Explaining the Collapse of the British Electrical Supply Industry in the 1880s: Gas versus Electric Lighting Prices

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In the late 1870s there was a tremendous interest in the development of electric lighting, which at long last looked to become commercially viable. In the early 1880s electric lighting systems were being installed in many cities in the US, to light factories, stores, public buildings and streets. While Britain had perhaps fewer inventors than the US, it appeared to be on the verge of adopting the electric light. There was much excitement in the press in the late 1870s and early 1880s, and 1882 proved to be a watershed year, when the industry boomed, many entrepreneurs entered the business, much money was invested through the stock market in new companies formed to supply electric equipment and power, and government legislation was passed to set up rules for central power supply installations. Yet despite the early frantic activity, the boom soon turned to bust, the industry appeared to have stalled in the mid-1880s, and by 1890 Britain had fallen far behind the Americans in installing and using electric power for lighting and other purposes. In 1890 there were 235,000 arc lights in use in the US, and streets in virtually every American city were lit up by these bright lights. Meanwhile in Britain in that year there were only 700 arc lights on the streets. While Edison, Thomson-Houston and Westinghouse had established central power stations across the United States, with almost 2000 central stations in existence in 1891, in Britain there were just a handful, 25 by one count in 1889 [2, p. 22; 3, p. 218; 5, pp. xxvi-xxvii; 17].

This failure of the British electrical supply industry in the 1880s has been much commented on, and it has been blamed for the later troubles of the electrical manufacturing industry, especially since British electrical equipment producers were slow to develop and found themselves unable to fend off the invasion of the British market by foreign producers in the late 1890s. The primary causes that have been asserted in the past, by numerous contemporary writers and later historians are: the rash of ill-conceived promotions of electrical supply companies and the stock market bubble and crash in shares of these firms, often called the Brush boom, in 1882; the much lower price of gas lighting, electric lighting's chief competitor, in Britain compared to the US; the poor state of the British economy in the 1880s; contemporary

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observations that there was a lack of innovation and "get-up-and-go" in Britain compared to America; inadequate organization of electrical manufacturing firms, hindering their efforts to develop and promote their systems; the difficulties of British electrical firms in obtaining needed patent rights from foreign inventors; and government legislation enacted to regulate the nascent industry, called the Electric Lighting Act of 1882, that may have been poorly designed, and was quickly blamed by business interests for the industry's woes [2, 9, 10].

This paper will examine the argument that Byatt has brought to the forefront, which many other historians have accepted, that British electrical supply was unable to develop because of the comparatively much lower prices of its main competitor, the gas lighting industry. While the other explanations undoubtedly played an important role, and will need to be examined carefully at some future time, this explanation is currently considered to be the most important one. Due to limitations of space and time, the emphasis here will be on arc lighting, which was the most successful sector in the early 1880s. The costs and prices of the electrical and gas industries will be compared between the US and Britain, to put the British problem in an international context.

First it is necessary to describe the structure of the early electric lighting industry. The earliest electric light used was the arc light, in which electricity crossed a small gap between two carbon rods to form an arc, which produced light. Arc lighting was very bright, generally of 1500-6000 c.p. (candle power), and was considered too strong for indoor lighting except where large spaces were involved, such as in factories, theaters and stores. It came into use in the 1870s, when Charles Brush developed the best system in the US, and by 1880 2264 of his lights were in use there. Incandescent lighting, which was of much lower intensity, of 10-20 c.p. (which solved the much-discussed problem of "subdividing the electric light"), could be used indoors. The most important early developer of it was Thomas Edison, who began selling incandescent lighting systems in the early 1880s. Both arc and incandescent lighting systems were competing with manufactured gas lighting, which was made from coal, was well established in most cities, and was supplied from a central station through pipes to individual residences, businesses, office buildings and street lights. Gas lighting had the disadvantages of producing heat and polluting ("vitiating" they called it) the air, and its light was yellow, while arc lighting produced a flickering bluish-white light. Yet it was cheap, and could produce varying intensities of light, although it was difficult and costly to achieve brighter gas lighting than the usual 16 c.p. brightness.

Gas companies and electricity supply companies were competitors for the home, street and office lighting business. Higher gas prices in the US may have made it easier for the new electric lighting industry to find customers than in Britain, where gas prices were low. The average price of gas in Britain in 1883 was about 64¢ per thousand cubic feet (from now on for convenience all gas prices and costs will be listed in US dollars, assuming a $5:£1 exchange rate, and in price per thousand cubic feet, as is traditional), while in London the largest company was charging 79¢ [14]. In the US in 1878 the average gas price was $3.15, which steadily fell during the 1880s to $1.77 in

1886 and $1.42 in 1890 [17, p. 202; 18, p. 54]. In New York the price was $2.25 in the early 1880s, falling to $1.75 in 1884, to $1.50 in 1885. Since the price of gas was $2.00 or over in many major US cities in the early 1880s, while gas prices were under $0.90 in Britain, the difference in prices could explain why gas lighting was less successful in fending off electric lighting, if they were considered to be close substitutes.

Yet this point is not so simple. We need to know whether gas companies could have kept electric lighting out through a limit pricing policy, as it is described in the industrial organization literature. Three questions first need to be answered with respect to prices and costs: (1) Were gas prices higher in the US due to higher costs or because of monopoly pricing? (2) If monopoly pricing was being used, why didn't they immediately lower their prices to keep out electric lighting? (3) If gas companies had higher costs in the US, were those factors pushing up gas costs also pushing up electric lighting costs? Finally, because gas and electric lighting were not identical products, we must examine how they competed with each other. Did customers value them equally, and if not, were some customers willing to pay a premium for one of them, and did this premium vary in different markets? Did this premium vary between Britain and the US, and why?

Explaining the Gas Price Difference

A survey of British gas companies showed that the cost of producing gas in Britain averaged 47¢ per 1000 cubic feet in 1883, not counting depreciation or interest on debt [14, p. 262]. Information about the US is not as good for the early 1880s, but costs appear to have varied widely according to region. Costs ranged from 40¢ to $1.20, although in the major eastern cities such as Boston and Philadelphia it averaged about a $1.00 [1, 19].

The cost of producing gas in the US should have been higher, because of the higher cost of coal and labor, and the weaker market for residuals. Coal, the main ingredient of coal gas, was about $3.50-$3.75 per ton in London, while in New York it was $4-$4.50 per ton [21, p. 208]. According to a contemporary estimate by Theobald Forstall, the cost of coal, net of residuals sold, should be 12¢ higher per 1000 cubic feet in New York due to the higher price of coal and the weaker demand for residuals. In England two-thirds of the price of coal could be recouped through the sale of residuals, namely coke, tar and ammonia, while in the US usually only ¼ to ½ of the price paid could be regained. The higher price of labor in the US was estimated to cost 9¢ more, such that gas in New York should have been 21¢ more per 1000 than in London. Forstall estimated that therefore with coal costing 25¢, labor 15¢, other materials at 5¢ and 20¢ for repairs, distribution and other costs, the total cost of producing and delivering gas when done efficiently should be 65¢ [11, p. 63]. Costs would vary according to location due to differences in the price of coal, labor, and the market for residuals.

Since gas prices were much higher than costs, gas companies were enjoying large profits. The price of gas fell steadily, but high profits were enjoyed by the gas companies throughout the 1880s. This was revealed most clearly by a New York Senate Committee investigating the New York City gas

industry, which estimated the cost of making gas for the 7 major companies in New York City in 1883 at 117.7¢ per 1000. These companies had revenue of 216.6¢, yielding a profit of 98.9¢ [13].

So if we compare London's and New York's prices for gas, New York gas was $1.46 higher. Of this, 21¢ could be accounted for by the higher cost of coal and labor, and 70¢ came from higher profits, leaving 55¢ which presumably was due to inefficiency and the need for bribes. Thus the main reason prices were higher in the US was monopoly pricing and inefficiency. The source of the inefficiency is not clear, but it may have been due to the younger age of the industry, and the excessive capital the firms were burdened with due to a recent bout of heavy competition in the 1870s and early 1880s [20]. Some writers have argued that American gas companies lacked competence, or as the editor of a gas journal put it: "It is astonishing how many superintendents and managers, when pinned down to details, have to confess ignorance of the real cost of gas in their own holders." [1, p. 133]

While in Britain the gas industry was regulated in the 1850s, after it had begun to consolidate, in the US this phase of development was not reached until the 1880s, when city governments such as Philadelphia, and state governments in New York, Massachusetts, California and Illinois became involved in forcing down prices or even buying up the private firms to create municipal plants. Regulation in Britain appears to have been more effective and more intelligently designed than that in the US. The British fixed the dividends their gas companies could pay out at 10% on capital, prohibited the watering down of capital, and allowed higher dividends only if gas prices were lowered, at a fixed trade-off, on the "sliding scale system" as it was known. The rising municipal movement meant that a third of gas sold came from municipal corporations. While British profits were fairly good, averaging 27¢, they were much lower than the usual profits in the US of $1.

The much higher gas price in the US would appear to indicate that electric lighting would have had a much easier time there than in Britain. But from the cost analysis above, US gas companies should have had much room to lower prices if they felt the threat was serious. It appears that the main threat electric lighting posed was not in terms of undercutting the price of gas, but in terms of providing a better quality product. In 1878 Edison's announcement of a new light bulb frightened the gas interests, and gas stocks in both the US and Britain plunged in value. Yet they soon recovered, and as discussed before, profits remained high. It was reported that the introduction of electric lighting actually increased gas sales, since customers who became used to the brighter electric light on the street began to use more gas indoors to obtain the same level of light [1; 7, X, p. 17].

Prices came down, but not so quickly as would be expected from an industry under heavy competition from a new competing product. In New York the price of gas was pushed up to $2.25 in 1879 from a secret agreement of the current producers where it remained until late 1884, when it dropped to $1.75 after competition developed from a new firm. In 1885 the New York State Legislature had to pass a law to lower the price of gas to $1.50 [13]. Thus in 1882 and 1883 the industry was not threatened with immediate replacement, as many had thought. Gas prices were coming down in other

cities as well, partly from competition from electric lighting, but mostly from pressure from public authorities and from competition from other gas companies. It was widely believed that gas companies were fairly safe in the short run, but that electric lighting would probably take away their business in the long run. To meet the competition of electric lighting gas companies searched for qualitative improvements, such as the use of water gas, which allowed the production of gas of 21-25 c.p., the introduction in the 1890s of the Welsbach gas mantle, which produced a much better light using less gas, and the use of gas stoves for heating and cooking. Gas candlepower rose during the 1880s to produce better light for customers.

The reason for the delay in the fall of gas prices may be that electric lighting was not ready to be the light for the masses in the US, any more than it was in Britain. The slowness in lowering prices by gas lighting interests may have been due to the small size of the early electric lighting central stations, which were too small to be worth trying to match their price. If they wanted to keep uniform prices, lowering prices for one district would hurt profits for the whole area of supply. To some extent the gas companies ceded those markets that electric lighting was best suited. Even in street lighting contracts, where the competition was the most severe, gas companies did not always respond to the arc lighting companies intrusions. In New York the gas companies offered almost the same prices throughout the 1880s to light the streets, collusively keeping their bid prices high, and despite the high prices, which the city council complained about, they still kept most of their business, losing only about 10% of the street lighting business to Brush by 1885. While they lost the downtown areas, in outlying areas arc lighting was less suitable.

Electric lighting is best thought of as a niche market, for people and cities looking for a higher quality product, and willing to pay a higher cost. It produced a brighter light, with no pollution of the air, among other qualities that proved useful. As *Electrical World* noted, "It has been said that the battle for electric light should not be fought on the ground of cheapness, but on the ground that as compared with gas it is a desirable luxury" [1; 6, IV, p. 20; 2; 20].

Cost of Arc Lighting

The qualitative advantage of arc electric lighting was that it was very bright, it could be quickly turned on and off in a storm or a fog from the central station, and the brighter light was alleged to reduce crime and accidents. These advantages were played up in the electrical literature. Many store owners agitated for the electric light in large cities and small, pressuring the city council to install the brighter lights in major thoroughfares in the downtown areas. For the outlying areas, and for smaller streets, arc lighting was less useful because of the reduced number of lights to cover every sidestreet and alleyway, and the schemes of raising powerful arc lights hundreds of feet in the air were of limited effectiveness for the sprawling suburbs. In Chicago, the earliest areas lit by electric street light were around the clothing stores in the downtown area, and a local supplier believed stores on side streets would also want it, saying in 1884 "doubtless the property-

owners interested would cheerfully pay the difference in the cost, whatever it might be, in consideration of the greater attractiveness at night of the business section so illuminated" [6, IV, pp. 199-200].

We have poor data on the cost of electric street lighting, and on the differences in prices between electric and gas lighting, partly due to qualitative differences. While a 1500 c.p. arc light from Brush produces 100 times more light than does a 15 c.p. gas light, it proved necessary to replace 100 gas lights with more than one arc light in order to eliminate the dark areas between the bright lights and ensure that complete coverage of a street was provided. In New York, for example, initially in 1881 one arc light was used to replace every 22.7 gas lights. By 1885 each arc light replaced 4.6 gas lights [17, p. 49]. One source says that one arc light could generally replace 5 gas lights [8]. Arc lights would often be hung from high towers to spread their light over many blocks and alleys. But generally they were used for main commercial thoroughfares and parks, while gas lamps were often retained for smaller streets. A serious problem in doing cost comparisons for street contracts is that the number of hours of lighting per night is usually not stated, and makes a large difference in the cost per hour of the two systems. Thus to do a complete comparison we need to know both how many hours a night the systems would be used (which could range between 1000 and 4000 hours a year), and how many gas lights were replaced by electric lighting.

In many American cities in the early years the Brush electric company would set up a local supply firm, which would offer to supply the city for less than the gas company, and sometimes for free, for a limited demonstration. Later it would raise the price demanded, and the city would often want to expand the area lit, and the amount of light provided. In New York while initially the cost of arc lighting in 1881 was 17% less than using gas lighting for the proportion of the city given to arc lighting, with the increased number of arc lights used in 1885 it cost more than 3 times more. In 1881 the annual cost per arc light was $336 or 92¢ per night, while in 1885 it had fallen to $254 or 70¢ per night [17, p. 49]. In Detroit the city accepted the bid of the Brush company in 1884 at a cost of 35% more than the gas bid to put up arc lighting, using 66 104-foot and 6 150-foot towers to light up the city. After a year the cost settled at about 50-55¢ per night, or $180-$200 per year. Private customers were charged 56¢ per night for lights burned all night, or about 5¢ per hour. In a survey of 56 cities in 1887 there was an average cost of $162.74 per lamp per year, for 9472 lamps. However, we do not know how many hours a night these lights were to be lit, nor their strength, to be able to confidently compare their cost with gas lighting costs [16; 17, p. 20].

From the statistics from the big cities, which probably were requiring the lights be used all night, and many of which were paying $200 by the mid-1880s, for a 4000 hour year this represented a cost of 5¢ per lamp per hour, or 1¢ per gas lamp replaced (assuming 5 gas lights per arc light). Other sources also give a typical price of 50¢ per night for Brush arc lighting [4, p. 63; 6, IV, pp. 265-6]. Meanwhile gas at $1.50 per 1000 would cost 0.75¢ per hour for a 16 c.p. light burning 5 feet of gas per hour ($2 gas cost 1¢ per hour) [16]. Thus arc lighting would represent a 33% premium over gas lighting, but more light would be gained (10 times more on average). Some

cities had to increase their lighting appropriations in their budget to cover the higher costs.

After initial trial runs in the early years, most American cities appear to have been willing to pay a premium of 5% to 40% and even 200% (for New York) for electric lighting, and despite the falling price of electricity, the desire for more lighting increased the number of arc lights per gas light replaced, sometimes raising the cost. Few cities tried and abandoned arc lighting for the streets, like Boston did in 1884 for a 21% savings [6, IV, p. 38].

In Britain there was an extensive discussion in the newspapers of the relative costs of electric versus gas lighting. While many reports were made about the costs of electric lighting, few of them were reliable, either because they were over-optimistic, or failed to account for capital costs, or trials were run in unusual circumstances. Whether surplus power (from steam engines or water mills) or labor (from factory or other kinds of workers) was available, and the number of hours of usage per year, would make a great difference in the cost of electricity. The much lower cost of gas in Britain compared to the US should have hurt the British electrical industry, but inasmuch as this was due to lower prices for coal and labor, the cost of electricity should have been lower as well. British producers of electricity should therefore have been able to achieve prices below American rates offered, especially for the widely popular Brush system, which was the most heavily used system in both the US and Britain. For the nominally 2,000 c.p. lamps, which were actually about 550-600 c.p., in the US the charge was often 55¢ per night, or 5¢ per lamp-hour. Coal was about $1 cheaper in London vs. New York, which if 3.5 lbs coal were needed per lamp hour (according to an 1882 estimate for 32 lamps hooked up to 2 dynamos), then this reduced costs by 0.16¢ per lamp-hour. Labor was probably a bigger factor, comprising 25% to 40% of the cost of electricity due to the people hired to run the steam engine and clean and replace the carbons. In England labor costs appear to have been 25% to 50% less, which should have reduced the price of electricity by another 0.5¢ (assuming 30% of the cost and a third lower labor cost) or more [7, IX, pp. 355, 524-6, 548-9; 21, pp. 165, 168].

British firms should have then been able to offer Brush lighting at about 4.3¢ or 2d. per lamp-hour. In Scotland the Brush Electric Light and Power Company of Scotland offered it for 3d. per lamp-hour, for users who would use it for 3650 hours per year, with higher rates for those using it less. In London the Brush company supplied light to one district at a cost of about 1.1d. per lamp-hour, at which rate it was reported to be losing money [7, VII, pp. 376-7, X, p. 380].

British cities did not adopt electric lighting for the streets, despite extensive tests in 1882. These tests, with electric companies hired to provide the lighting, showed a higher cost of electric lighting compared to the gas lighting it replaced, and many cities switched back to gas immediately afterwards. The vestry of Chelsea in London found that the bid for electric lighting was double that of their gas bill [2, pp. 21-2; 7, X, p. 578, XI, p. 15].

The difference in prices might explain the difference in reaction to the use of arc lighting for the streets. While the cost of electricity was perhaps

10-40% less than in the US, between London and New York gas cost 60-70% less in 1882, and 47% less in 1885, increasing the premium required for electric lighting. Yet it seems surprising that almost no British cities, including London, were interested in paying a little more for a high-quality product, while virtually every American city did so for its downtown areas.

British gas companies responded to the threat from electric lighting by developing a number of brighter gas lamps, such as Sugg's lamp of 80 c.p., Siemen's regenerative gas lamp of 130 to 400 c.p., and Bray's lamp of 500 c.p. While this helped recapture the streets, in London a test using these lamps to replace the rejected electric lighting systems was also in turn rejected, because it cost 3-4 times more, despite the much brighter light obtained [7, X, pp. 380, 507]. The well-lit London of 1881-82 became dark again, such that one traveller commented in 1884 "I know nothing more dismal than to be transplanted from the brilliantly illuminated avenues of New York to the dull and dark streets of London" [6, IV, p. 265].

British municipal authorities were thorough in examining the relative cost of electric versus gas lighting, perhaps obsessed with it. The Newington Vestry announced "The main question arising out of the subject of electric lighting is one of cost, and it is to this question that your committee have devoted considerable attention" [7, X, p. 267]. Meanwhile American cities were lured with a higher quality good, and were less sophisticated at determining the cost of it, and more influenced by corruption. This difference in emphasis extended to individual buyers, suppliers and manufacturers. While American gas managers were reported to be often ignorant of their own costs, British gas managers and shareholders analyzed down to the hundredths of a penny the possible gains from new technologies [15, p. 973]. According to one historian of the leading American arc lighting system manufacturers, "Nowhere in the surviving papers of Thomson, Brush, or Charles Van Depoele does one find any comparison of arc lighting to gas lighting" [3, p. 132]. Yet virtually every British inventor and manufacturer spoke on the subject. The British literature was filled with analyses of the cost of electricity, while in the US there was much less published about the subject.

Some British cities do not appear to have seriously considered adopting electric lighting. Many spent more time worrying about the implications of granting a monopoly to an electric supply company, than whether their district wanted electric lighting. One local authority in London announced it was taking bids for electric lighting in order to force gas prices down [7, X, p. 267].

Greater interest was shown by the public in the US in getting electric lighting for their downtown areas. There was agitation in many small towns to install electric lights, in order to get the higher quality light there. The poorer quality of gas lighting (where the new high c.p. burners were not generally used) increased this interest. Imprecise as this sounds, there was momentum in the US for electric lighting, while in Britain everyone "knew" that electric lighting was too expensive to be adopted [1].

Yet American investors in central stations in smaller US cities also appear to have been overoptimistic in their estimates of private demand for their lighting services. Many went bankrupt and were reorganized, while

others struggled along barely surviving [12, pp. 94-5; 19]. Promoters would travel around to attract local investors to buy systems from the manufacturer, and often there was inadequate local demand to support a central station. It is not even clear whether the big central stations in the large cities, particularly those set up by Edison, were profitable in the early years. Edison's plant in New York was believed to have lost money until the late 1880s. Therefore the belief that demand would grow, and costs would fall, made this a long-term investment, which perhaps the shareholders in Britain, expecting a quick return on an immediately valuable product, were unwilling to wait for.

The result was that Britain did not adopt much street lighting while virtually every US city was using it by 1890. American cities became known for their bright lighting by the mid-1880s. *Electrical World* noted in 1891 that "We in America have become so thoroughly familiar with the effectiveness of powerful electric lamps for street lighting that it seems queer to think of the long period that has passed without adequate illumination in the streets of a great metropolis like the city of London" [6, XVIII, p. 39]. While arc lighting was fairly widely used in Britain in factories, stores, and offices, its distribution from central stations, with which street lighting contracts became closely tied, was halted. Although the difference in price was certainly important, developments in the US showed that quality of the product was also important. While New York City was willing to pay three times the gas price for electric lighting for its downtown district, British cities were not. The British emphasis on cost minimization, combined with the legal difficulties posed by the Electric Lighting Act of 1882 and the hostility of local authorities to private companies (not discussed here), helped prevent the spread of the "light of luxury."

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