THE ELECTRIC CENTURY

How the Taming of Lightning Shaped the Modern World

J. B. Williams

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Punch Cartoon of 1881. King Coal and King Steam look on the infant Electricity with concern

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Introduction

In January 1882, the prolific American inventor and entrepreneur, Thomas Edison, opened a public electric power station—not in New York or even in America, but at the Holborn Viaduct in London, England. This was some 8 months earlier than the one in Pearl Street in New York which is often claimed as the first. Even the Holborn viaduct station had been preceded by one in the previous year at Godalming in Surrey, also in England. All these were local schemes supplying a small area, but showed progress, as before this an electricity generator had only supplied single buildings.

The power station in Godalming lit only a few arc lamps and some of the new incandescent light bulbs in street lamps, while that at the Holborn viaduct provided lighting for the few shops built along it. The advantage of the site was that the cables could be run along the bridge and it was simple, hence providing a prototype for the Pearl Street station. Even the latter was limited to supplying a small number of customers within just the square mile around it.

However, by the end of the twentieth century nearly every house was full of electrical equipment. These would be made up of switches, plugs and sockets, appliances, kitchen equipment, heating controllers and so on. To do the washing we expect washing machines, dryers, irons. To preserve food, we couldn't do without refrigerators and freezers; to process it mixers, grinders, blenders; and then to cook it, ovens, hobs. Life is unimaginable without electric lights and electrically controlled central heating to keep us warm, or air conditioning to keep us cool.

Outside, there is likely to be a car which, while it may not be "electric", as a minimum uses an electric starter, lights and wipers. As we drive along the roads electric traffic lights control the flow. Or we may well travel on an electric railway to work, or travel up and down in electric elevators, lifts or escalators. In the workplace electric-powered machinery is everywhere.

But in 1900, in all but a tiny minority of houses, there were none of these things; not a single one. It is very difficult for us now to imagine a world without electric equipment everywhere, and yet it has only taken one hundred years. The objective of *The Electric Century* is to examine how we got from there to here, following the links of how a few basic inventions, such as the electric motor, could spawn such a vast range of applications.

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The intention is not to give a "history of technology" but to show how the technology shaped the modern world. These developments had a profound effect on the lives of everyone, and yet the route by which they were achieved is largely ignored. Without electric streetcars or trams, and then railroads and railways, suburbs would not have grown, and our towns and cities would be dense and unmanageable. Without electric elevators or lifts the tall buildings of the modern cityscape would not exist. Without the knowledge brought by high-speed printing that enables mass circulation newspapers and cinema newsreels, universal suffrage would hardly have been be possible.

It was Lenin who appreciated that electrification could be a force for social change. He said: "Communism is Soviet Power plus the electrification of the whole country." While it may not have brought communism, electricity has brought a great leveling out of society, as now everyone has access to the basics of life, heat, light, and mobility. The change had been partly in the direction he expected, but not quite. Maybe part of the trend has been from a collective society to a more individualistic one.

The nineteenth century was still one of horse and muscle power. Yes, steam engines existed, but they were large and inflexible. They powered the railways successfully, and many factories, but there was no simple way to subdivide that power. Hence, the large mill became the norm for employment, and the train for transport. Small factories or even road buses were not very successful. It was the coming of electricity that changed all that, and turned the nineteenth "steam" century, into the twentieth "electric" century.

It is the amount of "power" available that has made such a huge difference to our lives. In 1900, the amount of electricity was very small, and mostly used for shop and street lighting. In Britain, for example, it was the equivalent of less than 8 W per head of population. In 2000, the capacity of the generation stations had risen to 1.2 kW per person, or far more than a hundred times greater. This is for every man, woman and child in the population. On top of this is the power of engines, of gasoline and of gas or oil central heating that has been brought under control on our behalf. Horses are now only for sport or leisure, and muscle power is used so sparingly that many feel the need to use up the excess energy in sport or in the gym.

At the turn of the century most people lived their lives within a very small area of where they lived. If they needed to go anywhere, it was on foot. Horses were for rich people and simply too expensive for the average person, and even the coach services were too dear to consider using for more than that special journey, perhaps once a year. It was the coming of cheap, electrically-powered streetcars, trams and trains that changed all this. Gradually, the systems spread out until everyone could benefit.

So often, as in the case of the telephone, a new invention was taken up by business, and then slowly spread into more affluent houses. The take-up in ordinary homes was remarkably slow. Half the century had gone before more than a quarter of British households had a phone, though large numbers were in use for business. By the end of the twentieth century nearly all homes were connected. Something that was the plaything of the few is now the norm for everyone.

How was all this achieved? Not by "Science" but by engineering and technology. Virtually all the knowledge of the relevant physical laws of nature—the work of Ampere, Ørsted, Faraday, Ohm and so on—was understood at the beginning of the twentieth century. It was its exploitation that took the time and effort. In the end, it is only when the knowledge is turned into real devices that it starts to have an impact and change people's lives.

To follow the story we need to look at the people who made things happen. The twentieth century was characterized by the rise of large organizations so the developments are often hidden behind the corporate façade, but where the individuals can be identified their stories are told. Some of these people will be well-known, but others may well be surprising. There are many unsung heroes who made the vital contribution but received little credit because someone else was better at the publicity.

Marconi naturally features, though he invented little himself. He took the ideas of others and put them together into a system, and made it work. That, coupled with commercial acumen which enabled him to pinpoint the initial markets, led to the development of wireless communication. Even then, he had to share his Nobel Prize. Others, such as Charles Merz, Frank Sprague or Samuel Insull, are hardly known and yet their contribution was great.

We don't want to get bogged down in the sterile arguments about who was the first to invent something. When the time was ripe often a number of people came up with much the same idea. Simultaneous invention is quite common. Four people, who may or may not have known of each other's work, came up with similar designs for an incandescent light bulb within a year or so of each other; although only Edison, and to a lesser extent Swan, are remembered. The interest is in those who developed the technology that ended up actually being used, not in those who went charging up technological blind alleys.

To introduce a major technological change there are three distinct phases: invention, development, and exploitation. It can be argued that Swan and Edison didn't even make the invention; it already existed. What they did do was to develop the idea into a practical device and then (particularly Edison) exploit it in the marketplace. That was their real contribution. Marconi took ideas from other people, but put all these together into a system, identified that ships needed what he had to offer and got a whole industry started.

Often there were enormous lengths of time from an original invention to its real exploitation. The electric drill was a nineteenth-century invention, but it was really after World War II that it came into use for the handyman. The simple addition of a battery to produce a portable device took even longer to come through. Again, it took an immense length of time before refrigerators and freezers were a standard in the kitchen.

The Electric Century looks at how electricity provided light and comfort in our home and, in the form of appliances, eased life. Outside it gave us greater freedom of movement. It was left to its children—electronics, computing and telecommunications—to give us entertainment, communications and computing. That is another story and is treated elsewhere.

Yes, electricity is everywhere, and we can't imagine life without it. To slightly misquote an electricity company advert, it is as though our whole lives run through those wires.

2

Chaotic Beginnings

Electricity is really just organized lightning.

George Carlin

On January 4, 1900 Dr. J. Fletcher Little of Harley Street, London, wrote to *The Times*, as one did in those days when one wanted to complain about something. He had gone further and had already arranged for the President of the Board of Trade to receive a deputation and was canvassing for more people who might want to come with him to complain about the supply failures of the Metropolitan Electric Supply Company.[1]

The Metropolitan Electric Supply Company was one of the myriad small electric companies that had sprung up, putting a generator powered by a thumping steam engine in some back yard and starting to connect those locals who wanted a supply. Its patch was Marylebone, running from the north side of Oxford Street in London and covering the area around Harley Street. It had a number of small generating stations scattered about; one was in Manchester Square to the west and one in Rathbone Place to the east. As an example of the patchwork nature of supply, the south side of Oxford Street was supplied by the Westminster Co., and then came the London Co., and the St. James Co., all of whom were north of Green Park.[2]

The deputation met Mr. Ritchie, the President of the Board of Trade, on 17 January, 1900. The 36 members represented 600 complainants, which was a very considerable proportion of the company's customers. Amongst them were six doctors, a dentist, and an optician, representatives from Middlesex Hospital and numerous shopkeepers. Prominent amongst the latter, Mr. John Lewis who, with his Oxford Street store, was the area's largest ratepayer.

Their charge was that the supply repeatedly failed without warning. This meant that some other form of light had to be hastily obtained, which was not always a simple matter. In some establishments, when the electric lights had been put in the gas fittings had been removed, so they were forced to resort to lamps or candles. This was no laughing matter in the middle of a dinner party, but in a shop full of flammable material it became serious. The hospital had had cases where the power had failed in the operating theater in the middle of important operations.

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Even when there had been a supply the voltage had often been so low that it meant turning on more and more lamps in an attempt to obtain sufficient light. Where three or four lamps had once been sufficient now seven were needed and even those gave an unsatisfactory result. In a local church, the illumination had been so bad that they had had to return to using the gas lights. The complainants had considered taking the company to court but the penalties were not high enough to recompense the commercial undertakings for their losses.

The company had claimed to the Board of Trade that they had solved their problems on December 15, 1899 and there should have been no difficulties after that. The complainants gave details as to why that was not true. What they wanted Mr. Ritchie to do was to introduce a Bill into Parliament so that the electric supply companies would be open to being sued for their failures, like other businesses. Ritchie, a Conservative, had other ideas. He wanted to encourage the setting up of a competitive supplier in the area as he felt that some healthy competition would sort out all the problems. This idea was opposed by the Marylebone Vestry, the strange name for the local council, who didn't want another company "breaking up the streets" to lay cables.

In truth, the Metropolitan Electric Supply Company was still in difficulties and was playing for time. Its customer demand was rising and its backyard generating capacity was insufficient, but it had recognized the situation and had in hand a bold plan to resolve the problem. It wasn't quite as incompetent as many of its customers, particularly Dr. Little, seemed to think But it was laboring under a great many difficulties.

The company had realized that it was impossible to carry on trying to generate in their many small stations in the crowded area they served. They had thus built the first phase of a large power station in Willesden, where there was plenty of space for expansion. They bought an eight-and-a-half acre site bounded on two sides by railways and on the third by the Grand Junction canal (later to become the Grand Union canal). This gave them good access to supplies of cheap coal, essential for powering the station economically.

The first problem was that the generators were unavailable due to an engineers' strike, but they overcame this by obtaining them from the American Westinghouse company. The buildings were erected, the boilers, generators and all the other equipment were installed, and then were ready.

The next task was to transport the electricity to their customers some five miles away. This was where position of the station came into its own, because the supply cables could run along the towpath of the Grand Junction canal most of the way. It was in the last mile or so from there to where the cables needed to go under the streets that they ran into difficulties.

To do this the company had gone to Parliament to obtain the necessary statuary powers. Although opposed by the Paddington and Marylebone vestries, they obtained the powers and immediately started laying the cables. However, these local authorities, having lost the first round, were unhappy about the company laying cables to supply other parishes, and took them to court. The councils were only persuaded to suspend the action by an agreement that the Courts would determine whether the existing powers were adequate and, if not, the company would seek further Parliamentary powers.

Needless to say, the company were also trying to keep their customers happy whilst they fought their way through this morass. Some customers still took them to court and they were fined trivial sums, but this was hardly going to deflect them when they were investing vast amounts in the new system. This was, of course, on top of the actual technical problems of installing equipment and cables and getting this relatively untried technology to actually work.

In the midst of this, the Board of Trade was plowing its own furrow. They still thought that competition was the answer to the problems of supply in the Marylebone area and were encouraging new companies. In April, it passed a Provisional Order authorizing the Marylebone Electric Supply Company to set up in competition to the existing company. This was done despite the opposition of the Marylebone vestry which didn't want another company digging up the streets. In the end it did not pass in Parliament, which was a relief for many, including the existing company.

Dr. Little and his friends were not impressed and agreed with the vestry. He was still trying to persuade the Board that making the company liable for more substantial fines was the way forward, rightly realizing that the current level was not sufficient to deter them. He was also concerned about the high cost of the electricity which, at an average of 10 cents (5 old pence at the time) per unit, he claimed was considerably higher than in other parts of London where it ranged from 9.5 to 8.5 cents.

In the meantime, the company finally got its new Willesden station open with at least part of its customer base connected to the system. It still had a further section around Covent Garden to connect up but that was in hand. It seemed at last that its troubles were nearly over. A next phase was being constructed at Willesden, which should enable it to keep its supply capacity ahead of demand. It was trying to raise more capital so that it had sufficient funds to carry on with its expansion program.

Early the next year, just as things seemed to have settled down, more difficulties arose. The Borough of St. Marylebone (the vestry had become a borough) approached Parliament for powers to get the supply of electricity in its area into its own hands. There was a strong suspicion that the Borough had only become interested in supplying the area with electricity now that the company had at last become profitable.

In reality, it was a totally retrograde step, and driven by pure parochialism, making little economic sense. The Borough had to buy out the assets of the company in the area, and then set up their own local generating station as the Willesden one was not in the borough and so not part of the deal. Before that was completed they had to purchase a "bulk" supply from the company. In the end, it took some years and a great deal of money to finally get the whole thing properly set up.

This is the story of just one undertaking in one area in one city, but it is typical of the trials and tribulations of the infant electric supply industry in many countries. Whilst this example is about a small area in London, and that city may well have been one of the worst, such experiences were repeated elsewhere across the developed world. The *New York Times*, for example, was complaining that though the companies could supply electricity they couldn't do it reliably or cheaply, and they didn't seem to really have it under control.[3]

One of the problems affecting all cities was that the generating stations needed to be local and so were close to where people lived. Inevitably this caused difficulties for the neighbors. There were constant law suits as the residents reached the limits of their tolerance of the smoke, cinders and particularly the vibration from the machinery. In November 1900 in New York alone three cases of this nature came before the courts.[4]

In America, there were a few cities where the population was large enough to really interest the private electricity supply companies. In Boston, New York and Philadelphia, for example, the potential was such that a number of companies were competing for customers in the same areas.[5] Here, rather than digging up the streets, the wires were strung on posts past the users' houses. It meant that the householder could choose their supplier, but at the price that outside in the street there was a jungle of wires.

In some ways, for those who lived in the cities, it was a good time for customers but really it was crazy. Here there was competition, but out in the countryside, where long runs of wire were needed, it wasn't profitable, so people living outside the cities usually didn't have a supply. It was a situation that couldn't last. By the time of the Great Depression, the government had stepped in to rationalize the situation. One supplier in an area became the norm.

Already some of the basic issues surrounding an electricity supply were coming to the fore. Was it just a service which the customer could take or leave, or was it a utility which should aim to supply everyone? It was becoming clear that larger generators were more efficient, but how could the resulting monopoly be controlled? Inevitably, there was going to have to be some regulation of the industry as it grew.

As could be seen from the people who complained about the Metropolitan Electric Supply Company, most of the customers were either shops or other commercial establishments. There were very few private customers, and these tended to be the wealthy. Across the whole of Britain in 1900 there were possibly as few as 50,000 houses connected, representing about two-thirds of one percent of all households.[6] In America, things were a little further advanced and this was perhaps one or two percent.

It is hardly surprising that there were so few. The supply was very patchy, depending on where somebody decided to set up a generating station. In America, the companies just went where they thought they could make a profit. In Britain, as we have seen, it was such a struggle as to discourage most, requiring Parliamentary approval and so on. Then the generation was so inefficient that it was fabulously expensive. The unit cost of the electricity of the Metropolitan Electric Supply Company at 10 cents in 1900 is the equivalent of more than a dollar at the end of the century.[7] We can't imagine paying anything like this amount to light our houses. Charges in 2000 were more like one twenty-fifth of the cost at the beginning of the century.

It was hardly surprising that almost no one had electricity in their homes; far more basic things were missing. Few houses had running water. Most householders had to go to some well or pump or local supply and carry the water home in buckets. The lucky ones might have an outside faucet. Real luxury was an inside faucet in the kitchen. If water was needed anywhere else in the house for the laundry or the very occasional bath, then buckets had to be filled and carried to where it was needed. No wonder most of these activities took place in the kitchen.

With no piped water, running hot water was not even a dream. A tiny number of wealthy people had systems, but these were very complicated. With no electric pumps the systems depended on a "gravity" system where the large diameter pipes were gently angled up from the fire back boiler or furnace so the hot water could rise to where it was needed.

Washday was a nightmare. Quite apart from fetching all the water, the heating was a problem. The lucky ones had access to a "copper". This was a large bowl, usually made of copper, set into a brick structure where a fire could be laid underneath. Given enough time, this would heat the water which had been poured into the copper and could be used to boil the clothes. All steeping, rinsing and so on required the carrying of yet more water. Though some washing machines did exist they could hardly be used without electric power and running water.

Heating in houses was largely by coal. As we saw, the washing water could be heated in the copper, but most was in pans on the "range". This was a cast-iron monstrosity that dominated the kitchen. It was necessary to light the fire early in the morning to have hot water later on, and also so there was heat to cook the breakfast. There was considerable labor in humping coal to keep it running all day. For this reason, though other rooms would often have open grates, they were not often lit because of the labor involved (unless you could afford servants to do it).

All this coal being burnt in the densely-packed cities created another problem—smog. On a day when it was naturally foggy, all the smoke coming out of the thousands of chimneys was trapped under the mist and sat quite close to the ground. It was choking, eye-watering stuff, often so dense that you could barely see your hand in front of your face. In London, these smogs earned the nickname "pea-soupers" because they had a slight green tinge and about the same consistency.

Partly these problems were a function of the density of the city. People lived on top of each other, mainly because with no affordable transport they needed to be within walking distance of their place of work. What transport there was, was horsedrawn and relatively expensive. Railroads were for longer distances and not possible for most people as a means of commuting.

The problem was particularly acute in London. The population density in the center was such that the railroads had been unable to penetrate it, and their terminus stations sat in a ring around the edge. Within that there was no easy way to proceed. There were two approaches. It had been found that laying rails in the street, like for a train, meant that a horse or horses could pull a larger vehicle and the horsedrawn streetcar or tram became popular in the 1870s and 1880s. Though it did help, it was still out of the reach of many people on a regular basis.

The second method was to build underground railroads. In London, the Metropolitan and District companies were both set up to do this. It wasn't truly underground as all they did was to dig a large trench and then bridge it over where streets or buildings needed to be over the top. As much as possible was left open to let the smoke out from the steam engines. The foulness of the atmosphere in the tunnels had to be breathed to be believed. Again, this was relatively expensive method of travel, and not really the solution.

Though the internal combustion engine existed, there were very small numbers of vehicles and motor buses on the roads, so they were not yet able to make any contribution to relieving the congestion. So travel in the city centers really depended on horses, and they produce effluent in large quantities. With horses almost as common as people, the streets smelt like farmyards, and it was a worry that the problem of clearing the streets of the waste would be the limiting factor in the development of cities. Despite apocryphal stories of piles of horse manure many feet high, it never got that bad, but unless something changed the system was sooner or later going to choke itself.

Once people got to work, they mostly used muscle power. Ships were unloaded by cranes and then men humping the produce. Coal, on which the whole economy depended, was dug with picks and shovels and then hauled away by ponies. Fields of grain were cut by scythes, as were lawns, or if machines were available they were hand-powered or drawn by horses.

The only other form of power was steam. In textile mills, large steam engines drove long overhead shafts and lethal belts brought the power down to individual spinning machines or looms. This was practical where large numbers of similar machines were used, but very inconvenient on a smaller scale or where the machines varied widely in size and form. Clearly there was a need for something more flexible.

Electricity supply was still a shambles. London had around nineteen separate organizations, some private and some municipal, while New York had more than thirty companies supplying electricity.[8] The pattern all over was the same—small, local, inefficient operations set up to supply just the local patch, with only some commercial and a few rich customers. There was no real ambition to supply everyone, or to spread it around the countries. It didn't look very promising.

Despite the shaky start there were those who could see the potential. At the end of 1900 the editor of *The Times* in London thundered:

> The application of electricity on the largest scale to the satisfaction of the common wants of life is one of the most important questions with which the public and the legislature have to concern themselves in the present day. Owing in part to a certain slowness in accepting innovations which is characteristic of all of us, and in part to legislation of a confused and discouraging kind, we are behind most other nations in electric lighting, electric traction, and the distribution of electric motive power for machinery.[9]

What was exercising the editor was the obstructionism that was causing delays in getting a new electric streetcar tramway into operation, but even he could see beyond this. Thinking people were beginning to understand that Britain was falling behind in this area, and it can be argued that this was where the pre-eminence of the British Empire began to wane as it fell behind particularly America and to a lesser extent Germany in the exploitation of electricity.

However, everywhere things were stirring. In some quarters there was an expectation of great possibilities in the future, but it didn't seem likely then that electricity would define the century and it would become such an essential part of our lives.

We can now start to follow the specific strands that gradually built up into the network that now encases us.

NOTES

1. This whole saga comes from the pages of *The Times* starting on January 5, 1900 and running right through to December 14, 1904.
2. Poulter J.D. An Early history of Electricity supply. Map on page 103.
3. *New York Times*, December 29, 1900.

4. *New York Times*, November 14 and 17, 1900.
5. Buzz, How electricity grew up? A brief history of the electrical grid, available at: https://power2switch.com/blog/how-electricity-grew-up-a-brief-history-of-the-electrical-grid/.
6. There are no reliable statistics for this time. This estimate has been made by looking at the number of customers of the various supply organizations and estimating the domestic percentage, and also extrapolating back from the percentage of households connected figure of 1910 in the ratio of the amount of electricity supplied in these 2 years. These two methods give fairly close agreement.
7. Inflation figure from ‘Consumer price inflation since 1750’, Office for National Statistics.
8. Con Edison, A Brief History of Con Edison, available at: http://www.coned.com/history/.
9. *The Times*, December 29, 1900.

3

Lighting that Doesn't Need Lighting

How many people does it take to invent a light bulb?

In 1802, Humphrey Davy, of miner's lamp fame, built an enormous battery, to Volta's newly-invented form, in the basement of the Royal Institution in London. He took two carbon rods, and connected each one through wires to the ends of the battery. When the two rods were touched together and then pulled slightly apart, a brilliant white light was produced. He had invented the arc lamp. As not everyone could have a large battery in the basement it was another 50 years before it was any practical use.

At the time, light came mostly from candles, but it was gas lighting that took over in Europe and America. From the 1820s, its use steadily increased as more gasworks were built. In 1823, for example, 52 English towns were lit by gas, but by 1859 there were nearly a thousand gasworks.[1] After gas fittings were introduced into the new Houses of Parliament in that year its use spread even more rapidly.[2]

The light output of the jets, burning gas in the open, was 8 or 16 candlepower, which was a considerable improvement on the candles themselves. To get more illumination fittings often had more than one burner, and elaborate arrangements with multiple jets were used in the centers of rooms. These were similar to chandeliers and hence known as gasoliers. To light them was tricky; a match or spill had to be carefully brought to each output once the gas was turned on.

The arc lamp hadn't been forgotten, but what was needed for it to be more widely used was a continuous source of electricity. Michael Faraday's experiments on the relationship between electricity and magnetism in 1831 had led to many attempts to turn mechanical work into electricity. As usual this took a great deal of time and it wasn't until about 40 years later that practical generators started to appear. The way was now open for arc lighting, and a system was successfully trialed at the South Foreland lighthouse in Kent in 1857. Dungeness lighthouse was equipped with arc lamps in 1862.[3]

There was, however, a problem. As the arc burns the carbon rods are eaten away and must be adjusted from time to time to bring them back to the correct distance from each other. This difficulty was largely overcome in 1876 by a Russian telegraph engineer,

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