

More Than a Century Ago Nikola Tesla Envisioned the Age of Aluminum

Replacing Copper in Electrical Wiring

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Nikola Tesla, a Serbian American inventor and futurist, is considered to be one of the greatest electrical engineers of all time (Figure 1). Best known for harnessing alternating current (AC) for electrical transmission, Tesla was a true visionary, envisioning wireless transmission and communication technologies (now made reality in the form of cell phones and wireless internet). Although he was not a particularly good businessman and ultimately died penniless, Tesla's legacy lives on today in popular culture, with his name even being lent to electric car manufacturer, Tesla Inc.

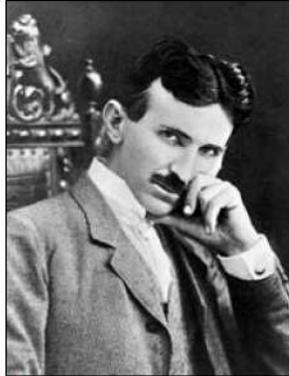


Figure 1. Nikola Tesla, engineer, inventor, and futurist.

Tesla's views on aluminum—although 125 years old—are particularly relevant to today. He believed aluminum had the potential to be a strong competitor against other materials, particularly against copper. Just as there had been ages of stone, bronze, iron, and steel, Tesla believed there would be an "Age of Aluminum." These views remain relevant because they point to aluminum's importance in meeting current environmental goals, such as achieving Net-Zero CO₂ emissions by 2050. Without aluminum, these goals could be disrupted by a constrained copper supply.¹

Biography

Even in his early years, Tesla was considered brilliant. At university, he was able to perform integral calculus in his head, and in later years, he was able to visualize inventions, perfecting them in his mind before building them. He first became curious about electricity after witnessing demonstrations as a young man.

Tesla joined the Continental Edison Company in Paris in 1882 before immigrating to the U.S. in 1884, when he was employed at the Edison Machine Works in New York. There, he worked on various projects, including improving generators and developing an arc lamp lighting system. After Edison denied him a bonus, Tesla left to start up his own business, the Tesla Electric Light and Manufacturing Company.

As the head of his own company, Tesla explored a wide range of electrical and communications technologies. He was issued hundreds of patents for his inventions, such as the Tesla coil (Figure 2), an induction motor, and the AC polyphase system. His work was driven by the desire to advance technology for the world. "The desire that guides me in all I do is the desire to harness the forces of nature to the service of mankind," said Tesla.²

His greatest technological advancement was harnessing high-voltage AC (which repeatedly switches direction and continuously varies in strength). The development of this technology enabled the transmission of electricity over



Figure 2. Tesla sitting in his laboratory, supposedly next to his Tesla coil, also called a magnifying transmitter (essentially, a high voltage generator). This dramatic image was created in 1899 through a double exposure, with the image of the huge bolts of electricity being photographed at a separate time from when the inventor was actually present.

long distances, and AC is used to this day to deliver energy to both homes and businesses.

At the time, however, Thomas Edison believed that his system, direct current (DC), in which the electrical charge flowed one-directionally, was the best for electrification. The problem with DC was that it was only good for relatively short distances, so the generation source had to be close to where the electricity was used. This disagreement on which system should be used to electrify the world led to a decade-plus-long competition between AC and DC, known as the "War of the Currents." The conflict wound down in the early 1900s, when electrical companies began incorporating AC into their operations.

Tesla licensed his early AC patents to George Westinghouse, which made him very wealthy for a short time. Later during an international financial crisis, Westinghouse begged Tesla for relief from the royalties—to which Tesla agreed. He tore up the royalty contract, walking away from millions of dollars in royalties that he was already owed and billions that would have accrued in the future.

Another significant development occurred in 1893, when Tesla was hired by the Niagara Falls Cataract Construction Company to consult on the development of the hydroelectric plant at Niagara Falls, the first large scale hydroelectric plant in the world. He advised the company that a two-phased system, available from Westinghouse Electric, would be the most reliable. Based on this information, Niagara Falls Cataract contracted with Westinghouse to build a two-phase AC system at the falls. Notably, the first customer of the Niagara Falls Power Company was the Pittsburg Reduction Company, which later became the Aluminum Company of America (Alcoa).

Tesla foresaw the need to shift from fossil fuels to renewable energy sources, including hydroelectricity and harnessing the sun's energy. In an article for *Cassier's Maga-*

zine,³ he wrote, “But we shall not satisfy ourselves simply with improving steam and explosive engines or inventing new batteries; we have something much better to work for, a greater task to fulfill. We have to evolve means for obtaining energy from stores which are forever inexhaustible, to perfect methods which do not imply consumption and waste of any material whatever.”

Views on Aluminum

Considering his accomplishments in the field of electricity, Tesla’s opinions on the subject of electrification deserve careful attention. Despite an appreciation for aluminum as a material, all of his electrical inventions—motors, coils, transformers, generators, etc.—were made using copper due to its availability and cost at the time.

To understand the price and availability difference between the two materials, compare the construction of the Washington Monument in 1885 and the Statue of Liberty in 1886. For the Washington Monument in Washington, DC, a 100-ounce aluminum cap was installed, which represented the largest aluminum casting in the world, with the price of aluminum being comparable to that of silver. By comparison, 200,000 lbs of copper were used to build the Statue of Liberty in New York Harbor.

Even if aluminum had been free in the 1880s, there just wasn’t enough of it to meet the needs of the growing electrical industry—and there wouldn’t be for decades. As a result, copper became known as the “Metal of Electrification,” not because it was the best electrical conductor, but because it was plentiful and inexpensive.

Nevertheless, Tesla recognized that aluminum was a better metal for conducting electricity, because it has twice the conductivity and weighs one third as much as copper. In an article published in *The Century Illustrated Monthly Magazine* in 1900,⁴ he predicted that aluminum would eventually completely replace copper for electrical applications. He highlighted the rapid growth of the aluminum industry, with the Hall-Héroult electrolytic process already significantly reducing the cost of the metal. “The absolutely unavoidable consequence of the advancement of the aluminum industry will be the annihilation of the copper industry,” explained Tesla. “Even now it is cheaper to convey an electric current through aluminum wires than through copper wires; aluminum castings cost less, and in many domestic and other uses copper has no chance of successfully competing. A further material reduction of the price of aluminum cannot but be fatal to copper.”

Tesla predicted that the copper industry would resist this change, and it did. From 1885 to 1945, copper held a 60-year monopoly in the electrical market—and breaking it was not an easy task. Aluminum smelters tried to sell metal to wire manufacturers without success. These wire producers were owned by large vertically integrated copper mining companies, and they didn’t want to make aluminum wire, as it would cannibalize their copper business. So, aluminum companies had to go into the wire fabricating business themselves to enable the use of aluminum for electrification.

A significant change to the market occurred in the 1940s during World War II when the U.S. and other countries began to scale up aluminum production for use in airplanes. When the war ended in 1945, aluminum finally became available in sufficient quantity and cost to be used for a wide variety of other applications, and the industry grew rapidly (Figure 3).

With that growth, aluminum is now more widely distributed in much greater quantities than copper worldwide. Three times more aluminum is produced than copper, and aluminum is sold for roughly one quarter of the price of

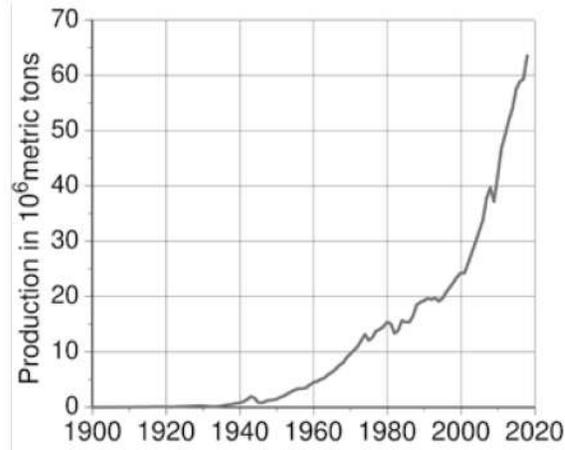


Figure 3. World production of aluminum, from 1900 to 2020. (Source: Leyo, Wikimedia Commons.)

copper. As Tesla predicted, electric utility companies welcomed the use of aluminum as the cost reduced. In a short period of time after WWII, the electrical utility industry completely converted its copper transmission lines to aluminum. Now, aluminum is the most widely used material for electricity transmission and distribution cables in the world.⁵ And aluminum is increasingly used in renewable energy applications.

One major challenge remains, in that all of the current electrical codes and standards, such as the 1914 International Annealed Copper Standard (IACS), are solely based on copper (because of the exclusive use of copper for the first 60 years of the electrical industry). Many of the existing electrical standards have not been modified to include the use of aluminum wire and cable. This is a huge oversight that needs to be addressed.

The fact that aluminum is of great value to the electrical industry is clear, as it represents a vital component in ensuring a more sustainable future. The amount of copper needed to electrify transportation and develop renewable energy sources is now projected to outstrip supply.¹ As a result, aluminum will increasingly be used to enable the global electrification of transportation and the transition from fossil fuels to renewable energy sources to meet goals for NetZero emissions by 2050. As aluminum continues to grow in electrical applications, the economics of Net Zero 2050 will also improve due to aluminum’s cost advantage over copper. Tesla’s predictions that aluminum would inevitably replace copper for electrification are certainly coming true.

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