CHAPTER 1

The Electric Revolution

The age of electric power began in 1800 when Alessandro Volta, a professor of natural history at the University of Pavia in Italy, announced the discovery of a new form of electricity in a paper entitled "On the Electricity Excited by the Mere Content of Condensing Substances of Different Kinds." Before Volta the only kind of electricity known was *static electricity*—the kind you get when you rub your shoes across a carpet and then touch a conductor. In fact, the word *electricity* comes from the Greek word for amber, *elektron*. The Greek philosopher Thales discovered that amber rubbed with a cloth has the power to attract light bodies such as feathers, leaves, straw and small bits of wood.

Static electricity was even harnessed to perform useful work. More than a hundred years before Volta, static electricity was used in the first electric machine. A sulfur ball turned by a crank on an axis was excited by the friction of the hand and produced the first electric light.

Volta's remarkable contribution to the development of modern electricity lay in his discovery of "current" electricity. He transformed electricity from a toy to a tool of vast potential. By chemical means he produced a steady current. He created the first electric battery by alternating disks of silver and zinc piled one on the other. Each pair was separated from the adjoining pair by a cloth or paper disk saturated in brine. From the ends of this pile Volta could draw a continuously flowing electric current.

The "voltaic pile" unleashed a wave of discoveries and inventions throughout the world. Experimenters and scientists quickly refined Volta's crude invention into tiny power plants with which to conduct experiments. Gradually they began to uncover the basic theoretical principles underlying electric power and to conceive the mathematical equations that coupled electricity and magnetism. Technicians designed devices to harness this new source of energy. Electric current was used to decompose water, to cause charcoal to glow with an intense light, and later to deposit metals by electrolysis.

Hans Christian Oersted discovered in 1820 that a wire connected to the ends of a voltaic pile was enveloped by a magnetic field. If the wire was looped into a coil, the magnetic strength of the field was greatly intensified. André Marie Ampère proposed that the effect could be used to transmit messages over great distances. By 1836, practical systems of electric telegraphy were developed by Wilhelm Eduard Weber and Karl Friedrich Gauss in Germany, Sir William Fothergill Cooke and Sir Charles Wheatstone in England, and Joseph Henry and Samuel Morse in the United States.

Soon after Oersted's discovery of the magnetic field of currents, Michael Faraday, the great English chemist and physicist, began to investigate the subject. In 1831 he found that when a current is started in a coil of wire, a momentary current is induced in another nearby coil. When the primary current is stopped, an induced current is again generated, but in the opposite direction. He demonstrated that the effect is due to the magnetic field of the primary current and that the induced current in any circuit is proportional to the rate of change of the number of lines of magnetic force cutting through the circuit.

Producing magnetism from electricity opened the way to converting mechanical energy into electrical energy. By wrapping a core in coils of wire and turning the core through stationary magnetic fields, an electric current could be induced. Thus, the *electric generator,* or dynamo, and its important adjunct, the *transformer,* were born.

That same year, Joseph Henry, a physics teacher in the Albany Academy in New York, constructed the first electromagnetic motor. He increased the lifting power of a magnet from 9 to 3,500 pounds. Indeed, every electric dynamo and motor now uses the electromagnet in virtually the same way that Henry's motor did.

A year later, Thomas Davenport, an inventor in Brandon, Vermont, perfected the first commercially successful electric motor. It weighed 50 pounds and turned at 450 revolutions a minute (RPM), cutting through the magnetic fields with each revolution. The same year Hippolyte Pixii developed the first practical generator. By coupling a steam-driven turbine to the generator he could produce electrical energy, freeing the electrical experimenter from a reliance on chemical batteries.

These breakthroughs commercialized electricity. Motive power could be sent long distances. To understand what this means, consider that in 1851 a 1-inch-diameter shaft could transmit perhaps 1 horsepower (HP), or 0.75 kilowatts (kw), with a bearing every 3 feet. In less than a mile, all that power would have been consumed in bearing friction, even with the finest bearings then available. By comparison, a 1-inch-diameter shaft made from copper could conduct over 2,000 amperes of electricity. At 115 volts (V), this copper wire could conduct

363 HP for a mile with very modest energy losses. Since there was no torque, no bearings were needed. Moreover, the conductor could be suspended from widespread poles or towers.[1] Is it any wonder that some people envisioned electricity as the tool that would make humans titans?

Industry was quick to pick up on the potential of electric power. Its first major commercial use was for lighting. The *arc light* was developed in 1810. The device forced an electric voltage to leap across a gap between two wire tips, producing a brilliant arc of light 5 inches long. By the 1860s, steam-driven generators lit arc lamps in Europe and the United States.

But the arc light had several key drawbacks. The tips burned away in less than a night, and the brilliant, glaring light was suitable only for illuminating streets or very large indoor spaces, such as theaters or factories. Even more restricting was the practice of linking each light in series. If one bulb burned out, the whole system went dark.

Edison and the Rise of the Modern Utility

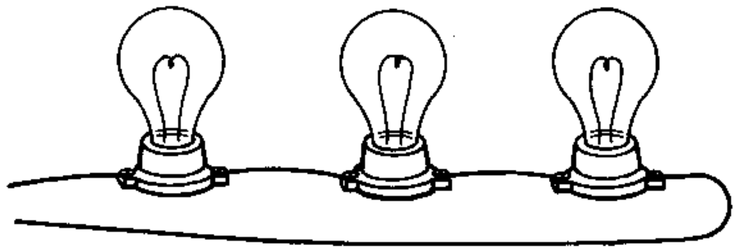
Enter the first electric entrepreneur—Thomas Alva Edison. Edison was a pragmatic inventor. Fresh from his triumphant innovations with the telegraph and the phonograph, he knew that the first step was to broaden the market for electricity. He knew immediately that the stumbling block was the electric industry's inability to bring electricity into individual buildings. The central problem was the use of series wiring. Edison later wrote, "I saw what had been done had never been made useful. The intense light had not been subdivided so that it could be brought into private homes."[2]

After only two nights of intense experimentation, he hit on a solution. By designing circuits in parallel, in effect duplicating the paths that electrons could flow through, he allowed the system to continue to function even if one individual component went dead.

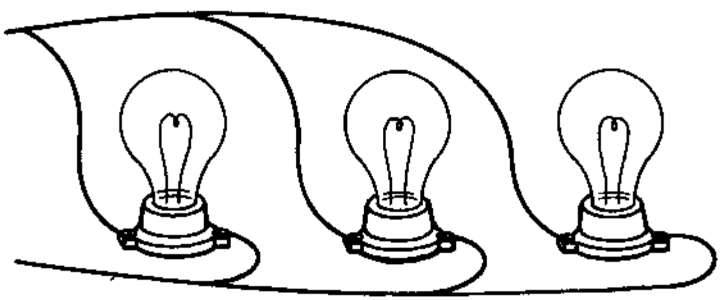
Having solved the problem of subdividing current, he proceeded to refine the first electric consumer product—the light bulb. After thousands of tries that gave credence to his motto that invention is 1 percent inspiration and 99 percent perspiration, Edison developed an incandescent light bulb with a very fine filament of carbon inside an evacuated bulb. The high resistance in the wire generated heat and light when a relatively low current was passed through it. The filament lasted much longer than the tips of the arc lamp.

Four years after he began his search for a better light bulb, Thomas Edison unveiled the first central electric power station, in downtown

Photo 1–1: Edison, shown here in his laboratory, had an important role in the creation of the modern electric utility. *Photograph courtesy of the Edison National Historic Site.*



series wiring (voltage is divided)



parallel wiring (voltage is constant across all bulbs)

Figure 1–1: If light bulbs are wired in series, the failure of any one bulb breaks the entire circuit. Parallel wiring, which Edison called *subdividing,* allows a continued flow of current even when one bulb fails.

Manhattan. The Pearl Street Station served 12 city blocks and was powered by steam generated from coal. Its initial capacity was 900 kw.

But steam was not the only force that could be used to drive a turbine. Commercial power plants immediately tapped into the kinetic energy of moving water. Mills that previously used on-site waterwheels to generate mechanical power now installed electric power plants. The first commercial hydroelectric plant was established in Appleton, Wisconsin, a year after the Pearl Street plant. Its original waterwheel measured 42 inches in diameter. It operated under a 10-foot head and had a speed of 72 RPM. Two Edison K dynamos were used, each capable of powering 250-candlepower of lighting, equivalent to a rating of 12.5 kw.

These early plants had none of the refinements of their modern successors. The Appleton plant had no voltage regulators. Operators depended on their eyes to gauge the brightness of the lamps. There were no meters and no fuse protection. Customers were charged by the lamp regardless of the hours of use. The original customers paid about 33¢ per lamp per month for service that lasted from dusk to dawn. Bare

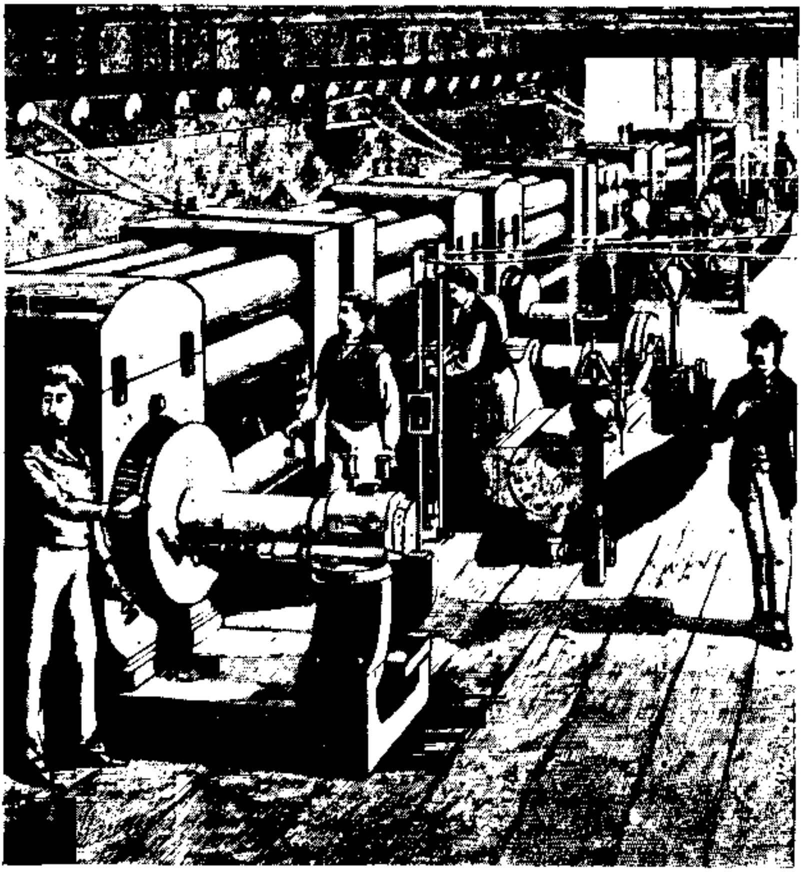


Figure 1–2: Pearl Street Station in downtown Manhattan was the nation's first central power plant. *Reprinted from* Scientific American, *26 August 1882.*

copper wire was used in the distribution lines. Needless to say, there was no uniform safety code to regulate the proper use of electric power.

Despite all his inventiveness, Edison did not have the electric power field all to himself. Strong competition arose. In its infancy, the industry sold complete systems in which every part was patented, from the bulbs to the power plant components to the relays and switches. Equipment purchased from one supplier wasn't always compatible with another's electrical system. Different motors operated on different frequencies.

But even with the handicaps caused by a lack of standardization, electric power immediately captured America's fancy. By 1890 a thou-

> This room is equipped with Edison Electric Light. Do Not Attempt to Light with Match. Simply Turn Key on Wall By the Door. The Use of Electricity for Lighting is in No Way Harmful to Health, nor Does it Affect the Soundness of Sleep.
>
> Message placed wherever electric light was present in the 1870s and early 1880s.

sand central stations were operating. Department stores, local governments and industries were lighted with electricity.

But it was in the transportation sector that electricity found its greatest use. The first trolley system began in 1888. Two years later, 51 municipalities had electric streetcars. By 1895 electric trolleys operated in 850 cities on more than 10,000 miles of track. The electric streetcar companies remained electricity's biggest customer until 1920.

The streetcar was well suited to Edison's power plants because they generated *direct current* (DC), that is, current moving in one direction only. Direct current's chief disadvantage was that its voltage couldn't be easily raised or lowered. Therefore the voltage that left the power plant had to be used by the customer. But commercial customers used relatively low voltages (110 v to 220 v), and low voltages could be sent only a short distance because of energy losses related to low-voltage transmission. Streetcar companies, however, used high voltages, and they tended to own local power plants. Until the electric industry could learn how to raise and lower voltages, electric power sales would depend on many small, dispersed power plants. Edison's utility systems could not economically transmit electricity more than 2 miles.

Soon after Edison began building DC power plants, George Westinghouse began experimenting with another form of electricity, *alternating current* (AC). Alternating current, with its alternating negative and positive voltages, moves back and forth, and its voltage can be raised (stepped up) or lowered (stepped down) by using transformers. By changing the ratios of the windings in the primary and secondary coils of a transformer, the voltage could be changed in any direction. In 1885 Westinghouse purchased the English patents to a series AC distribution system developed by Lucien Gaulard and John D. Gibbs. While working for Westinghouse, William Stanley improved the Gaulard-Gibbs system by designing induction coils (later called transformers) in parallel connection and developed the AC, constant-potential (voltage) generator.

In March of 1886 Stanley demonstrated the practicability of alternating current in Great Barrington, Massachusetts, by transmitting single-phase electric power a distance of 4,000 feet using one transformer to increase the output voltage to 3,000 v and another to reduce it at the receiving end to 500 v. Later in 1886, Westinghouse installed in Buffalo, New York, the first commercial AC system.

With Westinghouse's advance in generating and distributing alternating current, the supply side of the modern electric utility was in place. Within a year, between 30 and 40 plants were in successful operation. However, to make full use of alternating current, what the modern electric system now needed was a practical motor that would run on alternating current. It was developed through the genius of Nikola Tesla, a Serbian immigrant who had once worked with Edison. He developed the first AC motor and may be viewed as the true father of our modern electric system. As one admiring biographer noted, "He conceived of such practical alternating-current motors as polyphase induction, split-phase induction and polyphase synchronous as well as the whole polyphase and single-phase motor system for generating, transmitting and utilizing electric current. And indeed, practically all electricity in the world in time would be generated, transmitted, distributed and turned into mechanical power by means of the Tesla Polyphase System.[3]

Tesla's lecture on AC motors on 16 May 1888 before the American Institute of Electrical Engineers was a landmark event. With one lecture Tesla had literally set the stage for the new era of electric power generation that would utilize AC power. Tesla's motor used the principle of the rotating magnetic field produced by two or more alternating currents out of step (out of phase) with each other. By creating, in effect, a magnetic whirlwind produced by the out-of-step currents, he eliminated both the need for a *commutator* (the device used for reversing the direction of an electric current) and for brushes that provide for the passage of the current.

Westinghouse immediately purchased the patents to Tesla's motor and his polyphase system. Tesla's motors operated on 60-cycle current, so Westinghouse altered his entire generation system from 133 cycles to 60 cycles to accommodate Tesla's design. Today 60-cycle current is still the standard in the United States.

The battle between Edison and Westinghouse was fierce but short-lived. Edison initially called alternating current "the killer current" and waged a great but unsuccessful publicity campaign against its introduction. The only remnant from that struggle exists in New York, where in the early 1890s prison authorities agreed to adopt the electric chair, which used alternating current. Edison used to say that anyone dying in the electric chair had been "Westinghoused." Edison left the electric power plant business shortly after his company merged with another to form General Electric. Today General Electric and Westinghouse remain the two major suppliers of electric equipment in the United States. Edison may not have been the father of the modern electric utility but, as always, he foresaw the development of companies that sold electricity rather than power plants. In 1883 he patented the first electric meter. Five years later, O. B. Shallenberger invented the ampere-hour meter for measuring alternating current.

Alternating current opened the way for higher voltages and longer transmission lines. Remote waterfalls and rivers became large generators of electricity. In 1896 three Westinghouse 5,000-horsepower (HP) turbines rotated by the force of Niagara Falls sent some 12,000 kw of power surging across lines built by General Electric to run lights, streetcars and motors in Buffalo, 26 miles away.

From its inception the electric generation and distribution industry was widely viewed as the key to economic growth. It was also an extremely profitable business. During its first 30 years, the relationship between the electric industry and government was constantly changing, driven by the changing nature of the technologies underlying the industry. Two key issues formed the focus of public debate. Would the industry be a monopoly or would it be competitive? And, who would own and regulate the industry?

The first electric utilities were small, neighborhood businesses. The industry was private and largely unregulated. Typical of this competitive period was the granting by the Denver Common Council in 1880 of an electricity franchise "to all comers" with the sole restriction that these companies not block public streets and roads.

Cities often granted multiple franchises. Chicago, for example, had more than 29 electric utilities operating within its boundaries in the late nineteenth century. New York City awarded 6 franchises in a single day in 1887.

The modern electric utility operating under what is essentially a monopoly awarded by a city or state is a creature of the new steam turbine technology introduced at the end of the nineteenth century, which, because of its increasing scale, made larger plants feasible. The first steam turbine, a 2,000-kw plant, was installed by Westinghouse for the Hartford Electric Company in 1900, revolutionizing the generation of electricity from coal. In 1903 the Commonwealth Electric Company installed a 5,000-kw plant. Eighteen months later the country's largest power plant generated 10,000 kw, and by 1913, a 35,000-kw plant was operating. In the mid-1920s, a single power plant could generate 175,000 kw, enough to meet the needs of a small city.

High voltage lines carrying alternating current permitted long-distance power distribution. In 1907 E. M. Hewlett and H. W. Buck developed the first suspension insulators, making practical the transmission of very high voltages. By 1920 voltages up to 132,000 v, or 132 kilovolts (kv), were common, and some lines operated at 150 kv. By 1934 the Hoover Dam transmitted 287 kv to Los Angeles, a distance of 270 miles.

Samuel Insull, a former secretary and salesman for Thomas Edison, is considered the father of the modern utility. As president of Commonwealth Electric Company he justified a monopoly on the basis of technological advances. When he took office in 1900, almost two-thirds of the nation's electricity was generated on-site, primarily by streetcar companies and other commercial and industrial producers. His goal was to consolidate all the small electric utilities into one big company and to persuade those who owned their own power plants to abandon them and buy cheaper power from the emerging grid system.

Insull pointed to the higher efficiencies of the newer, larger steam turbines. He also argued that electric demand had an important "diversity factor." People tended to use electricity at different times. Therefore, he said, the increase in the number of users was not proportional to the increase in generating capacity. Insull's favorite illustration was of a block of northside Chicago homes. There were 193 apartments on that block, and 189 of them were customers of his utility. There were no appliances, motors or other electrical devices to speak of in that block of apartments—just electric lamps. The power demanded by all separate apartments on the block, if totaled, was 68.5 kw, but since different lamps would be in use at different times, the actual maximum demand was only 20 kw.[4]

Supplying all of those customers from a single source would thus require only a 20-kw peak generating capacity. But if each household were equipped with a separate generating plant to meet its own needs, 68.5 kw would be needed—more than three times as much.

Insull backed up his rhetoric with an attractive pricing structure for large customers. His was the first *declining block rate*—the more you used, the lower the price per kilowatt-hour. In 1915 Chicago's residential customers paid 15¢ per kilowatt-hour. Its industrial off-peak customers paid only a penny.

Insull's persuasive sales pitch, combined with promotional pricing and the increased efficiencies of steam turbines, proved an unbeatable combination. In 1900, 60 percent of electricity was generated on-site, but by 1920 only one out of five kilowatt-hours (kwh) of electricity was generated on-site. From 1919 to 1927, 52,000 steam engines were scrapped; 18,000 internal combustion engines were discarded; and 5,000 water wheels were abandoned. Plugging into the utility monopoly had become cheaper than producing power on-site.

By the early twentieth century, the issue of whether electric power would be produced and distributed through monopoly or competition was decided. It would be a monopoly. No distinction was made between a monopoly of the transmission and distribution system and a monopoly of the power generation system.

The organizational form was clear. Less clear was the answer to the second question. Who would own and control the electric monopoly?

Smaller cities and rural areas had fewer potential customers, which made these markets less profitable for investors. Smaller cities were forced to finance and build their own power plants to satisfy a growing demand. In 1896 there were 400 municipally owned electric plants, and by 1906 there were more than 1,250. At the same time, about 2,800 investor-owned utilities accounted for slightly less than 75 percent of the generation capacity of the country.

While smaller cities were becoming directly involved in the generation and distribution of electricity, the larger cities, where private ownership predominated, were relinquishing direct oversight responsibilities. The issue of public ownership in the larger cities was central to most municipal elections during the early part of this century. Elections were won or lost on one's stance toward the electric utilities (and their direct brethren, the electric transportation or traction companies). In most cities municipal ownership movements eventually failed, although in several, such as Los Angeles, Seattle and Cleveland, they were successful.

Cities then as now retained the right to allow an electric company to operate within their jurisdictions by issuing a franchise to sell electricity within their borders. The awarding of franchises was among the most corrupt events in local politics. Many franchises were voted "in perpetuity." Later courts and state legislatures overturned these permanent franchises, but in several states 50- to 90-year franchises are not uncommon even today.

City councils at first also directly regulated the utility, setting rates and operating conditions. But as utility industries grew more complex and the technology permitted regional and even interstate distribution systems, the need for greater expertise and the lack of system-wide control undermined municipal authority. Moreover, the political process of oversight often culminated in political corruption and drawnout court cases. A national movement arose to have independent state agencies regulate the utilities. It was led, ironically, by Samuel Insull, who consistently preached to his associates that only by allowing independent regulation could the industry hope to have the public accept its monopoly status.

The movement toward independent state regulatory commissions was fought by those involved in the municipal home-rule movement. A coalition of urban residents fighting for greater political autonomy from their state legislatures also fought for direct control over their physical infrastructure, their water systems, energy systems, roadways and transportation systems.

Those who argued for removing regulation to an independent state authority emphasized the efficiency of such a move. Those who supported regulation by the cities—such as Stiles P. Jones, a utility expert with the National Municipal League—considered democratic government, not scientific regulation, to be the goal. To him:

> *"Efficiency gained at the expense of citizenship is a dear purchase. Efficiency is a fine thing but successful self-government is better. Democratic government in a free city by an intelligent and disinterested citizenship is the greater ideal to work to and democracy plus efficiency is not unattainable."*[5]

But the dynamics of the technology undermined the arguments of even the most ardent supporters of local regulation. Even the most fervent believers in municipal home rule, such as Delos Wilcox, author of the two-volume text for citizen activists entitled *Municipal Franchises,* finally conceded that "public utilities, although still comparatively simple industries, have grown far enough beyond merely local bounds to require complex governmental machinery to operate or regulate them."[6]

Municipalities continued to own utilities, as later did rural electric cooperatives. The relationship between these publicly owned utilities and state regulatory bodies was, and continues to be, inconsistent, differing state-by-state.

Cooperative utilities are regulated in about two-thirds of the states. Municipally owned utilities are subject to the general jurisdiction of regulatory commissions in only nine states (Maine, Maryland, Nebraska, New York, Oregon, Rhode Island, Vermont, West Virginia and Wisconsin). Some states have unique statutes. For example, until 1981 a city in Illinois could regulate the local operation of public utilities if the electorate chose to do so through a referendum. In Kansas, local governments can still regulate public utilities that operate within a single municipality.

This inconsistency became important in the 1980s when small power producers found that, in some states, one state regulatory body would set prices for independently produced power, while in others, many individual publicly owned utilities retained that authority.

As transmission voltages increased and transmission lines fanned out, even the authority of state regulatory commissions was undermined. By 1935, 20 percent of the nation's electricity crossed state lines.

Such distribution systems made electricity part of interstate commerce and thus immune from state regulation, according to the Constitution of the United States. This was made clear by the U.S. Supreme Court in a 1927 case. The Narragansett Electric Lighting Company of Rhode Island sold a small amount of electric energy to the Attleboro Steam and Electric Company of Massachusetts. Because the Rhode Island Commission believed that the selling price was so low as to put an unjust burden on its other Rhode Island customers, it sought to raise the rate to the Massachusetts wholesale customer. But the Supreme Court held that the order of the Rhode Island Commission raising this specific rate constituted an unconstitutional burden on interstate commerce.

Into this regulatory vacuum stepped the Federal Power Commission, established in 1920 under the Federal Water Power Act. The Federal Power Act of 1935 consisted of amendments to the 1920 legislation, expanding the jurisdiction of the commission by giving it power to regulate the rates and service of electric utilities when the transactions are in interstate commerce. In the late 1970s the Federal Power Commission was renamed the Federal Energy Regulatory Commission (FERC).

Power plants grew larger and larger. A new form of organization arose—the *public utility holding company*. It was an umbrella organization that owned literally hundreds of individual systems. Middle West Utilities Company, Insull's holding company, provided utility services through its operating subsidiaries to more than 5,300 communities in 36 states. In 1932 Insull was president of 11 power companies, chairman of 65 and director of 85. The number of operating utilities dramatically declined. Between 1922 and 1928 the number of individual electric utilities decreased by 33 percent, whereas the number of communities served by the remainder increased by 5,000 or about 37 percent. Between 1917 and 1927, 900 municipal utilities were abandoned. In 1927 only 125 utilities generated electricity for more than 80 percent of the electric customers in the nation. If to this is added the amount of electricity purchased by these utilities for distribution, they supplied almost 97 percent of the nation's electricity. Senator George Norris, father of the Tennessee Valley Authority, proclaimed on the floor of Congress in 1925 that, "I have been dumbfounded and amazed, and the country will be dumbfounded and amazed when it learns that practically everything in the electric world . . . is controlled either directly or indirectly by this gigantic trust."[7]

As one student of public utilities writes:

> *"It was a race between the technical achievement of the economies of mass production and the invention of legal devices for mobilizing entrepreneurship to make use of them. . . . By using the devices of the lease, the trust, the corporate merger, and the holding corporation, great pyramids of ownership and control of public utility markets were set up . . . the jurisdiction of state commissions could not reach all the facets of this developing problem. Aggravated by the depression and by the fact that less than half the state commissions had adequate powers over security issues and over mergers and consolidations, the unsound financial structure of many holding companies collapsed in the financial storms which swept the country beginning in October 1929. The administration of President Hoover in Washington temporized with the problem, and hence the control of these "pyramids of power" became an issue in the campaign of 1932."*[8]

The New Deal Electrifies the Nation

When Franklin Delano Roosevelt (FDR) was governor of New York, he discovered that the electric bill at his country cottage in Georgia was four times higher than at his home in New York. "It started my long study of proper public utility charges for electric currents and the whole subject of getting electricity into farm homes," Roosevelt later said.[9] To FDR, electricity and development went hand-in-hand. His administration added three federal agencies to the electric system: the Tennessee Valley Authority (TVA), the Bonneville Power Administration (BPA) and the Rural Electrification Administration (REA).

The TVA, created in 1935, is a federally owned corporation for regional development. By 1970 it had become the single largest electric utility in the nation, with twice the installed capacity of any other utility and approximately 5 percent of the nation's total generating capacity.

The Bonneville Power Administration, also created in 1935, is primarily a marketing agency that transmits electricity from federal hydroelectric facilities to investor-owned and public utilities. By 1970 BPA could boast that it operated the nation's largest network of long-distance, high-voltage transmission lines.

In the mid-thirties, the REA offered rural electric cooperatives long-term, low-interest loans for electric generation capacity and transmission and distribution lines. Before REA, many power companies charged rural customers up to 15 times the cost of production. For $5 rural residents could become members of a cooperative or public utility district and own their own power plant or bargain with the previously recalcitrant investor-owned utility for more modest electric rates. The proportion of farms in the United States with electricity increased from 10 percent in 1930 to 43 percent in 1944 to 98 percent in 1975. Rural electric cooperatives, commonly called RECs, now serve 25 million people through 1,000 cooperatives in 46 states. Only a handful of RECs generate their own power (27 in 1974), but they own 42 percent of the electric distribution lines in the nation.

Many of the new utilities were based on hydroelectric power. Back in Teddy Roosevelt's era, the federal government decided that federally owned water resources should be used first to benefit publicly owned agencies. The Reclamation Act of 1906 empowered the Bureau of Reclamation to produce electricity in conjunction with federal irrigation projects and to dispose of any surplus for municipal power. The bureau's role was expanded in the Federal Water Power Act of 1920 and the Flood Control Act of 1944. Both gave a preference for public bodies and cooperatives. This preference clause became important in the 1980s as cities vied with investor-owned utilities to claim the rights to harness hydro on federally owned land. BPA was one marketing agency for federal hydroelectric power. To a lesser degree, the Southeastern, Southwestern and Alaska Power Administrations later played this role.

FDR brought electricity to areas of the country which previously had none. To do so, his administration created new organizational forms. Also on his agenda was the need to regulate the private utility corporation more closely, to avoid the abuses of the utility holding companies. The Securities Act of 1933 and the Securities and Exchange Act of 1934 established the Securities and Exchange Commission (SEC). The SEC had three main operating divisions, one of which was a Public Utilities Division. It had jurisdiction over the issuance of all securities to be sold in interstate commerce, including those of a utility and of a nonutility character.

The Public Utility Holding Company Act of 1935 provides for the physical disintegration of holding company systems and restructures the public utility industry.

These laws did not pass easily. After two stormy years the Public Utility Holding Company Act passed by one vote. Passage was assured only by eliminating the most controversial provisions. For example, bowing to pressure from utilities, Congress agreed not to convert electric utilities into "common carriers." Federal regulatory agencies were therefore denied the authority to order utilities to transmit electricity from an independent power producer to another buyer.

This concession was to return to haunt small power producers 50 years later. A common carrier is a monopolistically owned distribution system that must carry the goods of independent companies. For example, a highway is a common carrier. So are railroads and oil pipelines (although natural gas pipelines are not). If the electric grid system were to be a common carrier, the utilities would have to transmit anyone's electricity at a nondiscriminatory rate. Congress initially ordered them to do so, but then pointedly withdrew that provision. The courts repeatedly referred to this refusal by Congress in their decisions to deny state regulatory commissions the authority to order utilities to transmit electricity from one independent producer to some remote buyer. In the 1960s and 1970s the primary parties hurt by these rulings were the municipal utilities. Having given up their generation capacity because it was cheaper to buy into larger, privately owned systems, they found themselves unable to switch to cheaper producers because the utilities refused to transmit that electricity (this is called wheeling) over their grid system. In the 1980s this lack of common carrier status would inhibit all small power producers from getting the best price for their electricity by eliminating the possibility that they could sell to remote customers.

Power Pools and the National Grid System

The New Deal extended electric power to the entire country, rural as well as urban. It also substantially changed the organizational form of the corporations that generated and delivered electricity. But the technological underpinnings of the electric system remained inexorable. The dynamics of bigness continued to unfold.

Several utilities interconnected in what became known as regional power pools. The first one was established in 1927 when the Public Service Electric and Gas Company of New Jersey (PSE&G) and the Philadelphia Electric Company joined forces. By 1970 there were 17 power pools, representing 50 percent of the nation's generating capacity. By the late 1960s one utility expert could write, "The United States is already close to being a two-network country, and the process of interconnections across the Rockies to link the two networks has already begun."[10]

The interconnectedness of grid systems represented an increasing interdependence. Utility historians like to recall the story of an Ohio utility that suffered a service interruption during the 1960s. It was connected to a regional power pool. The electrical impulses set up by the failure were felt at progressively greater distances as each installation down the line had no available power. The first plant to respond to the need was an idling hydroelectric plant in Arkansas. When the demand reached it, the plant automatically started up. Its gates opened and a large volume of water was released below the plant. At that moment, a man was fishing in a boat too close to the plant, and the sudden rush of water capsized his boat. Utility operations had become so interrelated that a power outage in Ohio could cause a drowning in Arkansas.

Transmission lines were built to carry higher and higher voltages. From 1900 to 1950 the maximum AC voltage transmitted increased from less than 50,000 v to 230,000 v. In the late 1950s, 345-kv lines were in operation, and by 1980 there were 765-kv lines. These transmission lines became super highways for electric power. Each time the voltage was raised, the amount of traffic the line could carry went up. A transmission line rated at 500 kv typically handles about 2,000,000 kw, or 2,000 megawatts (Mw), the output of two giant generating plants. A 765-kv line handles about 3,000 Mw.

Higher transmission voltages went hand-in-hand with larger power plants. The largest steam power plant built in 1952 had a capacity of 125 Mw; in 1967 the largest was 1,000 Mw. On the average, unit size increased by more than 700 percent from 1947 to 1967—from 38 to 267 Mw.

In 1977 there were more than 4,000 power plants in operation, yet fewer than 300, or 7 percent, generated more than half the nation's power. The Federal Power Commission confidently predicted the trend toward bigness would continue. It foresaw 2,000-Mw fossil-fueled plants by the 1980s and 3,000-Mw plants by 1990. A single power plant would be able to serve a city the size of Houston!

Large power plants, with their cheaper power, convinced cities and rural cooperatives to abandon their own capacity and buy into larger systems. In 1935 almost half the municipally owned electric utilities generated all of their own power. By 1975 only one in ten did so.

In 1978 the United States electric utility industry nominally consisted of 3,500 systems, but 2,400 of them were involved solely in the transmission and distribution of power. The combined output of municipalities, public-utility districts and state power authorities accounted for less than 10 percent of the country's total generating capacity. Two hundred and fifty investor-owned utilities owned more than 80 percent of the nation's generating capacity. The top ten of this group owned almost half of this. The day of the small owner-operated power plant appeared to be over forever. Less than 5 percent of the nation's electricity was generated on-site in 1975, and all of this came from large industrial generators.

For all practical purposes the nation was divided into three separate power supply regions: Texas, the eastern states and the western states. The average kilowatt of electricity traveled 220 miles, the distance from New York to Washington, D.C. Electricity generated in British Columbia traveled as far as to southern California and Arizona, while some eastern Canadian electricity probably went nearly to Florida.

The nation continued to find new ways of using electricity. Streetcar companies gave way to industry as the major user by 1920. By the 1960s, residential and commercial buildings were the major consumers of electricity for space heating and cooling. A larger and larger portion of our primary fuels (coal, oil and gas) was being burned to generate power. In 1930, 10 percent of our fuels were used to generate electricity; in 1960, 20 percent and in 1980 almost 30 percent were used for this purpose.

Financial advisors recommended utility stocks for those who wanted a good return with no risk. It was especially attractive for the elderly and pension funds. This was the golden age.

The Golden Age Ends

High voltage transmission lines and interconnected power pools increased the electric system's complexity to an unprecedented level. Scientists and engineers began to encounter strange resonances throughout the system, a behavior and response pattern that could not be explained by existing theories. An entirely new science was needed to understand the new electric synergy.

After World War II, the utilities assessed their ratepayers to finance a new research and development (R&D) organization. The new R&D firm, the Electric Power Research Institute, now manages more than a thousand projects in all aspects of electric energy generation, delivery and use, with the actual R&D going on in industries, utilities and universities.

Power pools were initially justified as a way to reduce reserve margins, but individual utilities refused to view the pool as a reliable backup source. Each utility built its own back-up source. During the period that power pools proliferated, the reserve margins actually increased by almost 300 percent. Recommended reserve margins increased by 100 percent.

Now, however, the cost of transmitting power was becoming a significant factor. By 1972 the cost of building and maintaining the grid accounted for 70 percent of the cost of delivered electricity. We were paying twice as much to get the electricity from the plant to us as we were to get it generated.

The economies of large power plants proved illusory. After 1960 large power plants actually became less efficient. The larger the plant, the more it broke down. Coal plants of from 400 Mw to 800 Mw were inoperable about 8 percent more than plants half as big. For all coal- and oil-fired power plants in the United States during 1967 to 1976, the *forced outage rate* (the fraction of time a plant is involuntarily out of service) ranged from a tiny 2.5 percent for plants under 100 Mw to 16 percent for plants of 800 Mw, rising proportionately in between.

The complexity of the grid system continued to plague its originators. In 1965 a cascading power failure originating in a relay that malfunctioned in Canada interrupted the electrical supply of most of the northeastern United States. Thirty million people lost electric power for up to 13½ hours. Fully 23 percent of the 1965 peak electric demand in the United States was unfilled. A decade later, on 13 July 1977, just three days after the chairman of Consolidated Edison (Con Ed) of New York had said he could "guarantee" that a recurrence was remote, nearly nine million people were affected by a blackout, this time for as long as 25 hours. The assistant director for systems management of the Department of Energy (DOE) noted in 1976, "It is becoming apparent that the increasing complexities of the nation's electric system are rapidly outstripping its capabilities . . . . There does not exist any comprehensive applicable body of theory which can provide guidance to engineers responsible for the design of systems as complex as those which will be required beyond the next generation."[11]

Amory and Hunter Lovins, after an exhaustive analysis of the weakness of our electric transmission system, concluded in 1981, "We may well find, as power systems evolve in the present direction, that they have passed unexpectedly far beyond our ability to foresee and forestall their failures."[12]

The transmission systems increasingly became the soft underbelly of the electric system. Of the 12 worst power interruptions to the bulk power supply in the United States from 1974 to 1979, 6 were caused by failures in transmission, 6 in distribution and none in generation. Seven were initiated by bad weather, 4 by component failure and 1 by operator error. Sometimes the most minor mishap ended in widespread disaster. On 8 January 1981 a trash fire at the Utah State Prison apparently caused arcing in a major switchyard next door. The resulting quadruple transmission failure blacked out all of Utah and parts of Idaho and Wyoming. One and a half million people were affected.

Some observers have worried about the possibility of sabotage. The Government Accounting Office audited the electrical security of a typical part of the United States and determined that the sabotage of only eight electrical substations could black out an entire region. The sabotage of only four substations would leave a major city with no power for days and with rotating blackouts for a year.

The increasing separation of production and consumption in the electric system undermined the ability of communities to control their futures. Communities at different ends of the "electric pipeline" fought one another. For example, in western Utah around Delta, construction of the largest coal-fired facility in history began in the late 1970s. Electricity from the 3,000,000-kw facility would be transmitted 500 miles to southern California. Steam plants need water. Water is scarce and precious in Utah. The facility, 50 percent owned by California municipal utilities, bought up 40,000 acre-feet of water in 1981. To air-condition Los Angeles, the economy of western Utah was going to change from agriculture to mining.

The separation of the generation facilities from the final consumers meant the costs and benefits of electric power were imposed on different communities. While one community fought the disruption that came with new power plants, another community basked in increased electric capacity and increased its demand accordingly.

High-voltage transmission wires require wide rights-of-way. Using their power of eminent domain, utilities expropriated wide swaths of private land to erect the six- and seven-story towers. People fought against this intrusion on their property and against possible harm from the magnetic fields emanating from the 765-kv lines. Bitter confrontations took place from 1979 to 1980 between Minnesota farmers and utility companies trying to build these lines. Eight thousand fragile glass insulators were shot out by rifles. Guarding just the Minnesota section of line required 685 watchtowers spread over 176 miles. "Despite high-speed helicopters, a reward of one hundred thousand dollars, three hundred private guards and extensive FBI activity, not one of the perpetrators has been caught. It is not likely that they will be, given the depth of their local support,"[13] wrote the Lovins.

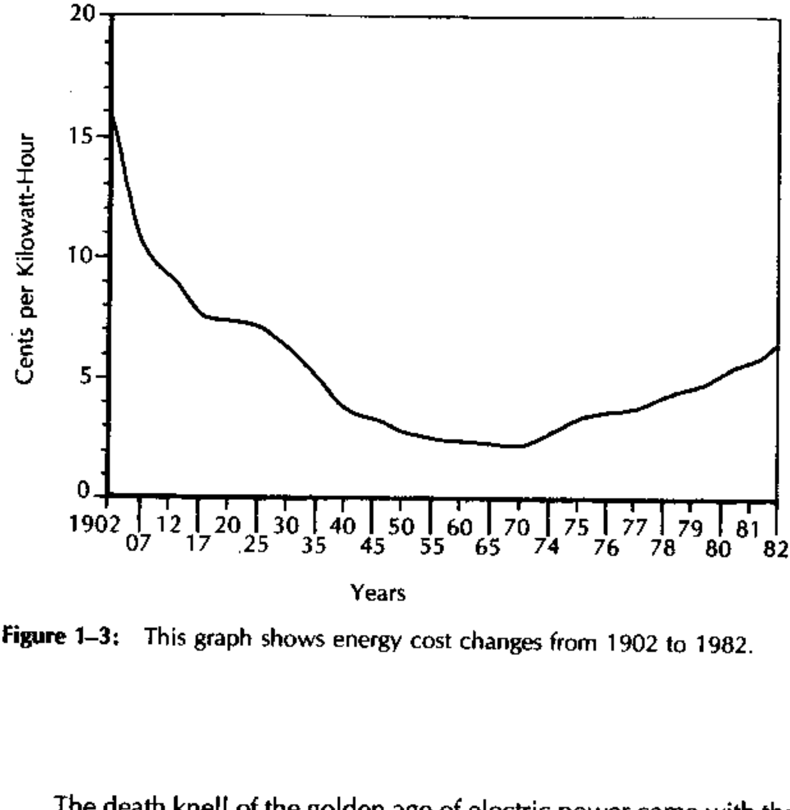


Figure 1–3: This graph shows energy cost changes from 1902 to 1982.

The death knell of the golden age of electric power came with the dramatic rise in fuel prices in the 1970s. By 1970 almost 40 percent of the nation's generating capacity was oil-fired at a time when a barrel of oil cost $1.75. By 1980 that price had risen to $33. The deregulation of natural gas would bring its price up to that of oil by the mid-1980s.

For the first time in a century, electric prices rose dramatically. The average cost per kilowatt hour in 1907 for the residential customer was 10.5¢. In 1970 the average price was 2.1¢. The average factory worker earned 20¢ an hour in 1907 and $3.36 an hour in 1970. Therefore, to keep a 100-watt light bulb burning all day, the laborer in 1907 had to work 30 minutes. The laborer in 1970 had to work 23 seconds to buy the same amount of electricity!

Regulatory commissioners, whose easy task had been to determine how fast prices should drop, now had to impose higher tariffs. Demand no longer rose at the historic 7 percent annual rate. In 1977 it rose by 4 percent; in 1980 by less than 2 percent. Instead of doubling every 10 years, demand was doubling every 35 years. In fact, growth continues to slow down. From January 1981 to January 1982, the total electricity sales in the country increased by only ½ of 1 percent. At that rate electric demand would double by the year 2126!

Demand forecasting has indeed proved to be a risky process. From 1973 to 1982, the Edison Electric Institute, the nationwide association of investor-owned utilities, overestimated projected demand by more than 100 percent every year. But even as forecasting was revealed to be an inexact science, the penalties for guessing wrong have become more severe. Nowadays, the bigger the power plant, the longer it takes to come on-line. By 1982 the size and complexity of nuclear power caused a 12-year delay between the preliminary planning and the actual generation of power. Power plants conceived (by projected growth rates) in 1970 weren't born until 1982. But during those 12 years, projected demand increases had fallen short by up to 90 percent. In most parts of the country, far more capacity was coming on-line than was needed to meet demand, even on the hottest summer day or coldest winter night. Electric rates had to increase to pay for these increasingly idle power plants. Meanwhile, the cost of idle plants rose. Utilities, used to paying 1 percent interest in the early 1960s, were forced to borrow money at the 15 to 18 percent interest rates of the early 1980s. Nuclear power plants built for $400 per kilowatt in 1970 cost $2,500 per kilowatt in 1982.

By the 1980s, the amounts that utilities were spending on a single power plant were astonishing. Building one nuclear plant could double a utility's entire previous investment in facilities. "We've never seen lumps like this in the past," said Alfred E. Kahn, a specialist in regulatory economics and former special advisor to Jimmy Carter. To pay for such plants, utilities have begun to ask for sharp rate hikes, but these hikes can dampen demand even further. One Long Island Lighting Company (LILCO) vice-president reflected in mid-1982 that "you have the problem of prices cutting into sales." LILCO asked the New York Public Service Commission for permission to phase in rate hikes over several years instead of all at once, even though doing so might alienate investors. Phasing in construction costs, in the opinion of Dan Scotto, vice-president for electric utility companies at Standard & Poor's Corporation, would mean that bond ratings would be lower. Lower bond ratings mean higher interest costs and, ironically, still higher electricity prices.

Meanwhile, the demand for electricity has continued to drop. TVA has canceled a half-dozen proposed nuclear plants. Utah Power and Light has recommended deferring half of the proposed capacity for the Intermountain Power Project outside of Delta. The Washington Public Power Supply System has admitted that two and possibly three of its nuclear plants under construction would not be needed for the foreseeable future.

The actual decline in electric demand in the early 1980s was largely a result of the economic recession that plagued the world in the aftermath of the rapid oil price increase of 1979. If the economy recovers, it is likely that the demand will once again rise. However, the rate of increase is unlikely to ever again reach the lofty previous levels. Efficiency and the substitution of other types of energy for electric energy have become very cost competitive. For example, General Electric's electric motor factory in Erie, Pennsylvania, is gearing up for an economic recovery by increasing its production several-fold. The new motors will use 40 percent less electricity per mechanical energy produced than did their predecessors. As industry upgrades its industrial processes, it will be buying newer, more energy-efficient equipment. Residents will be trading in their old cars and old appliances for more efficient ones.

The Pendulum Swings Back: Decentralized Power

The trend toward centralization reversed itself in the 1970s. Once again small dispersed power plants of less than 10 Mw became economically attractive. One reason was that smaller plants could come on-line rapidly, often in fewer than three years. Thus investments in additional capacity could be more easily matched to changes in demand. Forecasters would no longer have to bet billions on ten-year projections. Also, short-term financing in the uncertain capital markets of the 1980s is much easier to obtain than the 20- and 30-year bonds utilities have had to issue to finance large central power stations.

Large numbers of small power plants give the electric system greater reliability. Since they can be located nearer to the final user, the transmission and distribution costs can be reduced. Also, smaller plants lend themselves to mass production techniques that can lower unit costs.

New and refashioned electric generation technologies have entered the marketplace. For example, *cogeneration,* which has been in use since the last century, is now proven to be economical on a much smaller scale than was previously the norm. The same is true of hydropower systems: smaller is more profitable. Other technologies, such as wind power and photovoltaics, have also made gains with recent advances in electronics and materials sciences.

Cogeneration is a process by which systems produce both electrical (or mechanical) energy and thermal energy from the same primary energy source. Conventional energy systems supply either electricity or thermal energy, while a cogeneration system produces both.

A typical commercial boiler that is used to heat an apartment house or business complex has an efficiency of about 50 percent. More than half the energy in the fuel is wasted. A typical central power plant has an even lower efficiency, in the range of 33 percent. Subtract from that additional losses in transmission, and almost three-quarters of the energy burned in a power plant is lost before the electricity enters the building.

Cogenerators, on the other hand, have efficiencies of 75 to 95 percent. These efficiencies can be achieved only if a nearby use can be found for the waste heat. Thus cogeneration units are usually placed inside or near the buildings to be served. A 1978 study by the State of New Jersey discovered that 50 percent of the boilers in state buildings were over 25 years old and would soon need to be replaced.

The study recommended they be replaced with cogenerators that would increase their efficiency by 50 percent, generating electricity as well as thermal energy. In the early 1980s, several automobile and truck companies were redesigning their basic engines into household-

Photo 1–2: This single-family residence in Carlisle, Massachusetts, generates an annual surplus of electricity from its 7.5 peak kilowatt rooftop photovoltaic array. Solar Design Associates, Lincoln, Massachusetts, were the architects and engineers. *Photograph courtesy of Solarex Corporation.*

sized power plants by linking them up to generators and installing heat recovery equipment.

The benefits of small cogeneration systems are not restricted to plants that are fueled by gas or oil. Canada is developing a nuclear-powered cogeneration plant. Atomic Energy of Canada, Limited, is developing 2-Mw to 20-Mw units that could heat and power a small city. The plants would be unattended most of the time, responding automatically to daily variations in demand. The reactor core would contain enough uranium fuel to last two heating seasons. The Canadians are attempting to uprate (increase peak output) a 20-kw research reactor called SLOWPOKE, developed in 1970. The researchers conceded that the "public may not readily accept small nuclear reactors in place of oil furnaces," but they believe in the inherent safety of these miniature plants. "A decentralized system of small reactors, which effectively eliminates the possibility of a single big accident, may have significant advantage in licensing, insuring and gaining public acceptance. Eventually the public may accept accidents to small reactors to the same extent that they accept fires, explosions and air-crashes. . . ."[14]

Out of the reversals in the trends of energy costs, growth and demand, a new industry is being born to deliver the necessary goods and services for small-scale power production. Small businesses have developed prototypes, worked out the bugs, retooled and evolved reliable machines. Every increase in the price of conventional electricity has made solar power plants economically attractive in a wider range of locations. Hydroelectric plants were common a century ago. But by the 1950s, the price of oil was so low that, in order to be competitive, only huge systems could be built on the largest rivers. But as the price of oil has risen, smaller-scale facilities have again become attractive. Towns that had abandoned their turbines in the 1940s and 1950s have begun to refurbish them. In 1979 the Army Corps of Engineers identified more than 3,000 potentially economical hydro sites on existing dam sites alone. These sites could generate economical electricity for several thousand homes. The term *small-scale low-head hydro* entered the energy vocabulary. Today's prices for conventionally generated electric power have increased sufficiently so that even minor and slow-moving rivers and creeks could be economically harnessed. The term *micro hydro* was coined and quickly adopted. These systems are economical even if they serve only a few homes.

The wind power industry has evolved with equal dynamism. To be competitive with diesel generators in the 1950s, wind turbines would have required wind speeds higher than those in any part of the nation. By 1982 average wind speeds of less than 15 miles per hour (MPH),

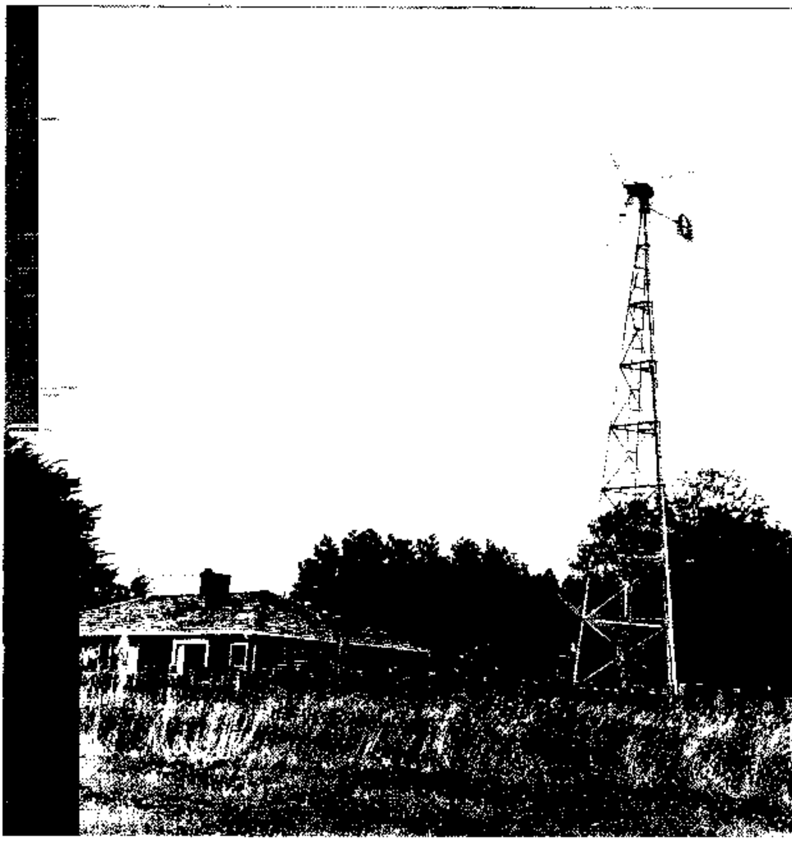


Photo 1–3: A 3-kw wind machine is pictured here. With adequate winds it could supply at least one half of an average residential electric load, not including electric space or domestic water heating. *Photograph courtesy of Joe Carter.*

which are available in significant portions of the country, could generate electricity competitively from some of the new generation models developed in the seventies.

The most dispersed of all energy sources, direct sunlight, has proved to be a strong competitor in the very near future. *Photovoltaics,* involving the use of *solar cells,* had only been in existence since the early 1950s. They were used only to power satellites until 1973, but in 1974 the first manufacturer of cells for terrestrial applications set up business. At that time the price for photovoltaic power was more than 300 times that of conventional power plants, but by the late 1970s the price had dropped to where it was 50 times more costly. By 1982 the cost of photovoltaic electricity was only 10 times that of conventional electric power. Although it is still too expensive for widespread applications, almost 1,000 households are using solar cells. They are mostly used on homes located off the grid system. Compared to the cost of laying miles of electric cable to connect to the grid, the solar cells proved to be more economical. The photovoltaic industry has predicted that, by the mid-1980s, its products will be competitive for grid-connected applications in most parts of the nation.

The increasingly marginal economics of modern electric power plants and transmission systems has encouraged businesses to design technologies that could operate efficiently in dispersed arrays. But the new breed of electric producer threatened the existing utility structure. As the Congressional Office of Technology Assessment concluded in 1978, "If energy can be produced from on-site solar energy systems at competitive prices, the increasing centralization that has characterized the equipment and institutions associated with energy industries for the past thirty years could be drastically altered; basic patterns of energy consumption and production could be changed; energy-producing equipment could be owned by many types of organizations and even individual homeowners."[15]

Utilities have worried about the fragmentation of the electric system. To them it represented a regressive tendency. Thomas Hurcomb of Central Vermont Power expressed such concerns before Congress in 1978. He warned, "If we continue to break down . . . we come up with what we had back 50 or 60 years ago of a hundred or more utilities. . . . I believe that will make the planning process more difficult. I believe it will make energy more expensive. I do not think that the course that we should be following is continually to break down into smaller energy groups."[16] Utilities certainly had the means to delay significantly the proliferation of independent power systems. They controlled the grid. They had no responsibility to interconnect with the small power producer. They could, and did, charge very high prices to those they allowed to interconnect, thereby forestalling potential future interconnections.

Under existing law, there was little the state regulatory commissions could do to aid the independent producer. A survey of the 50 regulatory commissions in 1978 found the vast majority believed they lacked the legal power to order utilities to interconnect and they could not require utilities to buy power from independent producers.

In 1978 Congress made a landmark decision that resolved the dilemma and opened the floodgates of independent power production. The Public Utility Regulatory Policies Act (PURPA) abolished the century-old monopoly utilities had over power generation. To reduce the nation's dependence on imported oil and increase the efficiency with which electricity is generated, PURPA required utilities to interconnect with qualifying facilities and to purchase power from them at premium rates. The act applied to all utilities, whether investor owned, cooperative or municipally owned. And it exempted these new producers from state or federal utility regulations.

The passage of PURPA and the coincident enactment of tax benefits for cogeneration and renewable energy electric plants created a new industry almost overnight. Investors quickly rushed in to buy up the windiest terrain and the best hydropower sites. Journalist John McPhee described the excitement in the small hydro market in the *New Yorker* in 1981. "It is possible that in 1897 less action was stirred by the discoveries in the Yukon. There was a great difference, of course. The convergence of the Klondike was focused. This one—

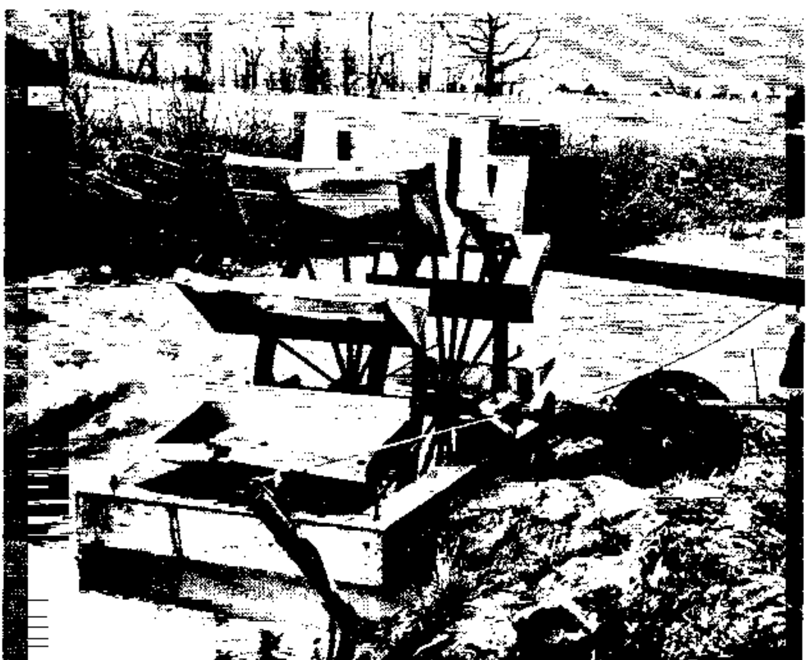


Photo 1–4: This owner-built paddle wheel is the heart of a small-scale hydroelectric system. The paddle wheel is designed to work in this low head application where most of the power is gained from the rate of flow rather than from water falling to a lower level. *Photograph courtesy of Tanya Berry.*

this modern bonanza—was diffused, spread among countless localities in every part of the nation. As a result it was a paradox—a generally invisible feverish rush for riches."[17] Wind prospectors scoured America's windy coastlines and plains.

Applications for licenses to refurbish existing hydroelectric sites poured into the FERC. Enterprising companies have recently set up hundreds of small wind turbines in densely packed arrays. The nation's first wind farm started operating on a New Hampshire hilltop in late December 1980 with ten machines of about 50 kw each. By mid-1982 seven more wind farms were operating, primarily in California. As the Idaho Public Utilities Commission noted in August 1980, "No longer is [electric generation] to be the exclusive domain of public utilities. Their natural monopoly has always been and will continue to be the distribution of electricity. Henceforth, however, electric generation is to be a competitive enterprise with regulation intervening only to the extent necessary to stimulate a free market."[18]

The transition is not going to be an easy one. Upon the enactment of PURPA, many utilities immediately filed suit to overturn the legislation. In March of 1981, the same month the PURPA regulations were to go into effect, Judge Harold Cox of the Southern District Court of Mississippi upheld the contention of the Mississippi Power and Light Company, the state of Mississippi and the Mississippi Public Service Commission in declaring PURPA unconstitutional. "The sovereign state of Mississippi is not a robot or lackey which may be shuttled back and forth to suit the whim and caprice of the federal government," he ruled.[19] In the spring of 1982, by one vote the United States Supreme Court overruled Cox. PURPA stands.

The industry of dispersed power production is still embryonic. Yet at its present rate of growth, it threatens soon to surpass investments by utilities in conventional power plants. In 1982 investor-owned utilities spent about $25 billion for generation capacity. The Edison Electric Institute predicts this investment will shrink to less than $15 billion in 1986 (in 1982 dollars). On the other hand, the FERC reports that filings from potential qualifying facilities (QFs) under PURPA have risen from 30 in 1980 to more than 500 in 1982. The 500 plants proposed in 1982 have a combined capacity of more than 11,000 Mw. Assuming an average investment of $1,000 per kilowatt of installed capacity, this will represent an $11 billion investment. All that investment will not be spent in one year, but disbursed over three years. Thus $4 billion will be invested in nonconventional power plants in 1982, 15 percent of the utility total. By 1986 investments in cogeneration and small power production facilities could exceed those by conventional utilities in traditional power plants.

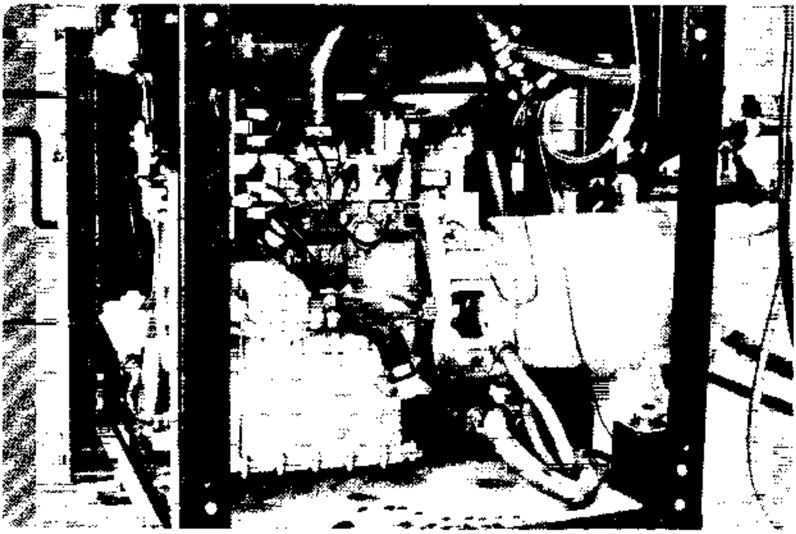


Photo 1–5: Cogeneration is exactly what the name implies: a system that simultaneously produces both electricity and heat from the same primary source of energy. Early in this century, cogeneration systems provided over half of the energy used in the United States. But the technology fell into disuse because of cheap oil prices and the rise of modern central electric utilities. Now, because of ever-increasing oil prices and the high cost of building new central power plants, cogeneration, which can yield efficiencies of 75 percent and more, is once again economically attractive. *Photograph courtesy of Agway Research Center.*

These phenomenal increases are a direct result of PURPA and ensuing state legislation. In 1979 utilities in New Hampshire were paying an average 2¢ per kilowatt-hour for electricity generated by independents. That year the state legislature set the price at a minimum of 4¢. In 1980 the public service commission raised that minimum to almost 8¢ per kilowatt-hour. In Montana, the first contract signed under PURPA regulations included a 3¢ per kilowatt-hour price. In 1982 Montana raised the minimum to 6¢. The 1982 New York State legislature mandated a minimum 6¢ per kilowatt-hour rate pending a public service commission investigation of whether higher rates were warranted.

Meanwhile, new trade associations have been formed. The American Wind Energy Association, the National Alliance of Hydroelectric Enterprises and the Cogeneration Coalition were formed from 1979 through 1981. The California Independent Energy Producers Association brought all technologies under one umbrella in mid-1982.

PURPA was designed to encourage competition in power generation. However, it retained the utilities' monopoly over transmission and distribution. Even as the 50 state regulatory commissions and thousands of business corporations and cities were working out ways to disperse generating capacity, other groups were exploring the next step. At the Massachusetts Institute of Technology (MIT), the Homeostatic Energy Group explored the feasibility of transforming the grid system into a giant marketplace. The small power producers would sell their electricity to the grid as if it were a brokerage agency. As demand and supply fluctuated, the price of electricity would also fluctuate. Electricity sold in the morning hours in areas with low demand would receive a low price. Electricity sold during summer afternoons in places with a high air-conditioning load would receive a high price. Microprocessors would record all transactions and establish prices on five-minute intervals.

In early 1983 the Pennsylvania Electric Utility Efficiency Task Force recommended experiments to open up the grid system to what it called "self-help electricity." Self-help electricity programs would allow consumers to contract for power directly with independent electricity sources. Self-help customers would use their local utilities only to carry the contracted electricity over the utilities' transmission lines.

It is important to keep in mind that PURPA was not enacted to promote small power production. It was enacted to reduce dependence on foreign oil and to increase efficiency in generating electricity. The benefits of PURPA are available to any producer that uses renewable resources in a power plant as large as 80,000 kw. Cogenerators have no size limits at all. The size limit of 80 Mw may be small by investor-owned utility standards, but it is not small by the standards of most municipal utilities or rural cooperatives. For these utilities, the irony is that PURPA could actually encourage more centralized electric power production. One could imagine a cogenerator of 300 Mw swamping a small municipal utility with two 80-Mw power plants. Already a small 20-Mw nuclear reactor, at Argonne National Laboratory, has become a qualifying facility under PURPA. Since PURPA basically eliminates regulatory oversight for these facilities, there is the potential that a system that is dominated by a few regulated companies will be traded in for one dominated by a few unregulated companies. This is one reason this book discusses only facilities with less than 200-kw capacities. Another reason is that PURPA makes a distinction between those facilities with more or less than 100-kw capacity. A standard tariff must be offered those under this size. Those above 100 kw are usually required to negotiate individual contracts. By choosing the 200-kw limit, both cases are covered. This limit also allows the book to go beyond the individual household application to include small commercial and apartment house facilities. The rough rule of thumb is that a kilowatt of capacity serves one person. Therefore, a 200-kw power plant can serve a small apartment building or a commercial complex or a nursing home or motel.

Finally, there are valid arguments that facilities of less than 200 kw present different burdens and benefits on the electric system from those of the 50-Mw to 300-Mw range. Certainly a utility with a 100-Mw average load can argue that a 200-Mw power plant can, in fact, unbalance and make less reliable its electric system, unlike a series of dispersed 10-kw to 100-kw power plants. The standards for interconnection should also differ considerably for small and larger plants.

The New Power Producers

As one might suspect, the first owners of small power systems come from many backgrounds. Yet they possess two common characteristics: a strong entrepreneurial drive and an ability to understand electrical circuits.

Ted Keck, the 37-year-old owner of a 70-kw hydroelectric facility at a once-abandoned mill site in Pillow, Pennsylvania, learned electronics as the owner of a theatrical lighting company. He used to live 14 miles from the Three Mile Island nuclear facility. The near-meltdown there catalyzed his investigation of alternative energy. Beginning with a solar greenhouse, he eventually explored the feasibility of producing electric power beyond his own needs. He sold his lighting business and moved to the mill.

Joseph Ellen is the owner of a 180-kw hydro facility on an existing dam in the Piedmont section of North Carolina. He is an industrial electrical contractor and, having worked with utility engineers "my whole career," he encountered few problems working out interconnection standards for his facility. Bruce Sloat owns three hydro facilities in New Hampshire. He is both a farmer and a master electrician. Pentii Aalto, a mechanical engineer, owns a 5-kw diesel (oil-fired) cogeneration system in his basement in Braintree, Massachusetts. Bill Clayton owns an 80-kw wood gasifier cogeneration system in Huntsville, Alabama. He is an electronics engineer who designs microcircuits.

Those with technical expertise and a curiosity about independent power production may indeed be the first ones in the water. But hard on their heels are a second generation of pioneers. Ernest L. Copley III, owner of a 15-kw photovoltaic system in Denton, Maryland, is a broker for E. F. Hutton. His facility has only one function: to feed electricity into the grid. Copley views it solely as an investment vehicle and chose to site it in Denton because the local utility pays the highest PURPA rates in Maryland. He is already negotiating for a second qualifying facility in Florida. Victor Lund has installed a 75-kw, gas-fired cogeneration system in one of the eight hotel-like retirement homes he owns in Escondido, California. A $6,000-a-month electric bill made him look for a better investment. H. L. Ayers owns three 20-kw wind turbines near Crowell, Texas, and is a full-time farmer growing wheat, cotton and alfalfa.

The pioneers' motivations vary. Some, like Copley, are attracted by the investment potential. Others, like Sloat, view hydro power as another "cash crop" to be harvested along with apples and vegetables. Still others, like Lund, worry about the impact of rising energy bills on his senior citizens. Most like the feeling of achieving a certain self-reliance that comes from having an independent source of electric power.

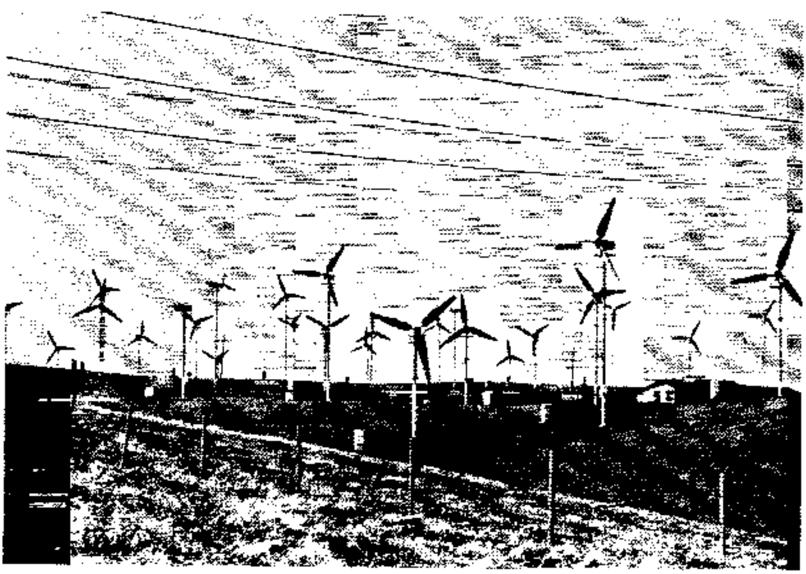


Photo 1–6: Wind farms like this one in the Altamont Pass, about 45 miles east of San Francisco, are a portent of the future when there will be thousands of energy farms throughout the country producing electricity from wind, solar, cogeneration and hydro power. The wind machines pictured here are among the first of some 500 that one company is installing under contract with Pacific Gas and Electric. The turbines are mounted on 40- and 60-foot towers. The rotors are about 32 feet in diameter, and each machine has a peak output of 80 kilowatts. *Photograph courtesy of Pacific Gas and Electric Company.*

Be Your Own Power Company

This book is written as an aid to understanding the new age of electric power. It is not so much a how-to manual as a primer on utility economics that emphasizes on-site power generation. At present the negotiation process between the independent power producer and the utility is lopsidedly in favor of the utility. This book is intended as a step toward redressing that imbalance by providing information and a conceptual framework for those who desire to become more independent and/or to use their ability to generate electricity to gain a source of revenue.

Four technologies are discussed: cogeneration, wind power, hydropower and photovoltaics. Each technology is discussed and evaluated in terms of grid-connected or stand-alone power generation.

The present utility system is not easy to understand. As with all industries, the utilities have their own jargon. Certain electrical concepts, such as harmonics, are still not clearly understood even by learned electrical engineers. But, ready or not, the nation is plunging into one of the most dramatic structural changes in its history. This book is intended to aid those desiring to understand these changes and to be part of the changes themselves.