy in their execution. In the United States de-regulation driven by federal policy but interpreted at the state level in many different (and occasionally, nearly inept) ways created very high levels of stress on utility finances and customer service quality.

For example, in California, price volatility caused by de-regulation pushed several utilities to the brink of bankruptcy, among them one of the largest and arguably best run utilities in the industry (Pacific Gas and Electric). Utilities were caught between escalating prices for power at the wholesale level that they had to buy, and frozen, regulated rates at which they could sell that power at the retail level. A lack of perfection in de-regulated rules was partially to blame for a series of rolling blackouts that were common throughout the state in 2001.[11, 12] (The reader should see the comments and footnote at the end of Section 2.7 on the root causes of the California energy deficiency: de-regulation did not create the root cause of the problem, but did make it worse).

In August 2003, a blackout occurred over the entire northeast US and into southeastern Canada. It started with the failure of several transmission lines in northern Ohio (a situation any power system should be able to tolerate well) that cascaded in a matter of a few moments over multiple states and regions, putting more than 50 million people in the dark, some for a day or more. Whether this was caused by de-regulation is a matter of interpretation, but the very wide interconnection of the power grid in the Midwest with that in the Northeast, along with the heavy, long-distance power flows through the grid, were both

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[11] A rolling blackout occurs when a utility or regional grid operator knows their power system will not have enough electric power to meet all demand. To avoid an uncontrolled (cascading) blackout that might take down the entire grid, it shut down portions of the grid, deliberately turning off power to perhaps a million consumers at one time. To spread the pain evenly, it "rolls" the blackouts over the region: one hour without power here, then one hour without power there, etc.

[12] It has become quite popular to blame large de-regulated energy suppliers like Duke and Enron for manipulating the market and causing these blackouts. In the authors' opinion, that is missing the point: California set up rules and incentives for its energy market that encouraged a type of look-the-other way "cheating" or even worse, that provided no financial incentive for running generators at some times. California's rules were simply not a balanced, sound system.

due to de-regulation.[13] These contributed to the problem (see Section 16.3).

Eventually, policy makers at both the federal and state levels adjusted their electric industry rules and structure, utilities adapted, and the competitive wholesale market, operating as it was expected to do under the open competition created by de-regulation, brought forth more energy supply and "solved" most of these problems. And politicians responsible for some of the most egregious errors in both pre-deregulation energy policy as well as mis-guided de-regulation policy were voted out or recalled from office. At the time of this writing, de-regulation is not entirely fixed (see last section of Chapter 2), but it is working better, and with more fine-tuning, will work quite well.

## Fraud and Frustration

Chapter 2, Section 2.4 discussed the development of the trading market in wholesale commodity power that quickly grew under de-regulation. In the late 1990s several very large companies developed around buying, selling, and re-marketing electric power. Among these, the company that certainly cut the widest swath in the power industry for a short time was Enron, a Houston-based company that owned generation, wind power, gas resources, and numerous other assets, and that did an increasing volume of what appeared to be very profitable commodities trading in electric power. Ultimately, Enron collapsed due to over extension of its finances and allegedly fraudulent practices in its financial reporting and management, a spectacular scandal which brought financial ruin to thousands of its investors and disgrace to a number of executives who deserved that and a jail term.

At the time of this writing, the jury is still out (literally) on many parts of the Enron scandal, but in the authors' opinion, the "commoditization" of electricity through de-regulation created a situation where cheating was amazingly simple and quite tempting. As discussed in Chapters 2 and 10, de-regulation made

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[13] See Chapter 2. High voltage transmission grids covering multiple states and even several regions were necessary under de-regulation in order to create efficient wholesale power markets. Heavy, long-distance power flows became common due to the competition those markets fostered. The power grids in both the Midwest and the Northeast US, which were, along with southern Canada, all tied together, were originally designed as contingency-support power pools by regulated utilities, not for such heavy flows. This combination of wide regional grid and high power flow was caused, to a great extent, by de-regulation. But the Northeast blackout was also due to the fact that utilities were operating a bigger and more complex power system than anyone appreciated prior to the blackout. Complexities and problems that could develop in such a grid were not anticipated and had not been studied in sufficient depth by anyone in the industry, nor had equipment for precise, regional-wide timing coordination and other needed control systems been put in place. It is difficult to blame these failings on de-regulation, even if it did lead to the conditions that exposed this industry weakness.

electric power into a commodity, but it has significant differences from traditional commodities. It cannot be stored as can other tradeables like wheat, coffee, and soy beans. It cannot be seen as can other commodities. It was new, and not easily understood by investors and regulators and Wall Street analysts. Therefore, it was easy to "pump up" a business's appearance through circular sales and mis-representation of trading volume: one could not count grain silos or warehouses to help check a company's math or provide a sanity check on what it was reporting in its annual report.

Many other companies including some traditional utilities jumped into the power trading "game" in the late 1990s, many in a big way. Most adhered to sound, legal, and ethical standards of corporate conduct, although a few were infected by the temptation to bend the rules. Regardless, quite a few pushed their financial leveraging past the limit of prudence, and ultimately shared the same fate as Enron (which would have very likely collapsed, scandal or no scandal).

Briefly, the claimed success of Enron and several other energy trading companies gave the appearance that they were in a vastly profitable business. In the period 1995 – 2001, the industry as a whole focused on power trading and wholesale generation with respect to investment and business expectations. But the fact is that electric power is a very competitive, low-margin, and potentially high-risk "game," in which it is very easy to over-leverage a business and quickly "cash and burn." By 2003, many utilities and quite a few non-utilities had realized that operation of a T&D system along with retail electric sales offered more stable and perhaps ultimately a more profitable (certainly less volatile) business opportunity. One of the frustrations facing many utilities that had moved heavily into the "trading game" for a while is that while it did not destroy them, it left them with heavy debts and an inability to invest in T&D today, while they pay off those debts.

## 3.5 LOOKING TO THE FUTURE

### Aging Infrastructures

The last sentence in the preceding section emphasized how some utilities just cannot invest in their T&D systems. But the simple fact is that most modern utilities need to invest heavily in T&D over the next two decades, because much of their present system is nearly worn out. Looking to the future, the "aging electrical infrastructure" problem is one of the greatest challenges facing the still regulated part of the industry.

All electric utilities in the Unites States, and most in Europe and many other places throughout the world, have transmission and distribution equipment in their systems that has been in service for more than fifty years. In some cases, a utility may have facilities (a substation) where a good deal of the equipment is more than 80 years old, and the authors have equipment in "front line service" that pre-dates World War I. A few utilities have equipment that *averages* between 40 and 50 years of age.

This aging infrastructure problem is most prevalent in the still-regulated, T&D portions of the power industry. There *were* many very old generation plants, but the competition created by de-regulation tended to weed them out very quickly (but not without a good deal of financial loss to some of their owners). Basic electrical T&D equipment like transformers, transmission towers and conductors, wooden poles, breakers, and control replay panels is designed to be very robust. Much of it can survive fifty or even sixty or more years in service, if well cared for. But a considerable portion of the industry's in-service stock is approaching that age.

This problem grew very gradually. For what appears sound reasons if viewed on a short-term financial basis, electric utilities almost always practice a "run to failure" policy with regard to equipment: as long as repair will keep it in service they do not replace it even if it is quite old. Proper maintenance can keep electrical equipment in good repair for remarkably long lifetimes, one reason that large portions of many utility T&D systems are composed of so much old and sometimes rather inefficient, high-maintenance designs. This older equipment breaks down frequently and can require high levels of repair effort.

As a result, the problem is getting worse every year. Most utilities do add new equipment as their systems and customer base expand each year, and they have to replace perhaps .5% to .66% percent of their equipment each year because it fails. But in spite of that "new blood" added each year, the average utility system ages about 10 – 11 months per year.[14] Failure and "must-replace" rates are gradually creeping upward: one can keep old electrical equipment in repair for a long time but eventually it just starts wearing out no matter what one does.

Although they will be challenged by these increasing failure rates, most utilities will be able to manage the increasing rate of failures well for quite some time to come, preventing undue customer service interruptions due to those higher failure rates, and finding way to absorb the higher maintenance costs those failure rates cause through improved efficiency in their management and O&M practices.

But the big problem is more fundamental*: utilities can't afford to replace this equipment.* Sooner or later, most likely in the next two decades, all of that older equipment *will* fail and they will be compelled to replace it. But they will

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[14] A system in which no equipment was replaced and none was added would age at a rate of one year per year. One in which equipment was replaced at at a rate inversely proportional to its age (e.g., a 2% replacement rate for the oldest equipment in a set averaging 50 years old) would hardly age at all. Every utility system the authors know is much closer to the former than the latter situation.

not have the money. Utilities generally borrow money to buy electrical equipment and "finance it" for about 30 years, even if the average equipment lasts far longer than that. Today, most of the equipment that the average regulated utility has in its system was "paid for" long ago. They find themselves in a situation analogous to what many young people create during the first years of employment: They buy a new car and finance it for a period (say five years) less than its expected lifetime, making the payments without problem. When paid off, the car is still usable so they keep it and use it for several more years. During that time they gradually adjust to the lack of a monthly car payment, spending in other ways, until after several years that becomes the standard routine. Then the car fails and has to be replaced. They saved no money and thus have no cash to pay for a new car, and they can no longer afford car payments within their budget.

While many utilities face similar problems, the reason in many cases is not that they were "foolish" as much as that they are regulated. Although this is an oversimplification, regulated utilities are not really permitted to "save for the future." Since the equipment lasted longer than its depreciation period (analogous to the period of car payments) their costs dropped. Their rates are regulated based on costs. Many have gone four decades or more in situations that are not sustainable: *eventually they must spend more* than they currently take in. The amount of cost increase is significant but not staggering: on the order of 15% overall.

The problem is that the utilities cannot raise their prices to pay for needed equipment replacements unless they receive regulatory approval, and regulatory commissions, utilities, and utility customers alike have become accustomed to the present rates. Utility regulation is a political process that is reluctant to raise prices, period.

Chapter 15, Section 15.2, discusses aging infrastructures in much more detail. The authors have no doubt that this problem will gradually escalate in importance until it could dominate industry attention and utility business prospects and stock prices for a number of years. There can be no doubt, however, that the power industry will get through this problem: eventually regulatory commissions will have to recognize the need to increase replacement rates and customers will have to accept somewhat higher costs for power, but probably not before there is a considerable amount of controversy and stress for all concerned.

## Technology and Automation

Despite the fact that the electric industry is well over 100 years old, there continues to be a brisk pace of development in many of the technologies that electric utilities use. As a result, gradual improvements in cost, efficiency, environmental impact, and reliability can be expected for the foreseeable future.

A good deal of this improvement will be due to progress in "ancillary" technologies such as computers, software, and data communications. Utilities and power systems, by their nature complicated entities with a widely distributed asset base, benefit particularly from a combination of computerization (which can handle the complexity) and good data communication (which can address the dispersed nature of the systems).

Although utilities have long relied on computers for analysis, billing, facilities databases and control systems, computer technology is hardly yet mature, and data communications costs continue to drop. Two areas of development will improve business and customer performance. First, integration of "enterprise-wide" systems will consolidate business processes, achieve coherency and immediacy of function and focus, and drive an overall improvement in the productivity of people. While this may sound like prime, management-consultant BS, there is every reason to count on continual gradual increases in overall productivity of people and business equipment to a cumulative 10- 25% improvement.

The second area of expected improvement is in power system automation. Automation of equipment permits a utility to work the equipment harder. It can operate the equipment in "closed loop mode" (monitoring it in real time and allowing operators to push it to its prudent limits) and to do "when needed" maintenance and service, which improves equipment condition and lifetime, driving down the utility's maintenance costs.

Use of improved data communications technologies, including the internet, makes the ability to monitor and control dispersed equipment less costly. The major impact of this gradual reduction in automation cost is not that it reduces the utility's costs for control. Rather, it improves the bang-for-the-buck of automation, which *broadens* the base of equipment that the utility can afford to automate. Whereas today only major equipment can be automated, over time it will spread to smaller distribution equipment. Power systems will become more reliable and less costly.

## Fine Tuning De-Regulation's Regulations

Over a period of about 10 years beginning in the mid 1800s to the mid 20th century, electricity and the electric utility industry developed from a nascent and not-entirely understood curiosity into a trusted technology that was a cornerstone of mankind's civilizations. Regulation and monopoly franchises helped shield the industry's early development and channel its energy into productive growth, rather than competition and in-fighting. But by the late 20th century, many policy makers believed it was not just a mature, but a stagnant industry, innovation averse and unresponsive in some ways to the culture's larger needs.

While that view might be overly harsh, the fact is that the industry was de-regulated to reduce greatly the degree of monopoly involved. Many readers are no doubt struck by the complexity of the de-regulated industry structure, as compared to the traditional way electric power was produced, transmitted, distributed, and sold. But despite problems and its many complexities, de-regulation works better than most naysayers said it would, although not nearly as well, or as cleanly, as proponents hoped.

But while the industry is perhaps not in chaos at the moment, it is in a great deal of turmoil. In the US, the federal government (FERC) and the state regulatory agencies are often at odds on just who has what authority over which utilities, and there appear to be gaps, as well as overlaps, in policy and jurisdiction. What makes all of this so difficult is that there is little clear pattern to the differences and variations in policy, rules, and structure: a particular type of generation structure or policy in a region does not imply it will be accompanied by a particular type of transmission policy or marketplace policy or regulatory approach. As one looks across the industry, one can find all combinations of these different approaches, and a few not covered in this simple explanation.

There are efforts to unify national and state policies into a more coherent whole. At the federal, state, and local levels, different efforts are aimed at fixing different problems with different solutions. Most of this activity is proceeding with a speed, efficiency, and rationality no worse and no better than the political process displays any time there is money, power (literally) and blame to be apportioned. Eventually, the industry will be "fixed" and the solution will be acceptable if not elegantly simple and rational.

## FOR FURTHER READING

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