IEEE REACH

ELECTRIC LIGHTING UNIT PLAN

Compelling Question	**How would your life be different without electric lighting?**
Standards and Practices	*C3 Historical Thinking Standards* – D2.His.1.9-12. Evaluate how historical events and developments were shaped by unique circumstances of time and place as well as broader historical contexts. *C3 Historical Thinking Standards* – D2.His.2.9-12. Analyze change and continuity in historical eras. *Common Core Content Standards* – CCSS.ELA-LITERACY.WHST.9-10.1.B Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns. *AP World History Thematic Learning Objectives* – ENV-4 Explain how environmental factors have shaped the development of diverse technologies, industrialization, transportation methods, and exchange and communication networks. *AP World History Thematic Learning Objectives* – CUL-3 Explain how cross-cultural interactions resulted in diffusion of culture, technologies, and scientific knowledge. *AP World History Thematic Learning Objectives* – ECON-3 Explain how different modes and locations of production and commerce have developed and changed over time.
Staging the Question	Why do we need electric lights?

Supporting Question 1	Supporting Question 2	Supporting Question 3	Supporting Question 4
What was life like before electric lighting?	What inventions and innovations contributed to the development of the incandescent light?	What were the challenges associated with the mass delivery of electric lighting?	How has electric lighting been used to change the world we live in?

Formative Performance Task	Formative Performance Task	Formative Performance Task	Formative Performance Task
Imagine that you are living in the 1800s before electric lighting. Write a letter to your future self, describing your daily routine. Be sure to include specific details from the documents below.	Create a “family tree” to show the evolution of the electric light from ancient torch to incandescent lamp. Note the key characteristics of each innovation in the tree.	Prepare an opening argument for a debate between proponents of gas and electric lighting in the late 19th century. The proposition: *Your town should convert from its current manufactured gas system to an electric system.* Choose one of these two positions and, assuming that homes and businesses in your town already have gas lighting, argue for or against a new system.	Find photographs or descriptions of your town/city prior to the installation of electric lighting and identify the differences. Write an editorial for the local newspaper arguing for or against electrification. Use evidence of those differences in support of your argument.
Featured Sources	**Featured Sources**	**Featured Sources**	**Featured Sources**
1A. Vachon, John, photographer. Mrs. Sauer putting oil in lamp. Cavalier County, North Dakota, United States. Oct. 1940. Photograph. https://www.loc.gov/item/2017810962/. Accessed 13 April 2018. 1B. Vogel, Mike. "The Light of the Whale." *The Keeper’s Log*, 30, no.4 (Fall 2014): 56-62. https://www.mysticseaport.org/voyage/files/2015/05/Vogel_morgan.pdf. Accessed 12 May 2018. 1C. Freeman, Laura. "The Most Magical Job in Britain: Enchanting Story of Our Last Gas	2A. Welsbach Street Lighting Co., advertisement, *American Gas Light Journal* 90, no. 1 (4 Jan. 1909): 30. https://babel.hathitrust.org/cgi/pt?id=mdp.39015085552910;view=1up;seq=40. Accessed 4 June 2018 2B. “Charles F. Brush.: Lighting Up the World.” Electrical and Computer Engineering at Michigan: A History of People Powering Innovation. University of Michigan. ece.umich.edu/bicentennial/stories/charles-brush-lighting-up-the-world.html. Accessed 4 June 2008. 2C. Charles F. Brush, http://ethw.org/Charles_	3A. “Light Thrown on a Dark Subject (Which Is Bad for the Gas Companies),” Illus. in Puck, 23 Oct. 1878, p. 16. Retrieved from the Library of Congress, www.loc.gov/pictures/resource/cph.3b03877/. Accessed 15 March 2018 3B. Hellrigel, Mary Ann C. "Your Engineering Heritage: Edison, the Electrical Engineer, Spearheaded Central Station Business." IEEE-USA *InSight*, 20 May 2016. https://insight.ieeeusa.org/articles/your-engineering-heritage-edison-the-electrical-engineer-spearheaded-central-station-business/. Accessed 3 June 2018.	4A. Van Ornum, Willard Attwood, Artist. “The curtain is up!” *Puck*, 14 Oct. 1914. Retrieved from the Library of Congress, https://www.loc.gov/item/2011649846/. Accessed 15 March 2018. 4B. Humphrey, John. “7 Things About Life in Puerto Rico with No Electricity,” *IEEE* Spectrum, 4 Dec. 2017 | 20:30 GMT. https://spectrum.ieee.org/energywise/energy/renewables/7-things-about-life-in-puerto-rico-with-no-electricity. Accessed: 23 Feb. 2018. 4C. Waff, Craig B. “September 2, 1880: Night baseball at Nantasket Beach.” Society for American Baseball

Street Lights, and the Five Men Who Keep Them Burning Just as They Did in Dickens' Day." *Daily Mail Online*, 24 Nov. 2014, updated 15 Nov. 2104. http://www.dailymail.co.uk/news/article-2848038/The-magical-job-Britain-Enchanting-story-gas-street-lights-five-men-burning-just-did-Dickens-day.html. Accessed 15 March 2018.

1D. "Ancient Oil Lamps." Egyptian Frog Lamp, ca. 2nd -5th century CE, 1900.1775.1. Archaeology and Anthropology Collections, Wesleyan University, Middletown, Conn. http://www.wesleyan.edu/archprog/collections/collection-highlights/lamps.html. Accessed 24 April 2018

1E. Eric A. Hegg, photographer. "Miners in Underground Gold Mine Lit by Candlelight, No. 27 Eldorado Creek, Yukon Territory, ca. 1898. Eric A. Hegg Photograph Collection, PH Coll 274. University of Washington Libraries Collections, Hegg 412A. http://cdm16786.contentdm.oclc.org/cdm/singleitem/collection/hegg/id/8/rec/403. Accessed 23 April 2018.

F._Brush. Accessed 4 June 2018.

2D. La Favre, Jeffrey. "Charles Francis Brush. The Brush Arc Lamp," 1998. www.lafavre.us/brush/lamparc.htm. Accessed 5 June 2018.

2E. Thomas A. Edison, "Fitting and Fixture for Electric Lamps." U.S. Patent 248,424, issued 18 Oct. 1881. Retrieved from the Thomas A. Edison Papers, http://edison.rutgers.edu/patenti2.htm. Accessed 5 June 2018.

3C. Edison, Thomas A. "The Success of the Electric Light." *The North American Review* 131, no. 287 (1880): 295-300. http://www.jstor.org/stable/25100894. Accessed 5 June 2018.

3D. Beall, Lester. "Now I'm Satisfied," Rural Electrification Administration, U.S. Department of Agriculture, ca. late 1930s. Poster. Library of Congress, www.loc.gov/pictures/item/2010650602/. Accessed 15 March 2018.

3E. PEARL STREET CENTRAL STATION, Doc.2243, p. 423-428. Israel, Paul B., Louis Carlat, David Hochfelder, Theresa M. Collins, and Brian C. Shipley. *The Papers of Thomas A. Edison. Volume 6. Electrifying New York and Abroad, April 1881-March 1883*. Baltimore: Johns Hopkins University Press, 2007. edison.rutgers.edu/yearofinno/EL/PearlStreetHeadnote.pdf. Accessed 4 June 2018.

3F. Snyder, W.P. "The Electric Light in Houses: Laying the Tubes for Wires in the Streets of New York." *Harper's Weekly*, 21 June 1881. https://commons.wikimedia.org/wiki/File:Laying_electric_lines_under_street_Edison_Pearl_Street_Utility_June_21_1882_Harpers_

Research website. http://sabr.org/gamesproj/game/september-2-1880-night-baseball-nantasket-beach. Accessed 13 April 2018.

4D. Detroit Publishing Co., Copyright Claimant, and Publisher Detroit Publishing Co. *Night in Luna Park, Coney Island, N.Y.* New York, New York State, United States, ca. 1905. Photograph. Retrieved from the Library of Congress, https://www.loc.gov/item/2016799885/. Accessed 14 March 2018.

		Weekly.png. Accessed 5 June 2018. 3G. "Member Biography of Tesla." *American Institute of Electrical Engineers*, May 1934. http://ethw.org/w/images/0/07/Tesla_-_member_bio.pdf. Accessed 1 June 2018. 3H. Lant, Karla. "Stanford Scientists Are Making Wireless Electricity Transmission a Reality." *Futurism*, 16 June 2017. https://futurism.com/stanford-scientists-are-making-wireless-electricity-transmission-a-reality/. Accessed 30 May 2018.	

Summative Performance Task	**Argument**	Write a thesis essay that directly addresses the compelling question using specific claims and relevant evidence from historical sources to support your claims while acknowledging competing views.
	Extension	Debate whether electric lights have actually made life better.
Taking Informed Action	**UNDERSTAND:** Research one alternative energy source. **ASSESS:** To what extent could widespread use of this alternative energy source benefit humanity? **ACTION:** Based on your assessment of its future impact on humanity, create an online campaign for your position and post (or repost) "articles" to help generate energy on your social network.	

TO THE TEACHER

All *REACH* Instructional Units are intended to be "classroom-ready." Each unit begins with a *Unit Plan* in the form of a *C3 Inquiry Design Model*. The *Unit Plan* includes learning objectives, content standards, formative and summative tasks, links to primary and secondary resources, and a warm-up activity.

Units are organized around a *Compelling Question* designed to inspire curiosity and promote discussion among students. To that end, we have also included a brief student introduction to the topic entitled, *Staging the Question*. Once students have been introduced to the topic, any number of *Formative Performance Tasks* may be completed using the included *Document Excerpts* (teachers may elect instead to utilize full-text documents linked within the *Featured Sources* section). *Document Excerpts* are print-ready in single-sheet format and keyed to the citations in the *Featured Sources* section of the *Unit Plan*. Teachers should select the *Formative Performance Tasks* and accompanying *Sources* that best suit their own instructional needs – content requirements, performance goals, student readiness, and time constraints. Upon the completion of each unit, students should be adequately prepared to complete the *Summative Performance Task* and *Taking Informed Action* sections of the *Unit Plan*.

To further assist the teacher, we have included a more thorough *Background Information* section. This document is intended to serve as professional reading prior to implementing the unit. Teachers may also wish to read the full-length primary and secondary sources from which the shorter excerpts were taken.

STAGING THE QUESTION

When was the last time you lived without electric lights? Maybe a thunderstorm, hurricane, or blizzard caused a power outage in your neighborhood. Many of us feel so uncomfortable without electricity that we keep gasoline-powered generators on hand to minimize the effects of such an unexpected loss of power. Nevertheless, just 150 years ago, most of the world lived their normal lives without electricity and the dependable light that it supplies. One hundred years before that, and "normal" life was almost what it had been for perhaps 5000 years – only fire (torch, candle, etc.) to light the night.

The evolution of lighting that continues today with LED technologies began in the 1700s with the introduction of improved oil lamps, which allowed for a brighter and steadier light than candles. New inventions and innovations resulted in the introduction of gas illumination by the end of the century, and by the era of Thomas Edison in the late 1800s, the manufactured gas light industry illuminated the modern world. Pioneers and entrepreneurs in London, Baltimore, and Philadelphia invested their fortunes building gas plants, burying pipes, and creating transmission systems that powered streetlights, businesses, and homes. However, as this booming industry approached maturity, the electric light became a practical alternative.

The arc lamp, introduced in the early 1800s, produced light by passing an electric current between two electrodes. The arc of current provided a brilliant white light and it eventually illuminated streets, factories, and lighthouses. At the time of its invention, however, the arc lamp faced several technological barriers to its practical use. The intensity of the electric arc quickly consumed the ends of the electrodes until the gap between them was too distant for the current to jump. In 1870, the Russian inventor, Pavel Nikolayevich Yablochkov, devised one solution, the Jablochkoff Candles, which awed visitors to the Paris World's Fair in 1878. While Yablochkov's two parallel carbon rods solved the original problem, his "candles" needed frequent adjustments to maintain a constant arc, and so they too remained an impractical solution.

Cleveland inventor, Charles F. Brush, also tackled the problems with arc lighting. Arc lamps used massive amounts of current and were originally powered by batteries. The limited charge of even the best batteries in the early 19th century meant that a single arc lamp required frequent battery replacement. Brush solved this problem in the 1870s with an improved electric-generating dynamo, which produced a constant and continuous current. He developed a solution to the arc lamp's second big problem as well – the short life of the electrodes that produce the arc. Brush created an electro-mechanical device that adjusted the distance between the electrodes to match the current that passed through the system. By combining his dynamo and arc lamp improvements, Brush made the arc lighting system a commercially viable alternative to gas lights. In the early 1880s, the Brush Electric Company illuminated the streets of major cities, like New York, Baltimore, Boston, and Montreal.

While Brush worked to improve the life of the arc lamp, Thomas Edison focused on a separate problem with the technology – the intensity of the light. The arc of current produced by the arc lamp, while acceptable for street lights, was too glaring for comfortable use in homes, offices, and shops. Edison theorized that a metal filament, connecting the two electrodes, could produce a more comfortable light when heated by the current. He was neither the only, nor the first inventor to create an incandescent electric light; however, he did invent the first practical incandescent lamp. Indeed, after experimenting with hundreds of metals and lamp designs, in 1879, Edison's incandescent lamp became a reality in 1879, and his basic design changed little until the very recent popularity of LED technology.

Document 1A

SOURCE: Vachon, John, photographer. Mrs. Sauer putting oil in lamp. Cavalier County, North Dakota, United States, Oct. 1940. Photograph. https://www.loc.gov/item/2017810962/. Accessed 13 April 2018.

Document 1B

“Sperm oil and whale oil are very different. Whale oil, generally, is rendered by boiling down blubber taken from such species as the bowfin and the right whale – named because it was the “right” whale to hunt for an abundant return. Spermaceti is taken from the head cavities of the sperm whale, although some poorer-quality sperm oil can be rendered from that species’ blubber as well.

Whale oil is basically a triglyceride, which made it eventually useful in such products as margarine. But it was first a fuel, burning easily but dirty, and producing both a relatively poor light and a distinct fishy odor. If you were poor, it was affordable light.

Sperm oil is basically a wax, with varying percentages of wax esters depending on the age of the whale. It comes from the sperm whale’s large head cavity, the “case,” where it probably functioned mainly to aid in the whale’s echolocation, and in the lower head cavities known as the “junk.” It was a prime lubricant from the dawn of the machine age to the dawn of the aerospace industry, because it wouldn’t break down in extreme conditions. It was used, until relatively recent whaling and whale product bans, in cosmetics, in automatic transmission fluid and as a watch lubricant, and it was the oleum in the original formulation of Rust-Oleum. It was more expensive, but it burned with a bright smokeless flame, better than tallow or beeswax, that had very little odor. Sperm oil was the illuminant of choice in high-income homes and, because the lighthouse service needed maximum brilliance and minimum soot for its critically important ship-guiding lights, in America’s lighthouses.

…the crew of a ship such as the Charles W. Morgan would delight in a successful hunt for a sperm whale.

Hauled alongside, the carcass would be secured and head cavities would be cut open and bailed out. If the temperature was moderate, the straw-colored spermaceti would start to congeal into a white waxy substance when it hit the air; it could be reheated in the try pots to reliquify it, and the liquids would be quickly packed in casks for processing ashore. Between the head cavities and the blubber, an average sperm whale might yield 100 barrels. Most of the oil was rendered from the blubber, with the head cases yielding 6 to 8 barrels, although one ship reported 10 from a large bull. The blubber oil had only about 66% wax esters compared to the 71% to 94% in the spermaceti from the head case of an adult; clandestine mixing was not unknown….

Casks of spermaceti were stored and allowed to freeze in the New England winter. Once frozen, the waxy substance was scooped into sacks and pressed; the oil that seeped out was the most valuable of all, the sperm oil that stayed liquid even in freezing cold. Partially thawed spermaceti would be pressed again in spring, and the congealed remainder would be pressed yet again in summer before what was left was sold as wax. The process produced winter-strained, spring-strained, and summer-strained grades of sperm oil, in descending order of value.

The Light-House Establishment … used the different grades, calling them simply winter, spring, and summer oil….

The transition from living whale to casks of oil started with a lookout’s cry from “the hoops” atop a whaleship mast and the lowering away of whaleboats. The oared pursuit, after species of whale that were slow enough to catch and buoyant enough to float when killed, could be short or long but always was dangerous. Modern eyes would be appalled by the slaughter, but in its day whaling was an

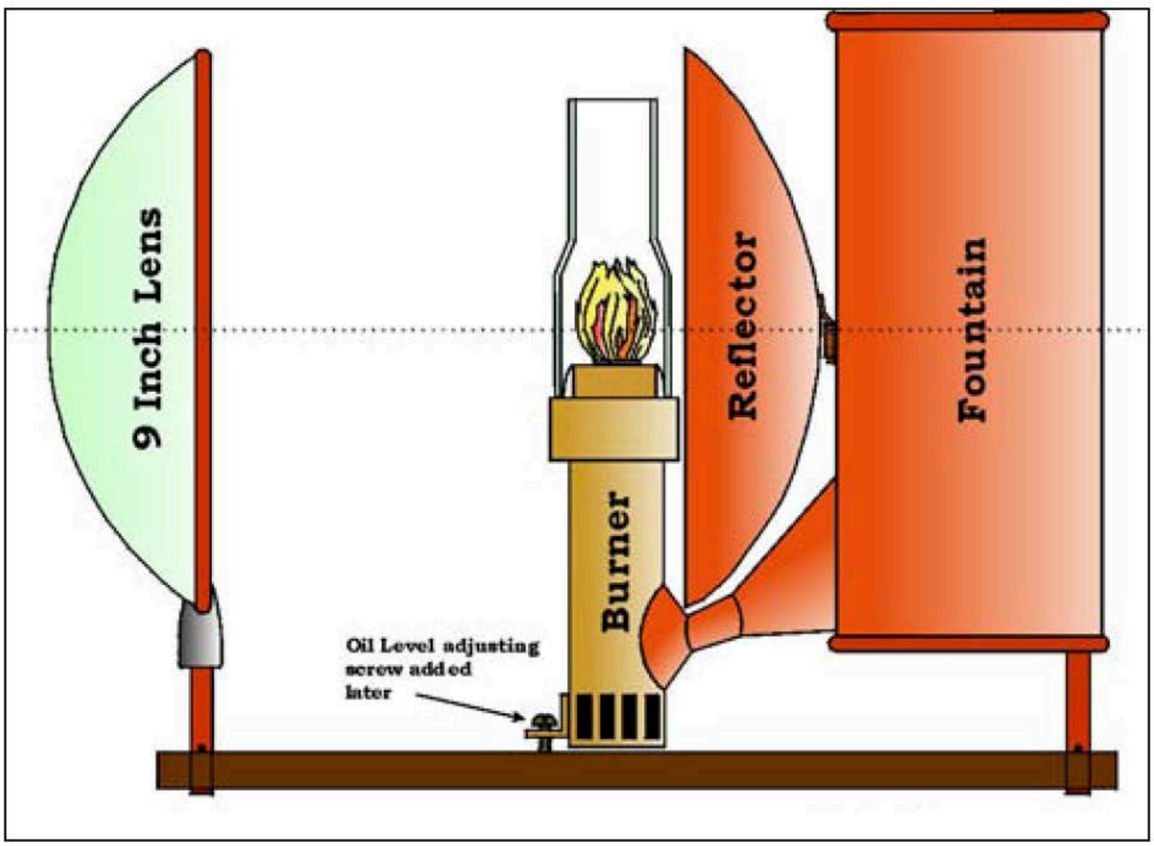
SOURCE: https://bit.ly/2JkipHp

important driver of the American economy and an industry that was absolutely vital to an emerging nation whose maritime trades thrust it upon the world stage.

America's whaling fleet was the largest in the world. In the 1840s there were 735 whaleships in the trade. Peak production in sperm oil happened in 1846, and then the petroleum industry began its rise and kerosene lit the way to the future. In 1876 there were just 39 whaleships left. Today there only is one….

But whale exploitation is part of our past; indeed, it was an important part of our economic entry onto the world stage. And while lighthouses used only a fraction of the take, they at least provided an altruistic use for the whale's oil….

Buffalo's first lighthouse, lit in 1818 as one of the first two simultaneously built American lights on the Great Lakes, had nine lamps and reflectors, with an oil need calculated at 38 gallons per lamp, including a 15 percent allowance for leakage in transit. That meant [each] lighthouse … would need 342 gallons, at a cost of $17.48 in that year.



Winslow Lewis' original 1810 lamp with nine-inch reflector and nine-inch lens. USLHS archive image.

SOURCE: Vogel, Mike. "The Light of the Whale." ***The Keeper's Log*****, 30, no.4 (Fall 2014): 56-62.** **https://www.mysticseaport.org/voyage/files/2015/05/Vogel_morgan.pdf. Accessed 12 May 2018.**

Document 1C

There are 1,500 gas lamps left in London, but hundreds of thousands of electric street lights. Westminster alone has 14,000 glaring electric lamps.

Who keeps London's gas lights burning?

If you were to stand on Lord North Street after dark, around the corner from the Houses of Parliament, you might see a man in blue overalls at the top of a ladder, silhouetted against Big Ben. You could set your watch by it; he sets his lamps by the clock face.

There are just five lamplighters left in London. Once, there were hundreds of them, pacing the city at dusk with long, lighted poles to spark the gas running up the iron posts.

That the gas lamps have survived is partly a tribute to English Heritage, which has protected and restored them. But the greater share of the glory goes to the lamplighters themselves.

The five remaining lamplighters are actually British Gas engineers. You won't find them servicing boilers or reading meters, but at the tops of ladders across London winding mechanisms and polishing the glass lanterns….

Before such men existed, London was a dark city. In the 18th century, it was a brave walker who ventured out without servants to lead the way with a lamp in one hand and a cudgel in the other.

Those who could not afford to keep servants would pay a few coins to a 'link boy', named after their 'links' or torch wicks.

These wild street urchins, the sons of harlots and thieves, would walk ahead, carrying a stick with a rag dipped in tar and set alight. Some were cutpurses, leading their customers into courts and alleyways and stealing what they could in the darkness. Yet they were preyed on in turn.

The link boys were vulnerable to the attentions of unscrupulous men who would have their way with the boys for a few more farthings.

Those who couldn't afford to be guided in the dark took their chances — or rushed home before sunset. Then, in 1807, an extraordinary conjuring trick was performed on Pall Mall.

To celebrate the birthday of King George III, Frederick Winsor, an engineer, lit the most spectacular of candles. To gasping crowds, he instantly illuminated a line of gas lamps.

Each one was fed with gas pipes made from the barrels of old musket guns and all Winsor had to do was apply a single spark to light up the whole street. The Mall was almost impassable with spectators until after midnight.

Over the following decades, thousands of gas lamps went up across London.

SOURCE: https://dailym.ai/1vHSxbp

Many panicked about the new-fangled technology — explosions were alarmingly common in the early days — but for the first time in its history, London was safe, relatively speaking, to walk at night. The Victorian periodical The Westminster Review wrote that the introduction of gas lamps had done more to eliminate immorality and criminality on the streets than any number of church sermons….

Unlike soulless, identical electric lights, the gas lamps are temperamental. Their mechanisms have to be wound and checked, the glass polished ('We use Mr Muscle,' confesses John), and the 'mantles' replaced.

These are teardrop-shaped elements which look, from the ground, like bulbs. But from the top of John's ladder they are revealed to be tiny, bell-shaped, silk casings coated in lime-oxide, which becomes white-hot to give the lamps their glow….

In daylight, each lamp burns with a tiny pilot light — if you look up on a grey and overcast day you can just see the flicker. At dusk, a timer fitted to each lamp moves a lever to release a stronger stream of gas which gives enough power to light up the mantles….

Each lamp is marked with the crest of the monarch in the year they were erected. During the great smog of the 19th and early 20th centuries, it was possible for a man to find his way home by spotting the glow of the lantern, then feeling the markings on the post to work out where he was in the city.

Outside the five-star Savoy Hotel is a rare example of a 'sewer lamp'. Its post is hollow and extends beneath the pavement to the great sewer below. The lamp was designed to extract foul smells and burn them off before they could reach the delicate nostrils of guests in the hotel's suites.

Since the 19th century, almost all the lamps have been extended to raise their lanterns above the height of traffic. Modern delivery vans and lorries are rather taller than horse-drawn carriages and sedan chairs….

The lamps that stand today have survived the coming of electric light, the Blitz and the best efforts of London's lorry drivers. Their survival is testament to the care of generations of lamplighters.

In 1939, the journalist H. V. Morton wrote a book called The Ghosts of London, which lamented the loss of the lamplighters who were once seen on every street at dusk. There were 412 of them then.

'We're the last of the old brigade,' one of them told Morton.

Today, there are just the five lamplighters left. It is thanks to them that this remarkable part of the city's history has endured and that in a few squares and parks and alleyways, it is still possible to walk the glowing streets which, long before electric light pollution, Dickens himself would have walked.

SOURCE: Freeman, Laura. "The Most Magical Job in Britain: Enchanting Story of Our Last Gas Street Lights, and the Five Men Who Keep Them Burning Just as They Did in Dickens' Day." ***Daily Mail Online*****, 24 Nov. 2014, updated 15 Nov. 2104. http://www.dailymail.co.uk/news/article-2848038/The-magical-job-Britain-Enchanting-story-gas-street-lights-five-men-burning-just-did-Dickens-day.html. Accessed 15 March 2018.**

Document 1D

Egyptian Frog Lamp
Egypt, ca. 2nd - 5th century CE
10.5 cm long x 8.7 cm wide x 3.7 cm high

This type of lamp was produced in Egypt under the Roman Empire. It is characterized by the bulbous kidney-like shape and abstract frog design (the shape of the folded legs can be seen at top center). Frogs held a special significance in Egypt, appearing as they did after the annual flooding of the Nile, which sustained all life. Heqet, the Egyptian goddess of fertility, childbirth, and resurrection, is often depicted as a frog.

Originally, this lamp was covered in a red slip, much brighter than the natural color of the clay. Traces can be seen in crevices, especially on the base.

SOURCE: "Ancient Oil Lamps." Egyptian Frog Lamp, ca. 2nd -5th century CE, 1900.1775.1. Archaeology and Anthropology Collections, Wesleyan University, Middletown, Conn. http://www.wesleyan.edu/archprog/collections/collection-highlights/lamps.html. Accessed 24 April 2018.

Document 1E

SOURCE: Eric A. Hegg, photographer. "Miners in Underground Gold Mine Lit by Candlelight, No. 27 Eldorado Creek, Yukon Territory, ca. 1898. Eric A. Hegg Photograph Collection, PH Coll 274. University of Washington Libraries Collections, Hegg 412A. http://cdm16786.contentdm.oclc.org/cdm/singleitem/collection/hegg/id/8/rec/403. Accessed 23 April 2018.

SOURCE: Welsbach Street Lighting Co., advertisement, *American Gas Light Journal* 90, no. 1 (4 Jan. 1909): 30. https://babel.hathitrust.org/cgi/pt?id=mdp.39015085552910;view=1up;seq=40. Accessed 4 June 2018.

Document 2B

Charles F. Brush (1849-1929), a U-M [University of Michigan] engineering alum from 1869, is considered one of the primary innovators of commercial lighting thanks to his arc lamps. This inventor and entrepreneur overcame both technical and social obstacles to provide the framework for the first-ever case of a utility selling electricity from a central plant to multiple consumers.

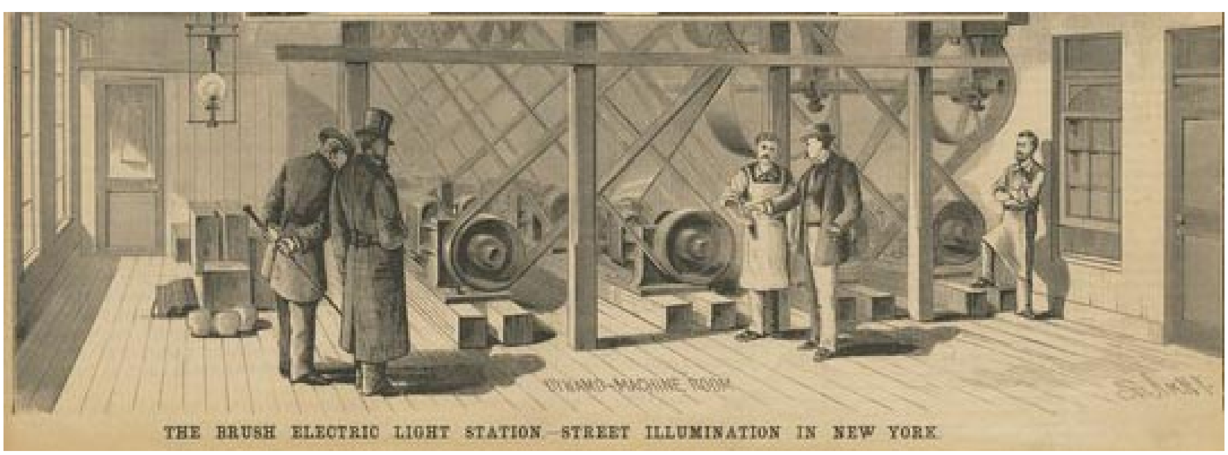
"Brush was born in Euclid Township, Ohio. He built his first static electric machine at age 12 and constructed his first arc light in high school. After graduating from the University of Michigan on an accelerated schedule, Brush worked as an iron ore salesman and experimented on an improved dynamo in his spare time. Brush`s dynamo was key to a commercially viable lighting system and was widely used."

There was a lot of pushback against early electrical lighting - many oil industry investors feared that their demand would dry up, while others scoffed at the very notion of an oil alternative ever catching on. Probably the biggest challenge, though, was swaying public opinion; many early adopters feared the bulbs and arc lamps because they were so bright that they hurt their eyes. As it turns out, many such customers would stare into the light sources for extended periods.

"One reason people stared was that they wondered where the light really came from," Benjamin Bailey noted in his memorial for Brush. "They thought there must be some trick to it - the light must come from oil, and where was the oil supply?"

Charles Brush was responsible for many design improvements to early arc lamps, and produced patents for the design of, and electrical generators (dynamos) for, the lamps. His arc lamps were deemed superior to all existing versions in 1878 by the Franklin Institute of Philadelphia, and became the standard for many decades.

He installed the first electric light system in the United States in Cleveland, Ohio, in 1879, and founded the Brush Electric Company in 1880. By 1881, his arc light systems could be found in New York, Boston, Philadelphia, Baltimore, Montreal, Buffalo, San Francisco, Cleveland and other cities, producing public light well into the 20th century. Brush's system was lighting Broadway two years before Thomas Edison's Pearl Street Station, the first central power plant in the U.S., began lighting New York.



"Brush central power station dynamos New York 1881" - cover of Scientific American, April 2, 1881.
[Licensed under Public Domain via Wikimedia Commons]

SOURCE: https://bit.ly/2Jq7wjk

"Although the filament light bulb eventually replaced the arc light for many uses, the arc light still is commonly used in searchlights and cinema projection. Of Brush`s more than fifty inventions, many were improvements on the arc light. After retiring from Brush Electric Company in 1891, Brush improved Carl Linde`s process for extracting oxygen from liquid air and became founder and first president of the Linde Air Products Company. He also was known for his invention of a more efficient basic storage battery."

In addition to his accomplishments with the arc lamp, Brush built the first automatically operated wind turbine generator in 1888 to power his Cleveland mansion. It was the first home powered by electricity in Cleveland. He also pioneered the first piezo-electric featherweight stylus, and later in life, wrote papers about the theory of gravitation.

Brush earned many awards throughout his lifetime for the contributions he made to practical electric arc lighting systems. He received the Edison Medal in 1913, a year before Alexander Graham Bell, and 3 years before Nikola Tesla. He received the French Legion of Honor in 1881 in recognition of his electrical discoveries. He also received the Rumford Prize of the American Academy of Arts and Sciences in 1899 for "the practical development of electric arc lighting," and in 1928, he received the Franklin Medal by the Franklin Institute.

He was a member of numerous professional societies, including the American Institute of Electrical Engineers (now IEEE), the American Society of Mechanical Engineers, and the American Institute of Mining and Metallurgical Engineers, and a fellow of the American Academy of Arts and Sciences, the American Physicists Society, and the British Academy of Arts. He was inducted into the National Inventors Hall of Fame in 2006.

Charles Brush established the Charles F. Brush Foundation for the Betterment of the Human Race with a $500,000 endowment. He was also chairman of the American Philosophical Society's fundraising campaign, so named shortly before his death.

The public's wariness of the new technology caused many obstacles, but Brush and others of the time managed to make electrical lighting a common commodity by the end of the 1880's. But even then, the Electrical Engineering department's third chair, Benjamin Bailey, still studied for his engineering degree primarily by kerosene lamplight. Widespread electricity had only come to campus in 1897.

[Includes link to "The Carbon Arch Lamp: The First Form of Electric Light," a four-minute video by the Edison Tech Center about the history of the arc lamp. https://www.youtube.com/watch?v=jcpS_Vz0BiA]

SOURCE: "Charles F. Brush.: Lighting Up the World." Electrical and Computer Engineering at Michigan: A History of People Powering Innovation. University of Michigan. http://ece.umich.edu/bicentennial/stories/charles-brush-lighting-up-the-world.html. Accessed 4 June 2018.

Document 2C

Charles F. Brush

Birthdate: 1849/03/17
Birthplace: Euclid, OH, USA
Death date: 1929/06/15
Associated organizations: Brush Electric, General Electric (GE)

Biography

Charles Francis Brush, an American pioneer in the commercial development of electricity, was born 17 March 1849, on his parents' farm in Euclid, Ohio, about ten miles east of Cleveland. While still at school, he became intensely interested in electrical apparatus. He developed an interest in science and electricity at an early age, building his first static electric machine at age twelve. Brush's parents realized that Charles would benefit greatly from a good education and they made the financial sacrifice to send him to Cleveland's Central High School. It was there that Brush fulfilled his boyhood dream of constructing an arc light. He graduated from Central High in 1867 with honors. An uncle of Charles' from his mother's side of the family provided a loan which enabled him to continue his education at the University of Michigan, from where he graduated in June 1869 at the age of twenty, later securing the degree of M.S. at this university. Brush later earned a Ph.D. from the Western Reserve University, Cleveland.

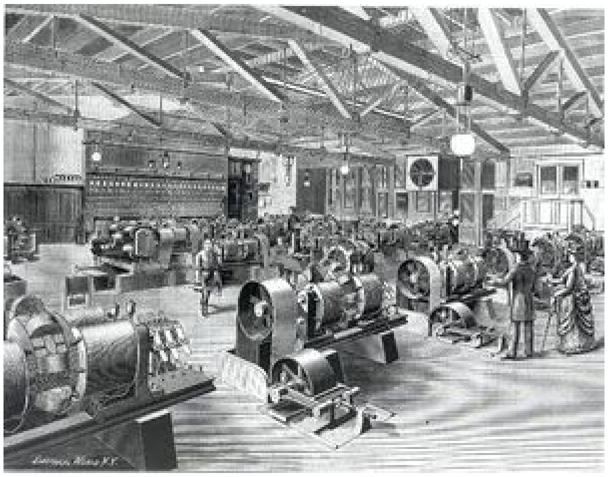
Dynamo Experiments

After graduation, Brush returned to Cleveland where he established himself as an analytical and consulting chemist. Around 1873 he became reacquainted with a boyhood friend, George Stockly, who was vice president and general manager of the Telegraph Supply Company of Cleveland. Brush related some of his early experimentation with electricity to Stockly and discussed his vision for the development of arc lighting. The lighting system would need an efficient means of generating electricity. One of the first to realize the value of the work of Gramme, Brush proposed to do by using a dynamo. Stockly was very impressed with Brush and his ideas and agreed to financially support his effort to construct a small dynamo. Brush assembled his first dynamo in the summer of 1876 while "vacationing" at his parents' farm. The following year he introduced the compound field winding for obtaining constant voltage. He used a horse-drawn treadmill to power the dynamo and was able to generate electricity with his new machine. He returned to the Telegraph Supply Company later that summer to continue the

SOURCE: https://bit.ly/2LvjPva

development work. These early efforts resulted in U.S. Patent No. 189 997, "Improvement in Magneto-Electric Machines", issued 24 April 1877.

Brush Arc Lights Illuminate Cities


Brush Electric Light Station


Arc System Generator

The dynamo provided an economic and efficient source of electricity for the arc light and this was a key factor in developing a commercially viable system of lighting. With a functional dynamo in hand, Brush turned next to developing an arc lamp while simultaneously continuing with development of the dynamo. The arc light was not a new idea but those in existence at the time were not very practical, their chief drawback being the lack of a good regulating system for the carbon electrodes. Brush developed an arc light that was regulated by a combination of electrical and mechanical means, with a simple and easy maintain design. He installed his first commercial arc lamp on the balcony of a doctor's residence in Cincinnati in 1878, and before the end of 1881, Brush arc light systems were illuminating the streets of New York, Boston, Philadelphia, Baltimore, Montreal, Buffalo, San Francisco, and other cities.

In order to keep pace with the rapidly increasing demand for Brush lighting systems, the Telegraph Supply Company of Cleveland underwent significant restructuring, giving birth to the Brush Electric Company in the summer of 1880.

Later Career and Recognition

In 1881, the Brush Electric Company was incorporated and capitalized at $3,000,000, being absorbed ten years later by the General Electric Company, when the works were removed to Schenectady, New York. Brush continued to develop much other apparatus, and contributed great improvement in the manufacture of storage batteries. He was a charter member of the Institute; he served in 1884-87 as one of the AIEE's first managers, and was a member of the Edison Medal committee at the time of his death.

In 1889, the company merged with competitor Thompson-Houston Electric Company. Only two years later, in 1891, the newly formed company merged again, this time with the Edison General Electric Company, to form the General Electric Company. These mergers marked Brush's exit from the emerging electrical industry. He sold his interest in Brush Electric and moved on to other fields of endeavor, never to return to the electric industry.

Brush was a charter member of AIEE and in 1913, he was awarded the AIEE Edison Medal "For meritorious achievements in invention and development of the series arc lighting system." He passed away on 15 June 1929. On that date, his name was being voted upon for honorary membership in the Institute, and this distinction was conferred upon him by the board of directors ten days after his death.

Further Reading:

Papers of Charles F. Brush

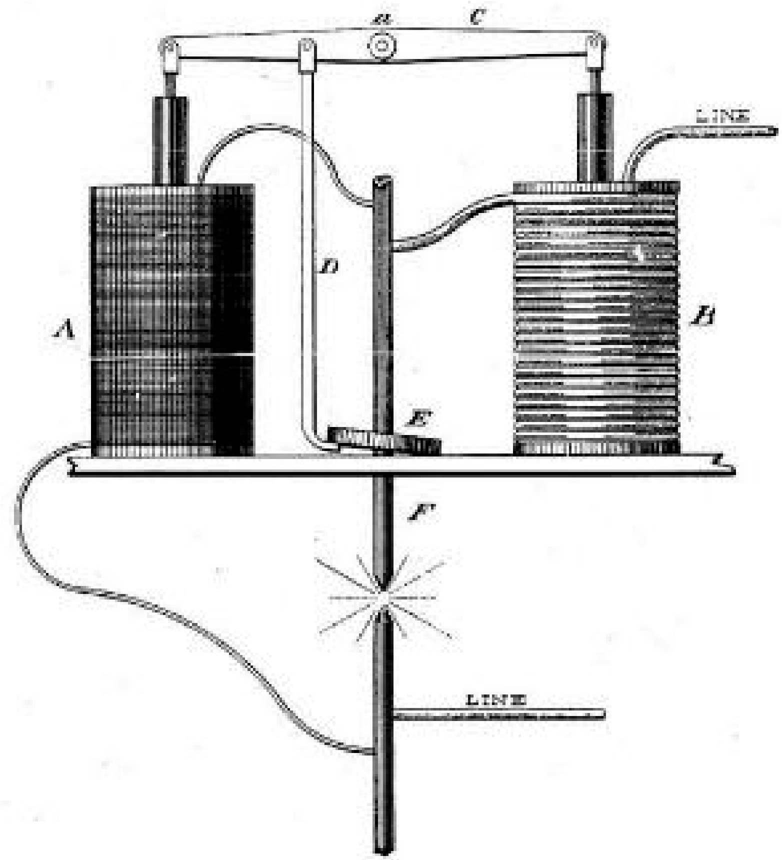
Charles Francis Brush, Encyclopedia of Cleveland, https://case.edu/ech/articles/b/brush-charles-francis

Charles F. Brush, Sr. Papers, Online Exhibit, Special Collections Research Center, Kelvin Smith Library Special Collections, Case Western Reserve University, Cleveland, Ohio. https://library.case.edu/ksl/collections/special/brush/archive/

The Charles F. Brush, Sr. Papers (1842-1967), Special Collections Research Center, Kelvin Smith Library, Case Western Reserve University, Cleveland, Ohio. http://library.case.edu/ksl/collections/special/manuscripts/brush/brushfinding.html

SOURCE: Charles F. Brush, http://ethw.org/Charles_F._Brush. Accessed 4 June 2018.

Document 2D



The illustration [above] is a semi-schematic drawing from Brush's US patent no. 312 184, Electric-Arc Lamp, dated February 10, 1885. It represents an improved regulator for the carbon arc and utilizes two solenoids, one with a heavy gauge coil (labeled B) and one with a light gauge coil (labeled A). The solenoid A is wired in parallel with the electrodes and solenoid B in series with the electrodes…. The solenoid A adds finer control to the regulator.

…When the lamp is first powered on, the current through solenoid B pulls its core down which also pulls the right side of the linkage lever (labeled C) down. The linkage rod (labeled D) and ring clutch (labeled E) move up because they are connected to the lever on the left side of its pivot point (labeled a). As the lamp operates and the arc gap widens, the current flow through the electrodes is reduced. And according to Ohm's Law for the case of parallel circuits, it is evident that the current through the coil of solenoid A will increase as the current through the electrodes decreases. Therefore, as the gap widens, solenoid A will pull down with increased force on the linkage lever and at the same time solenoid B will pull down with decreased force. The interplay of the two solenoids results in a finely controlled downward movement of the ring clutch as the current through the electrodes decreases. And as the current through the electrodes increases, the two solenoids work together to raise the carbon holder in a finely controlled manner. The regulator will move the upper carbon up and down until an equilibrium position is obtained, where the pull from both solenoids is balanced and the linkage lever remains stationary.

SOURCE: La Favre, Jeffrey. "Charles Francis Brush. "The Brush Arc Lamp," 1998. www.lafavre.us/brush/lamparc.htm. Accessed 5 June 2018.

Document 2E

FITTING AND FIXTURE FOR ELECTRIC LAMPS. No. 248,424. Patented Oct. 18, 1881.
UNITED STATES PATENT OFFICE.
THOMAS A. EDISON, OF MENLO PARK, NEW JERSEY, ASSIGNOR TO THE EDISON ELECTRIC LIGHT COMPANY, OF NEW YORK, N. Y.
Application filed March 26, 1581. (No model.)

Be it known that I, THOMAS A. EDISON, of Menlo Park, in the county of Middlesex and State of New Jersey, have invented a new and useful Improvement in Fittings and Fixtures for Electric Lamps; and I do hereby declare that the following is a full and exact description of the same, reference being had to the accompanying drawings, and to the letters of reference marked thereon.

This invention relates to improved means for hanging pendent electric lamps in an incandescent system, so that while applicable to a single lamp they may readily, when desired, be grouped into a chandelier….

In the drawings, Figure 1 is a view of a chandelier with dependent lamps, Fig. 2 a section of the base-piece and cap, Fig. 3 a plan view of the base-piece, Figs. 4 and 5 a plan and section of a shade or reflector, and Fig. 6 a section of the same shade or reflector with the lamp in position.

In Figs. 2 and 3, A is the base-piece of insulating material to which the conductors 1 2 lead, 2 ending in a block, 5, to which one of the wires 7 of the chandelier is connected, so that a circuit, via 2 5 7, is made. 1 ends in a block, 3, while the other wire of the chandelier, 8, terminates in a block, 4, these blocks 3 4 being electrically connected to complete the other portion of the circuit by the bit of safety-catch wire, 6, which is preferably a lead wire. This base-piece has a central screw-threaded aperture to receive and support the stem H of the single lamp or chandelier, as the case may be.

B is an ornamental or plain cap of metal, made by any suitable process, and having a central aperture, permitting it to be moved along the standard of the chandelier D. Bayonet catches or slots can be made at several points in the side of B, taking upon pins in the side of A, so as to hold it thereto, although any other effective fastening may he used. The cap B thus hides and protects the connections upon the base-piece and is in position to catch the molten metal should the safety-catch 6 ever be melted.

Attached to the arms of the chandeliers are lamps provided with necks and sockets, made as set forth in my application No. 298, of even date herewith, so that the lamps may be reversed, as shown.

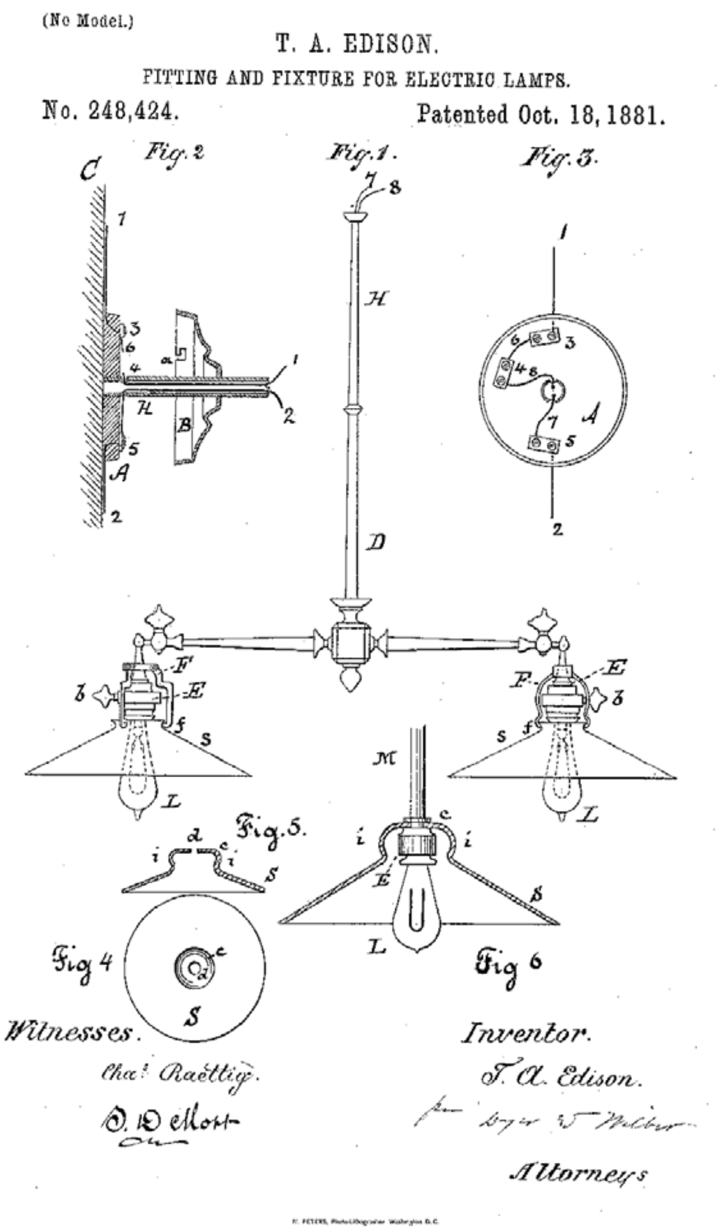
Above the sockets are secured spiders F, with fingers, rigid or spring in one case, pivoted in the other. The ends of these fingers take under the flange at the top of the shades or reflectors S, and so support them from above.

In Figs. 4, 5, and 6 a shade or reflector is shown in which the flanged opening of the shades or reflectors in Fig. 1 is closed by material, homogenous with and forming part of the shade or reflector, in the center of which is left the small aperture 1, which takes over the end of the pipe M, and rests against the usual shoulder thereon. The socket E is then screwed upon the end of M and holds 6 in place, as shown in Fig. 6. It is evident that S in this case may be made without the flange….

SOURCE: https://bit.ly/2LxRHYz

By such an arrangement as has herein been described the lamps and shades may be placed in any desired position, so that the light unimpaired by shadows may be thrown in the proper direction.

This specification signed and witnessed this 8th day of March, 1881.
THOS. A. EDISON.



SOURCE: Thomas A. Edison, "Fitting and Fixture for Electric Lamps." U.S. Patent 248,424, issued 18 Oct. 1881. Retrieved from the Thomas A. Edison Papers, http://edison.rutgers.edu/patenti2.htm. Accessed 5 June 2018.

Document 3A

LIGHT THROWN ON A DARK SUBJECT.
(Which is Bad for the Gas Companies.)

Thomas Edison, with his newly-invented electric light bulb, throws light on the gas company monopoly, personified by 2 men with monstrous gas-meter heads.

SOURCE: "Light Thrown on a Dark Subject (Which Is Bad for the Gas Companies)," Illus. in Puck, 23 Oct. 1878, p. 16. Retrieved from the Library of Congress, www.loc.gov/pictures/resource/cph.3b03877/. Accessed 15 March 2018.

Document 3B

In 1876, the United States of America experienced a complex mix of noteworthy events, including the Centennial International Exhibition held in Philadelphia to celebrate the country's birth and the 100th anniversary of the signing of the Declaration of Independence, as well as one of the most disputed presidential elections in history. The latter brought an end to the federal government's already-waning initiatives to reconstruct the South after the Civil War. The former created a festive venue for displaying some of the technological wonders of the age. The Corliss Steam Engine towered over visitors looking at the Statue of Liberty's arm, the Remington Typographic Machine, the Edison Electric Pen, an array of industrial and agricultural machinery, and Alexander G. Bell's mysterious contraption: the telephone. That same year, Thomas A. Edison built a research laboratory twenty-five miles south of New York City along the Pennsylvania Railroad, a short distance, but a world away, in the village of Menlo Park, New Jersey. Edison declared he would produce "a major invention every six months, a minor one every six weeks" at his invention factory. He and his team of "muckers" spent the next four years working on a variety of projects, including the carbon transmitter for the telephone receiver. Yes, "can you hear me now" was a pertinent question long before cellular telephone service. In addition to improving the telephone, Edison invented the phonograph, or talking machine. He demonstrated the cylinder phonograph at the Scientific American office in New York on 7 December 1877, and within a few months this new wonder brought international fame and garnered Edison the title, "the Wizard of Menlo Park." Today, however, most remember Edison as "the inventor of the light bulb," or more accurately the inventor of a practical and economical incandescent lamp and a direct current electric light and power system.

By the summer of 1878, Edison was exhausted by both constant work and new-found celebrity, so he took a western vacation after accompanying a scientific expedition to Rawlins, Wyoming to observe the eclipse of 29 July, and to measure the heat of the sun's corona with his recently invented tasimeter. In late August, back home at Menlo Park, Edison pursued a new interest: electric lighting. A few weeks later, in the New York Sun (16 Sept. 1878), he exclaimed "I have it now;" meaning he figured out how to make an electric lamp of much lower candle power than the arc light and suitable to indoor use. He also announced plans to create a complete electric lighting system to replace manufactured gas. These statements created a tidal-wave of anxiety amongst investors in manufactured gas companies. The humor magazine, Puck, published a cartoon "Light thrown on a dark subject (Which is Bad for the Gas Companies)," (23 Oct. 1878) depicting Thomas Edison with his newly-invented electric light bulb illuminating the gas company monopoly personified by two men with gas-meter heads. Many gas companies had terrible reputations for poor service and quality, high rates, shady political dealings, and unethical business practices. Gas stock prices tumbled and the gas companies were justifiably unnerved because Edison studied their technology and industry, figured out their limitations, and attacked them head-on. He also concentrated on the heart of the artificial illumination market, domestic lighting, because it was 90 percent of the market and it was very profitable for manufactured gas companies. For the time being, street and outdoor illumination remained the domain of the arc light and manufactured gas industries….

Nearly three decades later, Edison recalled the high-resistance carbon filament lamp experiment spanned two days, 21 and 22 October 1879. "We sat and watched it with anxiety growing into elation. It lasted about forty-five hours, and then I said, "If it will burn that number of hours now, I know I can make it burn a hundred!'" Edison artfully used the media for free publicity. While experiments continued

SOURCE: https://bit.ly/2Jxv2hH

on 21 December 1879 the *New York Herald* announced “the great inventor’s triumph in electric illumination.” Ten days later the public saw Edison’s lamp for the first time….

This public demonstration was only the beginning of Edison’s endeavor to develop and commercialize electric light and power technology. He expanded the laboratory staff and worked on a complete electric light system, but these efforts involved more than “the system.” Edison also created the electrical manufacturing industry by founding companies to make components, including lamps, conductors, dynamos, and light fixtures and to sell and install isolated plants, and later, central stations….

Shortly after the Menlo Park demonstration, the Edison Electric Illuminating Company of New York was incorporated in 1880 with one million dollars of capital stock. This new company leased Edison’s patents from the parent company and paid for the construction of the Pearl Street central station in lower Manhattan….

The Pearl Street central station, built in a prominent location, commenced operation with much fanfare. The “Miscellaneous City News” column of the *New York Times* reported that, on 4 September 1882, the “Jumbo” dynamos were started at 3:00 PM at the Edison Electric Illuminating Company of New York’s central station at 257 Pearl Street. The lights were turned on around 5:00 PM, but the true spectacle was not appreciated until it became dark nearly two hours later. With the simple turn of a thumbscrew, a lamp was turned on emitting a light “soft, mellow and grateful to the eye,” making rooms “as bright as day….”

If Edison merely invented a practical incandescent lamp, the story would have ended with the execution of his first patent application for a high-resistance carbon filament (U.S. Pat. 223,898) on 1 November 1879. Out of necessity, Edison and a few key associates founded companies to manufacture parts for the Edison system of electric lighting, and frustration and desperation drove Edison to take charge of the village plant business ….

It was Edison, the inventor and the businessman, that personally financed the Thomas A. Edison Central Station, Construction Department, presiding over it from early May 1883 until 1 October 1884, when the Edison Company for Isolated Lighting took over this line of work. In a little more than one year, the Construction Department built thirteen central stations in the northeastern and midwestern sections of the United States. In addition, by October 1885, thirty-one Edison central stations were in operation or under construction in the United States, with fourteen local companies organized in the past year. The following year, promotional literature distributed by the Edison Electric Light Company bragged “Now, even ‘our friends, the enemy’ (the Gas companies) acknowledge that the problem of supplying the Edison Incandescent Light for the service of the individual consumer, by a system of house-to-house lighting is a practical success, and are content with expressions of doubt as to our ability to make a profit in competition with them.” Business expanded rapidly, and by 1888, 169 Edison central stations were scattered across the United States and its territories….

SOURCE: Hellrigel, Mary Ann C. "Your Engineering Heritage: Edison, the Electrical Engineer, Spearheaded Central Station Business." IEEE-USA *InSight*, 20 May 2016. https://insight.ieeeusa.org/articles/your-engineering-heritage-edison-the-electrical-engineer-spearheaded-central-station-business/. Accessed 3 June 2018.

Document 3C

Not a little impatience has been manifested by the public at the seemingly unaccountable tardiness with which the work of introducing the "carbon-loop" electric lamp into general use has hitherto progressed. It is now several months since the announcement was made through the newspapers that all the obstacles in the way of the utilization of the electric light as a convenient and economical substitute for gaslight had been removed: that a method had been invented by which electricity for light or for power could be conveyed to considerable distances economically; that the current could be subdivided almost ad infinitum; and that the electric lamp was henceforth to be as manageable for household purposes as a gas-jet. But, so far as the public can see, the project has since that time made no appreciable advance toward realization…. Still it must be confessed that hitherto the "weight of scientific opinion" has inclined decidedly toward declaring the system a failure, an impracticability, and based on fallacies. It will not be deemed discourteous if we remind these critics that scientific men of equal eminence pronounced ocean steam-navigation, submarine telegraphy, and duplex telegraphy, impossibilities down to the day when they were demonstrated to be facts….

Now, the fact is, that this system of electrical lighting was from the first all that it was originally claimed to be, namely, a practical solution of the problem of adapting the electric light to domestic uses and of making it an economical substitute for gaslight. The delays which have occurred to defer its general introduction are chargeable, not to any defects since discovered in the original theory of the system or in its practical working, but to the enormous mass of details which have to be mastered before the system can go into operation on a large scale, and on a commercial basis as a rival of the existing system of lighting by gas….

But, fortunately, the unavoidable delay interposed by administrative and economic considerations afforded opportunity for further research and experiment, and the result has been to introduce many essential modifications at both ends of the system—both in the generator and in the lamp; at the same time sundry important changes, all in the direction of economy and simplification, have been made at almost every point in the system, as well as in the details of manufacturing the apparatus.

As for the lamp, it has been completely transformed. The external form of the two types of lamp is identical; the principle of illumination—incandescence of a solid body in vacuo—is also the same; but, in the earlier lamp, light was produced by the incandescence of a platinum wire wound on a spool of zircon; in the perfected lamp the source of light is incandescent carbon. Another essential difference between the two is found in the form given to the incandescent body: in the platinum lamp it was coiled compactly on a small spool; in the carbon lamp it is a loop some five inches in total length. This incandescent loop is found in practice to afford a better light for domestic purposes than an incandescent mass of compact form: the shadows it casts are not so sharply defined; their edges being softened.

This loop of carbon is now prepared from the fiber of a cultivated species of bamboo from Japan. A thread of this material, after undergoing a certain chemical process, is bent into the required shape, and then reduced to carbon. The resulting carbon loop is of a remarkably homogeneous structure, and possessed of a high degree of tenacity, so that it can withstand, without breaking, all the concussions it is likely to be subjected to in household use.

SOURCE: https://bit.ly/2LwW2uK

The perfected lamp consists of an oval bulb of glass about five inches in height, pointed at one end, and with a short stem three quarters of an inch in diameter at the other. Two wires of platinum enter the bulb through this stem, supporting the loop or ∩-shaped thread of carbon, which is about two inches in height. The stem is hermetically sealed after the introduction of the carbon loop. At its pointed end the bulb terminates in an open tube through which the air in the bulb is exhausted by means of a mercury-pump till not over one millionth part remains; the tube is then closed. The outer extremities of the two platinum wires are connected with the wires of an electric circuit, and at the base of the lamp is a screw by which the circuit is made or broken at pleasure. When the circuit is made, the resistance offered to the passage of the electric current by the carbon causes the loop to acquire a high temperature and to become incandescent; but, as this takes place in a vacuum, the carbon is not consumed. The "life" of a carbon loop through which a current is passed continuously varies from seven hundred and fifty to nine hundred hours. With an intermitted current, the loop has an equal duration of life; and, as the average time an artificial light is used is five hours per day, it follows that one lamp will last about six months. Each lamp costs about fifty cents, and when one fails another may easily be substituted for it.

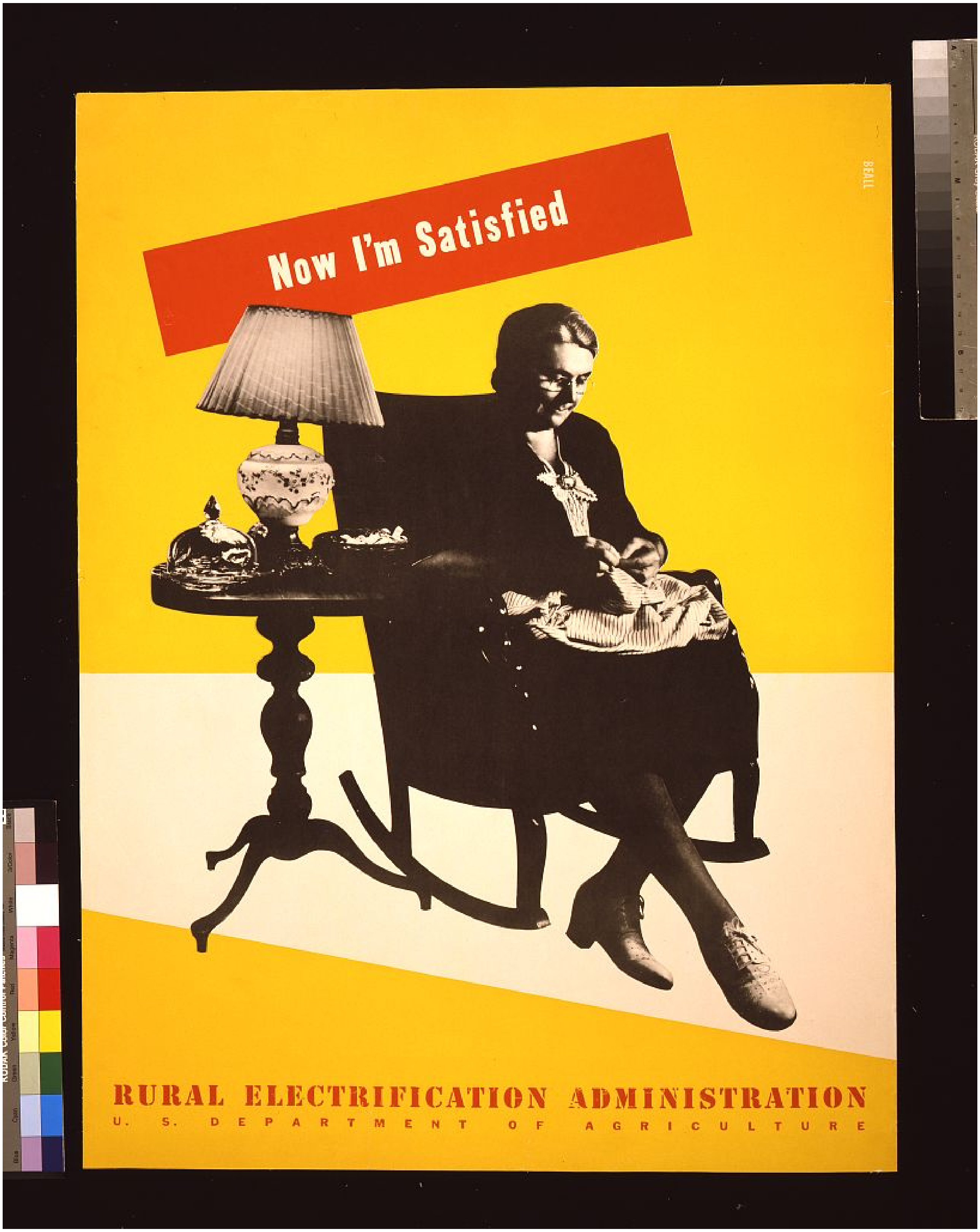
The light is designed to serve precisely the same purposes in domestic use as gaslights. It requires no shade, no screen of ground glass, to modify its intensity, but can be gazed at without dazzling the eyes. The amount of light is equal to that given by the gas-jets in common use; but the light is steadier, and consequently less trying to the eyes. It is also a purer light than gas, being white, while gaslight is yellow…. A sort of meter registers exactly the amount of electricity consumed in each house. Finally, not to enumerate all the advantages which this system possesses over gas-lighting, the lamp can be manipulated even by the most inexperienced domestic servant; nor can the most careless person do injury to himself, to others, or to property through not understanding its mechanism….

To the question which is so often asked, "When will a public demonstration of the working of this system be made?" – we would reply that such a demonstration will in all probability be made at Menlo Park within two months from this date…. The practical engineer and the man of business can best appreciate the difficulties that had to be overcome. Like difficulties have in the past retarded the general introduction of nearly all the great mechanical and chemical inventions. Years intervened between the discovery of photography and the taking of the first photograph; the steam-engine, the steamboat, the locomotive-engine, did not come till long years after the discovery of their scientific principles; the same is true of the telegraph.

A very important question is that of the cost of this light. The price of the electric light will, of course, be determined by the capitalists who invest their money in it as a business venture, but it will of necessity be low as compared with gaslight…. So much can be safely affirmed, that this light can be sold at a price which will make competition on the part of the gaslight companies impossible: …Because the companies can sell electricity for two uses—for light at night, and for power in the daytime… A canvass of the city of New York has shown that the demand for small powers, in private dwellings and minor industrial establishments, will give occupation to the central stations in the lower part of the city for ten hours daily. This power can be supplied at such a profit to the companies as to more than cover the expense of running the stations for six hours longer in producing electric light. It is evident, therefore, that, in a competition with gas, the electric light possesses an enormous advantage.

SOURCE: Edison, Thomas A. "The Success of the Electric Light." *The North American Review* 131, no. 287 (1880): 295-300. http://www.jstor.org/stable/25100894. Accessed 5 June 2018.

Document 3D



SOURCE: Beall, Lester. "Now I'm Satisfied," Rural Electrification Administration, U.S. Department of Agriculture, ca. late 1930s. Poster. Library of Congress, www.loc.gov/pictures/item/2010650602/. Accessed 15 March 2018.

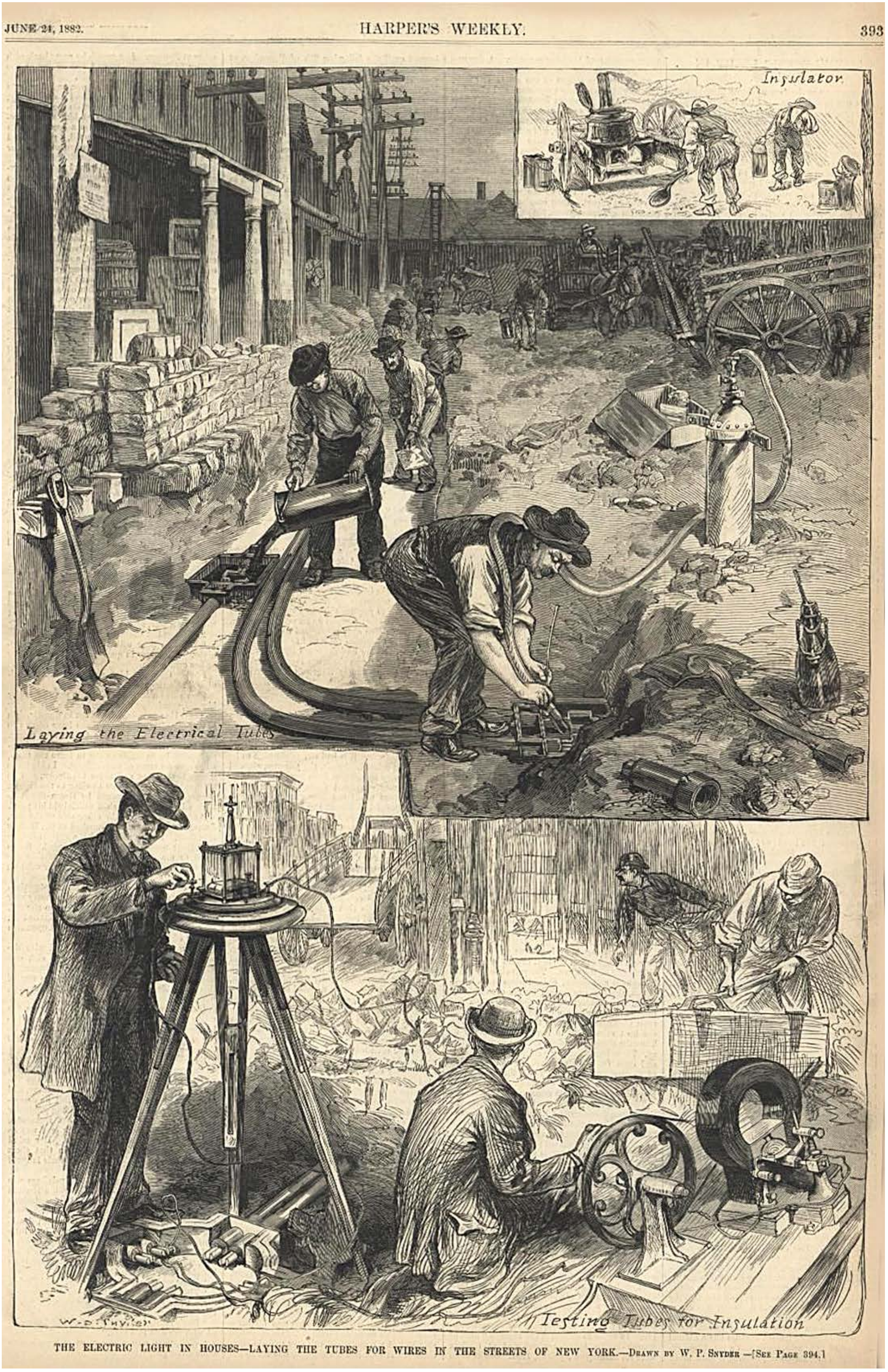
Document 3E

Edison had decided in 1880 to build his first commercial electric lighting system at the center of one of the world's great capital markets, New York's financial district in lower Manhattan. The boundaries of the distribution system he built in 1881 and 1882 encompassed banks, brokerages, offices, and newspaper publishers, just blocks away from other important institutions such as the Western Union Telegraph Company building and City Hall. The central station itself occupied two adjoining buildings on Manhattan's Lower East Side, near the new Brooklyn Bridge. The mechanical and electrical portion of the plant was located in 257 Pearl Street. The companion building at 255 Pearl Street was used for office, storage, and sleeping spaces; two Jumbo dynamos were installed in the basement in the spring of 1884…. John Lieb later wrote that 257 "was originally erected for commercial purposes, and as it was incapable of sustaining the weight of the engines and dynamos planned to be installed on the second floor, the old flooring was torn out, and a floor of heavy girders supported by stiff columns was substituted. This heavy construction, not unlike the supporting structure of the elevated railroad, was erected so as to be independent of the building walls, and occupied the full width of the building... and about three-quarters of its depth." A detailed description of the plant in the 26 August 1882 *Scientific American* reported that the ironwork included "pillars planted on heavy plates resting on three feet of solid concrete." Four 240 horsepower Babcock & Wilcox boilers occupied the basement. Above them on the new iron frame rested the six engine and dynamo assemblies, each unit weighing about thirty tons and rated for 1,200 lamps…. On the third floor, copper wire resistances wound on large wooden frames were used for manual regulation of the dynamo fields. An automatic indicator lighted a red lamp when the voltage rose too high, and a blue lamp when it dropped; the indicator was calibrated every few days against a reflecting galvanometer at the Edison Machine Works…. The top floor housed a battery of 1,000 lamps used to test dynamos removed from the main circuit for inspection or repair.

Construction of the station began in late summer 1881 and the Edison Electric Light Co. published progress reports in its *Bulletins* over the next year. On 22 September Edison, John Kreusi, and their work crews began excavating at the corner of Peck Slip and South Street for the network of underground conductors. Work stopped during the winter because of frozen ground, but resumed in late February 1882. By the first of April the crews had installed about two-thirds of the roughly 80,000 feet of conductors, although they had not yet connected the feeders to the mains. By mid-April 1882 the central station structure (including boilers) was largely complete. The mechanical and electrical equipment was not yet set up, although assembly of the dynamos was well under way at the Edison Machine Works and the finished Porter-Allen engines were on hand. The first engine and generator assembly was tested on 5 July. By late July crews had completed the installation of the underground feeders and mains except for connecting to individual buildings (946 in all). As they did this, a number of buildings were lighted to test the engines and dynamos. After the station officially began service on 4 September, it remained in operation until a fire partially destroyed it in January 1890. It was reconstructed and operated until 1894. The buildings were sold soon afterward and no longer exist. The Edison Electric Illuminating Co. paid about $300,000 to acquire the Pearl Street properties and construct the central station and distribution system. Administrative expenses, interest, canvassing, and patent license fees to the Edison Electric Light Co. brought the total cost chargeable to the first district to more than a half million dollars. The company did not charge customers for current until early 1883.

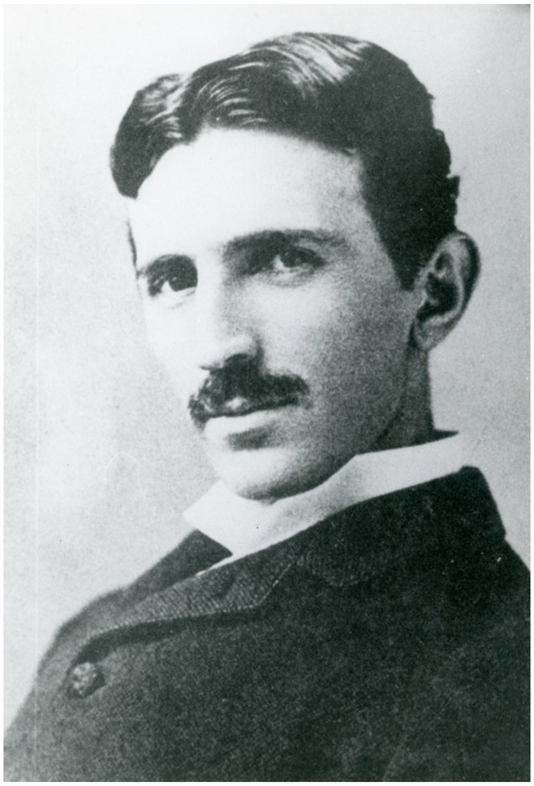
SOURCE: PEARL STREET CENTRAL STATION, Doc.2243, p. 423-428. Israel, Paul B., Louis Carlat, David Hochfelder, Theresa M. Collins, and Brian C. Shipley. *The Papers of Thomas A. Edison. Volume 6. Electrifying New York and Abroad, April 1881-March 1883*. Baltimore: Johns Hopkins University Press, 2007. edison.rutgers.edu/yearofinno/EL/PearlStreetHeadnote.pdf. Accessed 4 June 2018.

Document 3F



SOURCE: Snyder, W.P. "The Electric Light in Houses: Laying the Tubes for Wires in the Streets of New York." *Harper's Weekly*, 21 June 1882. https://commons.wikimedia.org/wiki/File:Laying_electric_lines_under_street_Edison_Pearl_Street_Utility_June_21_1882_Harpers_Weekly.png. Accessed 5 June 2018.

Document 3G



In the days when a commercial rivalry existed between the supporters of the a-c and d-c systems, Nikola Tesla invented independently the polyphase a-c system and built the first small polyphase motor, inaugurating a new epoch in the electrical industry. His other discoveries and inventions are many, principally connected with apparatus for the use and transmission of power, such as the polyphase generator and transformer, oscillation transformer, revolving field generator, and split-phase motor, as well as high-frequency apparatus. Mr. Tesla was born in Smiljan, Lika, a borderland region of Austria-Hungary, and was educated at the Polytechnical School in Gratz and at the University of Prague. His electrical career began in 1881 when he was 24, at Budapest, where he made his first electrical invention, a telephone repeater, and conceived his idea of the rotating magnetic field. He came to the United States in 1884 and became a naturalized citizen. At first he was employed at the Edison works, and later by the Westinghouse Company, which purchased his patents on the polyphase a-c system and manufactured the motor. In 1890 he left the Westinghouse organization and began experimenting with high-potential, high-frequency alternating currents. In the last few years he has been working on a method to derive power in large amounts without regard to location.

SOURCE: "Member Biography of Tesla." *American Institute of Electrical Engineers*, May 1934. http://ethw.org/w/images/0/07/Tesla_-_member_bio.pdf. Accessed 1 June 2018.

Document 3H

Nikola Tesla envisioned supplying power to the world without the need for a tangle of wires strung everywhere. The closest he ever came to realizing wireless transmission was the Tesla coil, which he created in 1891. However, his dreams were much bigger, encompassing a global wireless power grid that any home, business, or vehicle could tap into at will.

Now, researchers at Stanford University think they may have gotten the wireless charging technology right, as they've been able to transmit electricity wirelessly to a moving object nearby. If their technology is scalable, they may have discovered a way to allow electric cars to recharge as they're in motion, eliminating issues of charging station availability and EV battery range. If that final hurdle is truly overcome, electricity could easily become the standard vehicle fuel worldwide.

Senior study author and professor of electrical engineering Shanhui Fan said in an interview for *Stanford News*, "We still need to significantly increase the amount of electricity being transferred to charge electric cars, but we may not need to push the distance too much more."

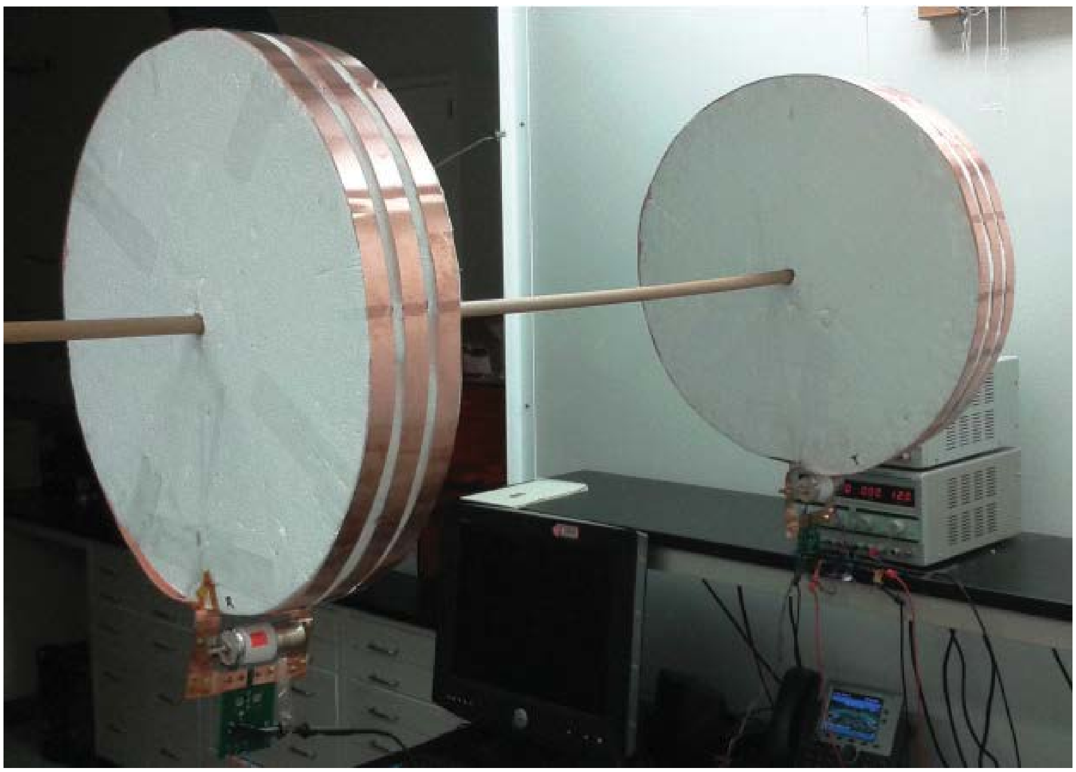


Image Credit: Sid Assawaworrarit/Stanford University

As the team described in their recently published Nature study, the transmission achieved was much smaller than would be needed to power vehicles. However, they did reach a kind of mid-range wireless power transfer based on magnetic resonance coupling. Electricity coursing through wires creates an oscillating magnetic field, and it's this field that causes a nearby coil's electrons to oscillate. This in turn transmits power wirelessly. However, it's a complex process and is only efficient when the oscillating coils are tuned with respect to the moving object.

SOURCE: https://bit.ly/2tEnRsl

Until now, this has been one of the primary problems for wireless energy transmission, because there hasn't been a way to get the coils to automatically tune to moving objects. The researchers solved this problem by using a feedback resistor and voltage amplifier system to detect where it should be tuned to without help from humans.

This research is part of an overall push toward safer, clean energy highways with more manageable traffic that will eventually support self-driving cars.

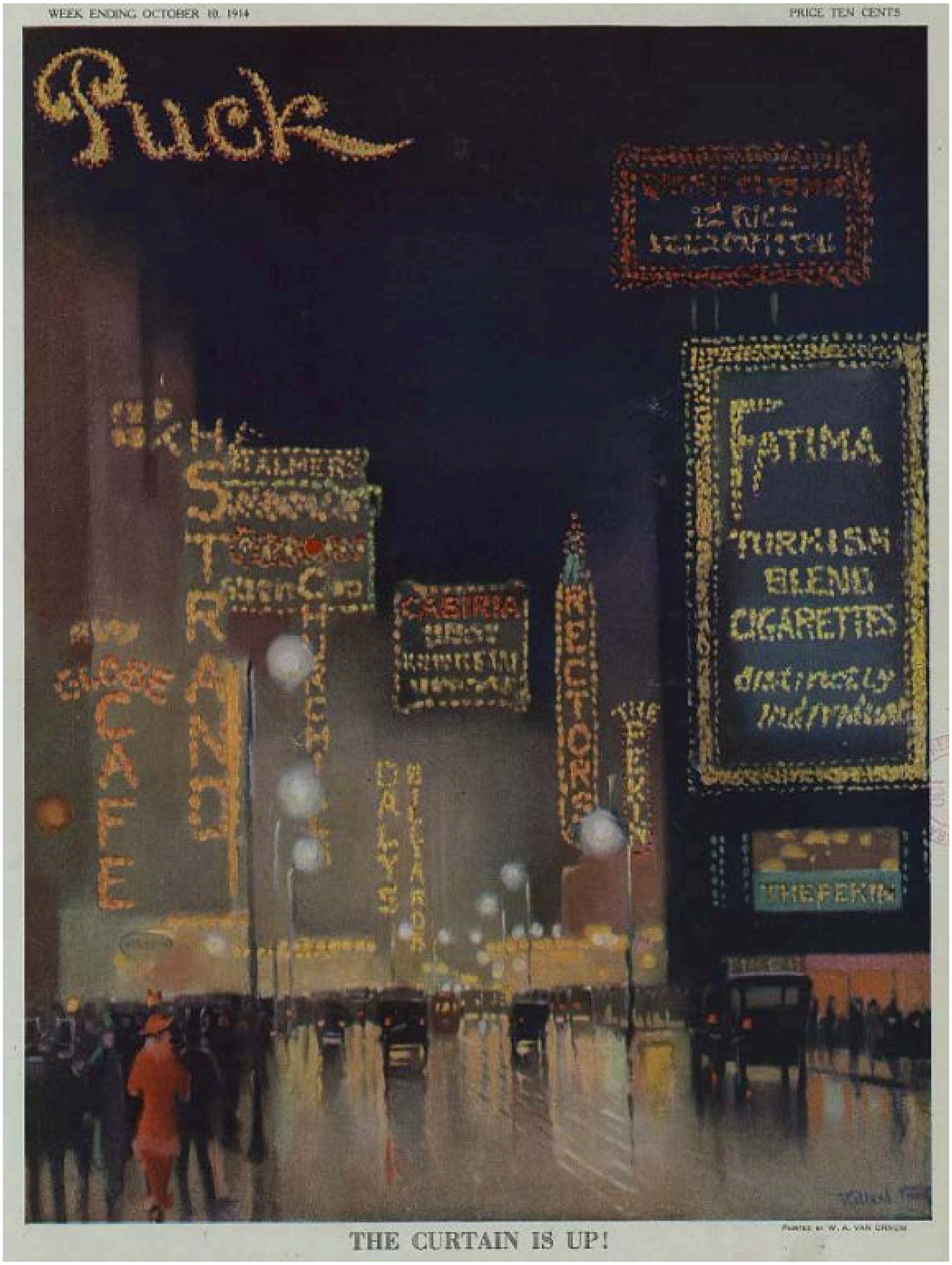
"In theory, one could drive for an unlimited amount of time without having to stop to recharge," Fan explained in the interview. "The hope is that you'll be able to charge your electric car while you're driving down the highway. A coil in the bottom of the vehicle could receive electricity from a series of coils connected to an electric current embedded in the road."

With coils embedded in the roads, we could eventually enjoy a totally automated highway system. Self-driving electric vesicles could be wirelessly charged en route, and GPS and other navigation systems would also be powered wirelessly. How different is this outcome compared to Tesla's vision of the global power grid?

His "World Wireless System" would have dotted the globe with wireless towers that transmitted power — along with data — to each other, and individual users could tap into the network with antennae. Although his plan never got past the first tower, which was demolished exactly 100 years ago, his vision of the future was really very accurate. Now that the Stanford team has this piece in place, hopefully we'll see the rest of it happening soon.

SOURCE: Lant, Karla. "Stanford Scientists Are Making Wireless Electricity Transmission a Reality." *Futurism*, 16 June 2017. https://futurism.com/stanford-scientists-are-making-wireless-electricity-transmission-a-reality/. Accessed 30 May 2018.

Document 4A



SOURCE: Van Ornum, Willard Attwood, Artist. "The curtain is up!" *Puck*, 14 Oct. 1914. Retrieved from the Library of Congress, https://www.loc.gov/item/2011649846/. Accessed 15 March 2018.

Document 4B

More than two months after Hurricane Maria devastated Puerto Rico, large sections of the island have yet to have electricity restored. The state of the power grid is still so unstable that even those areas that have been re-electrified can't really count on around-the-clock power. As many observers have noted, this is an untenable situation. I've worked for much of my adult life as a solar engineer, installing solar microgrids in remote parts of the world that previously had no access to electricity. But Puerto Rico is different. All over the island, people have relied for decades on steady, abundant electricity and the modern conveniences that come with it. And so to suddenly not have electricity presents all kinds of hardships—some obvious and some less so.

For me personally, this ongoing hardship is especially wrenching. I grew up in Puerto Rico, in the rainforest of El Yunque and on the beaches of Luquillo, and much of my family is still there. Immediately after the storm, I couldn't reach any of them because of course they had neither power nor phone service. When officials announced that power wouldn't be restored for months, I booked the earliest flight to San Juan that I could find. I spent a week in Puerto Rico in early October, checking on relatives and friends and helping where I could.

My time there veered from the absurd to the devastating. Several times a day, I'd manage to walk into a room, flick on the light switch, and then laugh at myself for having forgotten—again. There were emergencies happening seemingly everywhere I turned—people needing medical help they couldn't get, others unable to work or go to school, businesses unable to stay open. Since my return to New York, I've been working hard to get the word out about conditions on the ground there. Here are seven facts about living in Puerto Rico right now.

1. Stoplights don't work

Driving around after the storm was chaotic. Every intersection became a test of wills—the bold and reckless forged ahead, heedless of cross traffic, the meek waited for a break in traffic to make their move. Although a few of the busier intersections had traffic cops, the vast majority didn't. And the cops who had to stand out in the sun and the heat all day serving as stoplight replacements clearly were having a rough time. Did I mention there was a heatwave right after the storm?

2. ATMs and credit cards don't work

Puerto Rico has a modern banking system, but after the storm hit, many ATMs didn't work at all for lack of power. Those that were still operating quickly ran out of money. Without money, consumers couldn't buy anything, and businesses couldn't sell anything. And of course credit cards didn't work because there was no way to process transactions. The economy basically ground to a halt.

Businesses that did manage to stay open relied on generators and cash. Even then, it was a struggle. One day, I and some friends were having lunch at my favorite restaurant, Toro Salao, when the manager informed us that we were eating the last of the *tostones*, a delicious alternative to French fries made from plantains. The storm had knocked down nearly all of the island's plantain trees.

3. Cellphones don't work

Before the hurricane, the island enjoyed decent cellphone coverage pretty much everywhere. The storm knocked out 95 percent of Puerto Rico's cell service, according to the U.S. Federal Communications Commission. Throughout my stay, phone service remained down across most of the island, with only

SOURCE: https://bit.ly/2AxxQo8

limited service within San Juan and a few other spots. Restoring phone service will mean not just repairing cell towers that were damaged but also electrifying them. For most people I met, lack of communication was the single biggest source of stress. Going days on end without knowing whether family members were okay is something that no one should have to go through. I did manage to place a few calls either with a satellite phone or by calling when I happened to drive through an area that had reception. It's hard to describe that intense feeling of relief when you do finally hear from a loved one. I went through it myself when I got word that my parents and brothers were OK. I experienced an entirely different set of emotions when I learned that my favorite uncle had passed away right after the storm. By the time I found out, he had already been dead a week.

4. Water doesn't work

It takes electricity to run the pumps that move water through the system, and it takes electricity to filter and treat the water so that it's safe to drink. I visited some towns that had diesel-powered emergency generators to get the water flowing again. But much of the island's infrastructure was so badly damaged that even now, many places still lack clean running water. The water crisis has in turn prompted medical experts to warn of a looming health crisis in Puerto Rico.

5. Refrigeration doesn't work

No electricity means your fridge soon becomes just a big box with rotting food inside. As temperatures climb, food quickly goes bad, and so people are forced to shop for food every day. During my visit, supermarkets that were still open had long lines of people standing in the sun, waiting to shop for a very limited selection of goods. Ice is therefore in high demand, to keep food and drinks cool a little longer and maybe postpone another punishing trip to the store.

6. It's dark

No street lights or house lights or lights of any kind means the nights are really dark. I've camped in the desert before, but this was a different kind of dark. Trying to drive at night was surprisingly difficult—street signs were hard to read, buildings were indistinguishable from one another, and the usual landmarks weren't at all obvious.

7. Solar power works!

Fortunately, my experience designing and installing solar microgrids for rural villages in Haiti, India, and sub-Saharan Africa, and urban rooftops in New York City came in handy. Before my trip, I'd collected money via a crowd-sourcing fundraiser, and I arrived in Puerto Rico with a suitcase full of portable solar panels designed by Voltaic Systems of Brooklyn, N.Y., suitable for charging cell phones and other small devices. I also brought LED lights, water filters by LifeStraw, and Camp Stoves by Biolite. As I traveled around the island, I gave the equipment to people I met. The recipients were invariably overwhelmed and grateful, and I felt lucky to be able to offer them the means to connect with their loved ones, drink clean water, and prepare a meal.

There is still so much work to do. I'm back home in Brooklyn but I can't rest. Having worked in the energy industry for a long time, I know that I can make a difference, helping to build a cleaner, more resilient power system for Puerto Rico….

SOURCE: Humphrey, John. "7 Things About Life in Puerto Rico with No Electricity," ***IEEE*** **Spectrum, 4 Dec. 2017 | 20:30 GMT. https://spectrum.ieee.org/energywise/energy/renewables/7-things-about-life-in-puerto-rico-with-no-electricity. Accessed: 23 Feb. 2018**

Document 4C

Today many major league baseball games are played under artificial illumination. In the first few decades of “base ball” playing, however, games were often curtailed due to darkness. The increasing number of electric lighting systems being installed in the late 1870s made experimentation with artificial illumination at ball games almost inevitable.

The first known such experiment occurred during the evening of Sept. 2, 1880, when two teams, mostly employees from the dry-goods firms R. H. White and Company and Jordan Marsh and Company, played a nine-inning game on the back lawn of the Sea Foam House, a hotel near Nantasket Beach in Hull, Mass.

At that time, the prevailing means of nighttime artificial illumination was gas. But various electrical lighting firms were created to challenge the monopoly of the gas companies. The Boston-based Northern Electric Light Company, perhaps desiring a venue where thousands of people might be able to view a sample of the potential of their lighting equipment, erected at the beach three wooden towers 500 feet apart in an equilateral triangle. Each was 100 feet high, and mounted upon each of these was a circular row of 12 electrical lights “of the Weston patent.” Each light had an estimated 2,500 candle power; thus, the light of 90,000 candles was concentrated within a limited territory. The company used three “Weston machines,” undoubtedly dynamos, to generate “a motive-power of 36 horses,” that is 36 horsepower.

The mention of “Weston” equipment is an indication that the lighting apparatus involved was not incandescent lamps (invented by Thomas Edison a year earlier in 1879 and in which a filament gives off light when heated to incandescence by an electric current), but rather the electric arc lamps (electrical lamps that produce light by an arc made when a current passes between two incandescent electrodes surrounded by gas) and electric dynamos developed by Edward Weston. In 1873 he established the Harris & Weston Electroplating Company in partnership with George G. Harris, and in the same year he developed his first dynamo (a machine used to convert mechanical energy into electrical energy) for electroplating. Two years later, Weston patented what he called the “rational construction of the dynamo,” which enabled him, so he claimed, to increase its efficiency from 45 percent to more than 90 percent.

The New England Weston Electric Light Company was possibly a collaborator, perhaps with the idea that playing a base ball game under artificial illumination might bring added attention to its equipment. But it certainly had in mind a market much more extensive than just ball fields. The Boston Herald noted, “The design of the exhibition was to afford a model of the plan contemplated for lighting cities from overhead in vast areas, the estimate being that four towers to a square mile of area, each mounting lights aggregating 90,000 candle power, will suffice to flood the territory about with a light almost equal to mid-day.”

Reporters at the game assessed that the amount of lighting was insufficient for good ball play. Although reporting that the lights, with one single slight flicker, “burned steadily and brilliantly all evening” between 8 and 9:30 p.m., the Herald observed that “on account of the uncertain light, (resembling that of the moon at its full,) the batting was weak and the pitchers were poorly supported.” The historian Preston Orem summarized accounts in several Boston newspapers to conclude, “The light was quite imperfect and there were lots of errors made. The players had to bat and throw with caution. For the spectators the game had little interest as only the movements of the pitcher, in general, could be

SOURCE: https://bit.ly/2sDGJJJ

discerned, while the course of the ball eluded the vision of the watchers. ... None of the reporters believed the idea to be at all practical."

The game ended in a 16–16 tie after nine innings, with further play precluded by the desire of the players to catch the last ferry boat back to Boston. What the electric companies involved officially concluded from the experiment is not known. But The Boston Evening Transcript concluded that "if the projectors of the experiment wish to convince the public that they can shed light enough over a city from elevated stands to allow people to sit in their houses and pursue their ordinary evening occupations without gas, candle or lamp light, more light still will be necessary."

Arc-lamp outdoor lighting from a system of high towers, known as moonlight towers, did become briefly popular in the 1880s and 1890s in several cities in the United States and Europe. But the numbers of such towers decreased as incandescent electric street lighting became more common.

The contemporary accounts of the Nantasket Beach night game make no mention of individual participating players, which may have been deliberate. In 1909, nearly 30 years after it was played, an anonymous correspondent, stating that he had been the "Official Scorer" of the game, wrote to the New York Sun newspaper and claimed that "at almost the last moment the two firms mentioned [for an unspecified reason] forbade their employees taking part, so it was played *sub rosa*." The ban by the companies, according to the correspondent, made it "inexpedient [for him] to mention any names of players, as some of them may still be employed in these establishments, although a number of players were recruited from the various jobbing houses in the dry-goods trade."

Northern Electric did reward the players and officials for their efforts with a fine post-game supper (probably in Boston), of which the Sun correspondent had "the most vivid remembrance."

SOURCE: Waff, Craig B. "September 2, 1880: Night baseball at Nantasket Beach." Society for American Baseball Research website. http://sabr.org/gamesproj/game/september-2-1880-night-baseball-nantasket-beach. Accessed 13 April 2018.

Document 4D

SOURCE: Detroit Publishing Co., Copyright Claimant, and Publisher Detroit Publishing Co. *Night in Luna Park, Coney Island, N.Y*. New York, New York State, United States, ca. 1905. Photograph. Retrieved from the Library of Congress, https://www.loc.gov/item/2016799885/. Accessed 14 March 2018.