# Lithium Batteries: How they Affect the World, and What Else we can Use

By Oscar Bossart, December 5, 2022

**Abstract**

Since its discovery and incorporation into batteries, the alkali metal lithium has played a crucial role in humans' technological advancements in the past century. The reactive metal has powered millions of devices that radically shorten the time it would take to perform complex tasks from calculating the solutions to difficult mathematics problems to analyzing statistics from all over the world. The production of lithium batteries has yielded various positive geopolitical and environmental impacts, such as the creation of new jobs in areas where lithium is mined and the reduction of greenhouse gas emissions. However, there are also negative impacts associated with this mining, including chemical leaks into rivers and groundwater and the destruction of natural habitats and human-made societies where the metal is extracted. Meanwhile, some cautious scientists have been looking for safe and efficient alternatives to the current practices of producing batteries. These alternatives mainly involve one or both of the following: developing more environmentally friendly lithium extraction methods, and replacing the metal used in batteries with a metal similar in structure to lithium. In this thesis, I aim to answer the following questions: Why have we become so interested in lithium as a material for batteries? What are the impacts that lithium battery production has on global environments? Lastly, what alternative extraction methods and battery materials can be substituted for what we use now to power our lives? The answers to these questions, as presented here, should increase our understanding of how lithium batteries and their production have changed our world, both for the better and for the worse.

## **Introduction**

First commercialized by the Sony Corporation in 1991, lithium-ion batteries have been used all over the world to power numerous electronic devices, including cell phones, laptop computers, solar-powered calculators, and electric cars (Placek). These batteries are rechargeable devices where lithium (Li) ions move from the positively charged anode to the negatively charged cathode when both powering a device and being charged. Many of lithium's natural chemical properties, including its high energy density and light weight, drove many consumers to batteries powered by the metal from previous batteries powered by nickel and other metals. Furthermore, lithium was safer, cost less, and could recharge quicker than materials used in older batteries. In addition, both improvements in harnessing lithium ions for use in batteries and lowering the costs of several distinct types of battery packs is expected to increase demand and widen the range of applications for lithium ion batteries.

The demand for lithium batteries has risen so much that between 2015 and 2020, the number of battery factories across the world that had either been constructed or were in development skyrocketed from four to one hundred and eighty-one (Placek). Since 2020, the global demand has also been projected to increase elevenfold in ten years' time. For these reasons and others, battery production capacity has been projected to increase tremendously, from nearly 300 gigawatt-hours of energy in 2018 to over two terawatt-hours (nearly seven times the 2018 amount) in 2028. In 2020, seventy-seven percent of these batteries were manufactured from China, where most of the world's largest battery factories were located that year. Although China will still produce the majority of lithium-ion batteries for quite some time, European battery factories aim to produce one quarter of the global lithium battery supply by 2025.

A report by GlobeNewswire states that many of the electric vehicles sold throughout the world, whether they are hybrid with gasoline or fully electric, aim to produce zero carbon emission when used to travel between two points. Also, in the United States, supportive federal policies to increase electric vehicle sales, such as the National Infrastructural Plan (NIP) and the huge abundance of companies that can easily market products powered by lithium are expected to drive the demand upwards.

Battery companies are working hard so that millions of devices can possess a long life cycle courtesy of lithium. The global sales for electric cars is projected to reach between 40 million and 70 million by the end of 2025 (Agustinada, et al.). Also, the demand for lithium batteries' storage capacity increased almost eightfold from 2008 to 2018, and in that same time period, the market demand increased to 3.3 times its original amount. The amount of lithium consumed in battery production has also increased significantly, jumping from 5,160 metric tons in 2007 to 19,780 metric tons (almost fourfold) in 2017 (Agustinada, et al.).

A recent market report provided by GlobeNewswire details the current state of the lithium battery market. In 2021, over forty percent of lithium-ion batteries were used as part of consumer electronic products. Also that year, one type of lithium battery, the lithium-cobalt battery, accounted for thirty percent of the products powered by Li batteries across the globe. Meanwhile, in Brazil, the government has taken various initiatives to support the flourishing electric vehicle market by exempting its annual car ownership and import taxes on electric vehicles, thus drawing in more customers from wider arrays of incomes.

However, there are several factors that could inhibit the exponential growth of lithium batteries' demand. The report by GlobeNewswire walks through some of these inhibiting factors. First, the thermal stability and load capability, or specific power, are also relatively low, potentially making those lithium batteries hazardous in certain environments. Second, the production of lithium batteries can pose various threats to the environment, which will be discussed later. Lastly, there exists a rising demand for substitutes to lithium ions in batteries, to be discussed near the end of this thesis.

As lithium has increasingly integrated itself into our daily lives, demand for the metal has skyrocketed in many areas all over the world, as stated previously. However, not every country in the world may have the same methods of extracting lithium and putting it into batteries. Many methods of extracting lithium are based on separating the lithium ions from water, including evaporation and chemical replacement. These methods have been widely criticized by environmentalists for drying out the geographical areas in which lithium is extracted, and thus driving out local inhabitants to seek more hospitable locations (Brigham). Many lithium extraction companies are working together to find an environmentally friendly solution to this problem. For example, in the Salton Sea in southern California, three companies, mainly Berkshire Hathaway, EnergySource, and Controlled Thermal Resources (CTR), are looking to extract lithium from the sea using new chemical processes to extract lithium from the drying sea.

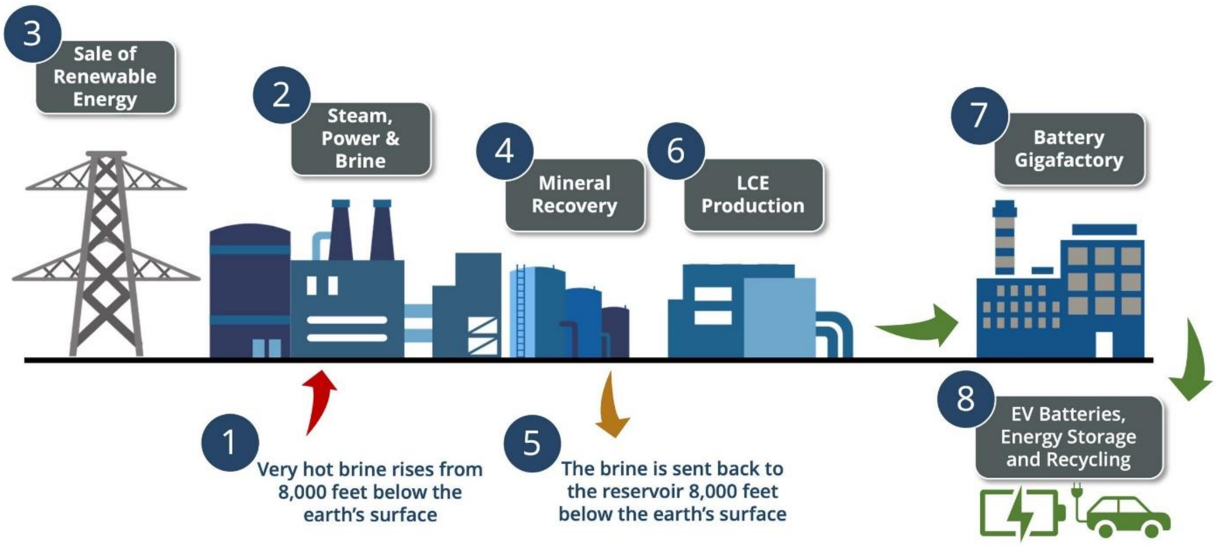


*Figure 1: A diagram depicting Controlled Thermal Resources' (CTR) strategy to harness lithium in an environmentally friendly way, courtesy of CTR. This strategy utilizes the natural rise of a brine containing lithium from a reservoir 8,000 feet below the surface of the earth. The hot brine is collected as steam in the renewable energy process, and lithium is recovered. After the purified brine is sent back to the reservoir to collect more lithium, the lithium is converted to a useable lithium carbonate equivalent (LCE) form and sent to a battery factory. There, the lithium is integrated into batteries and other electrical products.*

All three companies' methods for extracting lithium from the Salton Sea area utilize the same framework, illustrated in the above diagram. First, a brine solution containing lithium ions is recovered from nearby groundwater or the Salton Sea. Next, the brine is collected as a steam solution containing the lithium ions. The steam and ions are then split, with the steam being exported into renewable power and the ions undergoing further processing. Lastly, the processed lithium ions are converted into a solid form and are sent to a battery factory, where they are processed into batteries.

## History and Chemistry of Lithium Batteries

Two German scientists, named Johan August Arfwedson and Jöns Jakob Berzelius, were the first to discover the metal known as lithium by analyzing a sample of petalite ore in 1817 (Reddy). However, it was not until four years later during the electrolysis of a lithium oxide sample by William Thomas Brande and Humphry Davy that lithium was first isolated (Reddy).

Furthermore, the electrochemical properties of lithium were not explored until the twentieth century, where it was discovered to have a density of 0.534 grams per cubic centimeter, a specific capacity of 3860 milliAmp hours per gram, and an oxidation-reduction potential 3.04 volts less than the standard hydrogen electrode (SHE), giving lithium the highest oxidation potential of all the elements. With these properties, scientists almost immediately understood that the metal had immense potential as the anode of a battery. Later, in 1958, William Sidney Harris furthered the movement for lithium batteries by testing lithium's solubility in several non-aqueous electrolyte solutions (Reddy). Harris's findings included that in such environments, a special passivation layer forms that prevents lithium from reacting with the electrolyte, but still draws the lithium ions through it. This and other later studies proved that lithium batteries could be marketed as very stable for use in various devices, such as telegraphs, calculators, and early cell phones. Numerous types of lithium-ion batteries with several different cathodes have been commercially sold to the public for over fifty years, including non-aqueous 3-volt batteries with copper oxide cathodes.

The United States, until 1986, was the world leader in both extracting lithium and applying lithium to a usable form (Miatto, et al.). The States' lithium mining activity peaked in 1974, when approximately five gigagrams (five billion grams) were extracted from various locations throughout the country. Since that year, American lithium operations have been overtaken by increased mining activity in Australia, Zimbabwe, China, and Russia. American imports of lithium products have become critically important since America's last domestic lithium mine was closed in 1998. The United States has also not disclosed concrete information of their lithium production since 1955.

The global market for batteries using lithium aims to reach US$182.53 billion by 2030, according to a report by GlobeNewswire. This sharp market increase is due to numerous factors prevalent in the evolving world. One of these factors is the increase of electric vehicle sales in the United States and other parts of the world. Another is the increasingly high demand for lithium batteries to develop various consumer electronics used around the globe. Also, the use of electric vehicles will greatly reduce greenhouse gas emissions attributable to global warming.

Lithium has excellent chemical properties that make it the ideal choice for battery anode materials. It is the most highly reactive alkali metal found on the periodic table, meaning that it has one of the lowest electronegativity, electron affinity, and ionization energy values of all of the elements on the Periodic Table, thus increasing its willingness to give up an electron. It is additionally the most oxidizable element in the universe, which means that no element can easily give up an electron as lithium can.

One major battery design involving lithium is the lithium-cobalt battery. Like lithium, cobalt is a crucial element during electric vehicle battery development. A particularly large deposit of cobalt in Idaho has attracted several mining companies throughout the United States and the world (Stevenson and Fixler). The Victoria, Australia-based Jervois Global company formally started extracting the cobalt in the mine on October 14, 2022, and aims to become the world’s leading supplier of both cobalt and nickel for the purpose of battery development. Cobalt is also mined in the Democratic Republic of the Congo, but as observed by WIRED UK writer Amit Katwala, “unsafe and unethical” behaviors such as child labor are used to mine the metal in that country.

**The Geopolitical Aspects of the Lithium Battery Market**

As previously stated, the ever-growing range of applications for lithium batteries has caused the demand for them to skyrocket all over the world. This demand increases the need for lithium mining activity in several areas of the world. This includes the “lithium triangle” of South America, specifically arid territories of Bolivia, Chile, and Argentina where accessible and high-quality Lithium is largely concentrated (Agustinada, et al.). The salt lakes here contain approximately three quarters of the entire world’s supply of lithium for batteries and other possible uses. The European Commission states that increased mining activity from the lithium triangle and other sites to produce electric vehicles gradually reduces the need to use fossil fuels, as iterated previously. Our rapidly increasing use of lithium-based products has also rapidly increased global demand for electricity to charge and recharge those products. In some places, this electricity is powered by scarce raw materials subject to supply restrictions.

Several worldwide issues have impacted the global lithium market. Since 2018, the trade conflict between the United States and China has also played a role in the lithium battery market (Fajgelbaum and Khandelwal). In late September 2022, the Biden Administration noted that lithium-ion batteries exported from China are derived from child and forced labor in the Democratic Republic of the Congo, thus raising questions and concerns on workplace ethics at global lithium companies (Karim). Another conflict impacting the global push for lithium-powered devices is the ongoing war between Russia and Ukraine. Russia is one of the world’s leading suppliers of oil, and with the war driving a wedge of tension between Russia and the rest of the world, many countries are experiencing a huge spike in oil prices, especially those in Europe (Umar, et al.). Many European countries have relied on oil imports from Russia to power their vehicles. Without a major supplier of oil that they have depended on for years, Europeans may soon be forced to switch to electric-powered alternatives.


*Figure 2: A graph showing the impact of the outbreak of the Russia-Ukraine war on American oil prices in early 2022. Before the outbreak, oil prices tended to stay around $90 per barrel. Since the outbreak, it has fluctuated between about $95 per barrel and $125 per barrel (Appiah-Otoo).*

The United States has also seen a significant impact in their oil market, leaping from $84.50 in January to $123.60 in March (Appiah-Otoo). The American market has fluctuated since the initial jump, as seen on the above graph starting from the end of February. A recent study has suggested that countries impacted by the oil price hikes caused by the war should adopt policies that reduce local oil prices, such as transitioning towards renewable energy sources and the provision of government incentives. These policies will likely boost the electric vehicle market since electricity can be much more easily renewed through various means, such as solar and wind power.

Another recent and major impact on the lithium battery market is caused by both the Russia-Ukraine War and the COVID-19 pandemic. This reason is a major shortage of diesel fuel throughout the United States and the rest of the world. Diesel fuel is used to run the delivery trucks used to ship and deliver a wide variety of consumer products, including lithium batteries. The price of diesel fuel has increased by forty percent over the past year, thus limiting the trucks' ability to carry batteries and other products from factories to stores (Krauss). The diesel shortage is a direct impact of Russia closing off its oil supply from the rest of the world for the Ukraine War.

## **How Lithium Batteries Affect the Environment**

The use of lithium batteries over other fuel or power sources has several positive and negative effects to the environment around us. Of the positive benefits of using lithium batteries is that for every watt hour of lithium battery storage capacity, battery consumers reduce their greenhouse gas emissions by 110 grams (Agustinada, et al.). For the 11.3 million electric cars in use as of 2021, this equates to 1,243 metric tons of carbon dioxide per watt hour (Carlier). This is largely due to electric vehicles powered by lithium batteries eliminating the need for cars to consume hydrocarbon-based gasoline and thus create carbon monoxide and carbon dioxide exhaust. However, with this huge reduction in greenhouse gas emissions also come several significant environmental drawbacks regarding the production of lithium batteries. For example, in a case study, the annual carbon footprint of lithium battery production at a Chinese battery manufacturing company was 24,267.38 tons of carbon dioxide equivalent (Wang, et al.) Combined with the large amounts of carbon emissions from other sources, carbon gases are emitted at a rate that electric vehicles cannot slow down on their own. Slowing down carbon emissions will most likely require a full transition to electric vehicles for everyone and a more environmentally friendly way to produce the batteries.

Carbon emissions are not the only issue associated with the production of lithium. Lithium extraction has also caused harmful chemicals used to process extracted lithium into ions for battery cathodes, including hydrochloric acid (HCl), to leak into rivers in the Tibet region (Katwala). In Chile, near its part of the lithium triangle, locals are combating nearby mining companies, with evidence that lithium extraction has left not only the local landscapes "marred by mountains of discarded salt", but also canals "filled with contaminated water with an unnatural blue hue." The environmentalist group Friends of the Earth also has discovered that local lithium extraction harms the soil and causes air pollution. Furthermore, extracting lithium from the lithium triangle requires the use of nearly five hundred thousand gallons of water per metric ton of lithium extracted. 65% of the water from Chile's Salar de Atacama, the country's largest salt flat and the world's largest source of lithium, has been lost through this method of extraction. This method, which is the means for two thirds of lithium extraction performed in South America, has slowly dried out the land around mining sites (Flexer, et al.) (Izquierdo). Inhabitants of nearby villages have also had to flee their homes and ancestral settlements because much of the water they would use for maintaining a living environment is being extracted away (Agustinada, et al.).

Elsewhere, in Bolivia, described by journalist Thomas Cherico Wanger of the Society for Conservation Biology as the "Saudi Arabia of Lithium", lithium processors around the extraction sites often use polyvinyl chloride (PVC) barriers in their evaporation basins. These PVC barriers leak toxic chemicals such as softeners into important water and brine sources, resulting in several adverse effects, including severe reproductive and functional health problems in humans

(Wanger). Outside of human health problems, the PVC barriers allow toxic cyanobacteria to spread into the contaminated water, greatly reducing local biodiversity and potable water.

Recycling lithium is also an issue that has attracted controversy. In landfills in Australia, where only two percent of lithium-powered batteries and devices are recycled according to Amit Katwala's studies, "metals from [lithium and other] electrodes and ionic fluids from the electrolytes leak into the environment", polluting the water and air around the landfills. The lack of lithium recycling activity in Australia and other parts of the world is due to lithium's degradation over time, meaning lithium cathodes used in one battery cannot simply be reused for a newer battery. However, some efforts are underway at various battery manufacturing companies to repurpose old batteries from electric vehicles and other devices for other energy storage applications.

Some mines in the United States, and likely many other locations throughout the world, have also endangered local plant species. In September 2020, a cluster of Tiehm's buckwheat flowers in Nevada was allegedly "dug up and destroyed" by the Australian firm Ioneer Limited during a mining operation, although they initially denied any wrongdoing (Scheyder, March 2021). Projects where issues like this one arise could be slowed down or even stopped should the plant species in question be added to the United States' Endangered Species List. The Tiehm's buckwheat near Ioneer's mining site was permanently zoned off for protection in February 2022 (Scheyder, February 2022). Ioneer supported the government's decision and became confident that they could work together with the government through " a combination of avoidance, propagation and translocation", thereby achieving a successful coexistence of the endangered plants and their lithium mining project (Scheyder, October 2021).

**Alternatives to methods used today**

There are several ways that battery manufacturing companies can deviate from today's practices, regarding the geopolitical and environmental impacts of their production and use as well as the metal used to power devices. There are several unique electrode materials that could theoretically integrate themselves into the battery market, but none of them would perfectly match lithium's capabilities due to lithium being the most reactive metallic element that could be used.

One example of a replacement anode for lithium is sodium (Na). Sodium is cheaper than lithium, and the world's oceans, which are full of salt water, store a very plentiful supply of sodium ions that could one day be used in the production of battery electrodes (Braga, et al.). The volumetric capacity of rechargeable sodium cells is remarkably high, and batteries with them have a lengthy life cycle almost comparable to lithium batteries. However, when used as an anode, sodium exhibits unstable performance and limited capacities despite possessing a high theoretical capacity of 1165 milliamp hours per gram (Zhang, et al.). Sodium ions possess an unstable solid electrolyte interphase (SEI), and the sodium dendrite growth, which is when the metal cools and forms a branching structure during use, makes sodium battery anodes neither energy-efficient nor safe for practical applications.

A lithium-sulfur mixture is another cheap material that could be used for batteries (Carey and Lienert). Sulfur is incredibly cheap because of its abundance in fertilizers, insecticides, matches, and more. However, sulfur-based battery cells corrode too quickly for commercial use, and would have a higher introductory price than standard lithium. Both sodium and the lithium-sulfur mixture could even reduce China's dominance in battery manufacturing, ease global supply bottlenecks, and lead to electric vehicles integrating themselves into the mass market (Carey and Lienert).

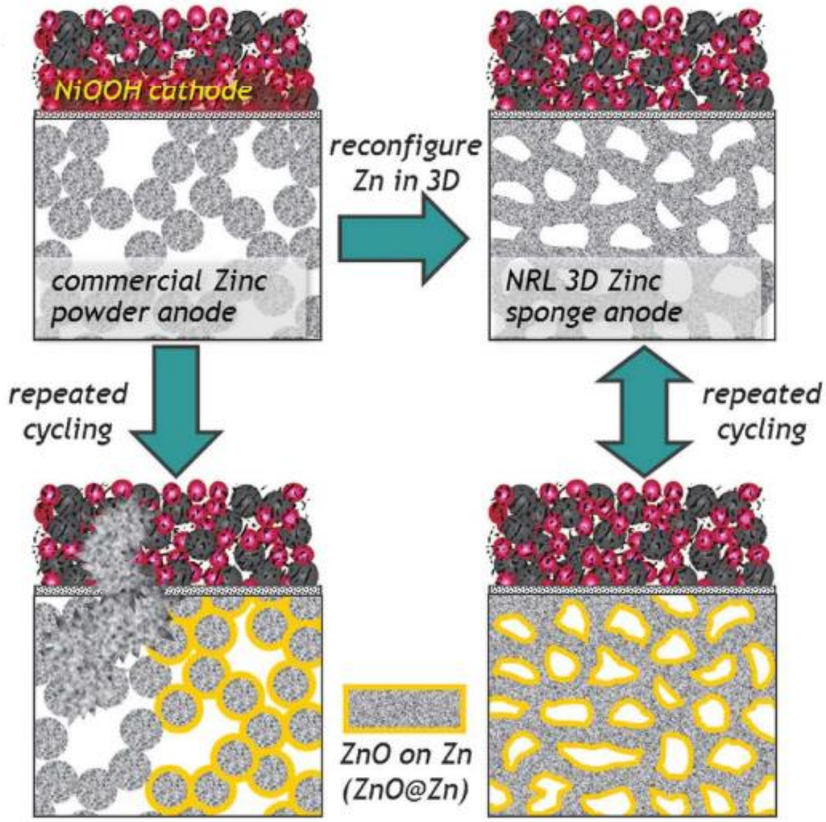


*Figure 3: Illustration of the effects of repeated use of two types of nickel-zinc batteries. Normally, the zinc powder anode gradually crosses a barrier into the nickel oxyhydroxide cathode with repeated use. However, if the zinc is reconfigured into a sponge-like form, all of the zinc particles stay on their own side of the barrier between the cathode and anode.*

Another pair of metals that can also be used as cheaper alternatives to lithium are nickel and zinc (Parker, et al.). Attempting to create a battery out of a pure zinc anode and a nickel oxyhydroxide (NiOOH) cathode poses the problem of the zinc molecules crossing over into the cathode. An aqueous battery cell containing nickel and zinc can last an exceptionally long time “without undergoing passivation or macroscale dendrite formation” (i. e. the metals do not attract to each other enough to form branches off of each other). This nickel-3D zinc-based battery type could soon aim to replace lithium-ion, lead-acid, and other nickel-metal batteries as the frontrunner of the modern battery market. Zinc is a good material for this type of battery because it is available all over the world and has low polarizability, meaning high specific capacity (the amount of electrical charge in milliamp hours per gram of material) and power. The zinc electrode in these batteries is a monolithic, aperiodic, and porous structure with an inner core of conductive zinc metal that persists through very deep levels of electrical discharge. In addition, nickel-3D zinc batteries not only have the same energy capacity as lithium-based electric vehicle batteries, but also a lighter weight, higher specific energy, and higher energy density than what modern electric vehicles use. Nickel-zinc batteries are not meant to have a complex structure compared to other batteries, and they also reduce the risk of fire from thermal runaway in battery anodes. These batteries are still in the early stages of development, but they could one day become part of the mass market.

**My Reflections**

I was genuinely amazed how far we have come with lithium-based power while authoring this thesis. I had known that lithium batteries are a rather novel invention, and I wasn't surprised when I read that they have only been a major consumer product for only thirty-one years. I had also known that lithium was an ideal metal for batteries from studying numerous chemical properties in previous chemistry classes.

Perhaps my biggest takeaway from authoring this thesis was the exact impact of lithium battery production on the environment. I had no idea that the production of lithium batteries still produces some carbon dioxide that could one day be outweighed by the amount saved using electric cars instead of gas-powered cars. I also learned that where the lithium is mined also matters in measuring its environmental footprint, as extraction in some places such as South America and the United States has damaged several local ecosystems and threatened endangered species.

When I read about the damage the lithium battery industry was doing to the environment, I knew that there would have to be scientists seeking to slow down these damages. I was fascinated with sodium's excellent similarities with lithium, but rather unwary as to what that could mean for our oceans if we were to produce sodium batteries in full scale. I was also fascinated that sulfur could work with lithium in a cheap battery that, with sodium, could shift China's dominance of the battery market. Lastly, I was intrigued to find out that with enough advancements in development, nickel-zinc batteries could work better than lithium batteries when used in our electric vehicles.

Despite the criticism lithium batteries may attract, I still believe that they will continue to advance our civilization for many years to come. Lithium-ion batteries have played a critical role in the recent development of human civilization, and our technology will improve alongside these batteries. Millions, if not billions, of electronic devices manufactured across the globe today have been made possible by lithium batteries. However, in order to move forward with the battery market, we would have to figure out different, more environmentally friendly ways to extract lithium for batteries and more alternatives to lithium like the nickel-zinc battery.

In this thesis, I aimed to answer three questions, and now, I have answers to all three of those questions. First, the world has become so interested in lithium as a material for batteries for a multitude of reasons, including its excellent electrochemical properties and the ongoing global push to reduce vehicles' greenhouse gas emissions. Second, the increasing demand for electronic devices has pressured mining companies to act posthaste and deliver enough lithium to advance the market, but the mining itself calls for greater amounts of electricity. Also, although the carbon footprint of electric vehicle users has decreased with the advent of lithium-based electric vehicle batteries, the means used to produce them have damaged the environment in numerous other ways, from water pollution to the near extinction of endangered plant species that make their habitat near the mining areas. Lastly, several potential alternatives to lithium have been proposed, and they all could one day surpass lithium as the leading battery materials. These materials are sodium, lithium-sulfur mixtures, and nickel-zinc mixtures. I hope these answers increased your understanding of how the production and use of lithium batteries have changed our world, both for the better and for the worse.

# **Works Cited**


Placek, Martin. "Lithium-ion Batteries - Statistics and Facts." *Statista*, 20 Apr. 2022, www.statista.com/topics/2049/lithium-ion-battery-industry.

"Global Lithium-ion Battery Markets Report 2022-2030: Increasing Government Funding in Grid Installations and Growing Consumption of Rechargeable Batteries in Consumer Electronics Driving Growth." *GlobeNewswire News Room*, 6 June 2022, www.globenewswire.com/en/news-release/2022/06/06/2456617/28124/en/Global-Lithium-ion-Battery-Markets-Report-2022-2030-Increasing-Government-Funding-In-Grid-Installations-Growing-Consumption-Of-Rechargeable-Batteries-In-Consumer-Electronics-Drivin.html.

Agusdinata, Datu, et al. "Socio-environmental Impacts of Lithium Mineral Extraction: Towards a Research Agenda." *IOP Science*, 27 Nov. 2018, iopscience.iop.org/article/10.1088/1748-9326/aae9b1/pdf.

Umar, Muhammad, et al. "Impact of Russian-Ukraine War on Clean Energy, Conventional Energy, and Metal Markets: Evidence From Event Study Approach." *ScienceDirect*, 18 Aug. 2022, www.sciencedirect.com/science/article/pii/S0301420722004093.

Appiah-Otoo, Isaac. "Russia–Ukraine War and US Oil Prices." *Energy RESEARCH LETTERS*, 15 Nov. 2022, https://erl.scholasticahq.com/article/37691-russia-ukraine-war-and-us-oil-prices.

Krauss, Clifford. "Price of Diesel, Which Powers the Economy, Is Still Climbing." *The New York Times*, 10 Nov. 2022, https://www.nytimes.com/2022/11/10/business/energy-environment/diesel-prices-inflation.html.

Brigham, Katie. “The Salton Sea Could Produce the World’s Greenest Lithium, if New Extraction Technologies Work.” *CNBC*, 4 May 2022, www.cnbc.com/2022/05/04/the-salton-sea-could-produce-the-worlds-greenest-lithium.html.

“Project.” *C Thermal*, www.cthermal.com/projects.

Reddy, Mogalahalli, V. “Brief History of Early Lithium-Battery Development.” *MDPI*, www.mdpi.com/1996-1944/13/8/1884/htm.

Miatto, Alessio, et al. “The Rise and Fall of American Lithium.” *ScienceDirect*, 27 June 2020, https://www.sciencedirect.com/science/article/pii/S0921344920303517.

Stevenson, Ian, and Kevin Fixler. “Cobalt Mining Excavations Return Amid Electric Vehicle Push. They’re Coming to Idaho.” *The Idaho Statesman*, 8 October 2022, www.msn.com/en-us/money/markets/cobalt-mining-excavations-return-amid-electric-vehicle-push-they-re-coming-to-idaho/ar-AA12I1FP?OCID=ansmsnnews11.

Katwala, Amit. “The Spiralling Environmental Cost of Our Lithium Battery Addiction.” *WIRED UK*, 5 Aug. 2018, www.wecanfigurethisout.org/ENERGY/Web_notes/Energy_Consumption/Greener_Cars_and_Trucks_Supporting_Files/Spiralling%20environmental%20cost%20of%20our%20lithium%20battery%20addiction%20-%20WIRED%20UK%20-%202018.pdf.

Fajgelbaum, Pablo, and Amit Khandelwal. “The Economic Impacts of the US-China Trade War.” *Annual Reviews*, Dec. 2021, www.nber.org/system/files/working_papers/w29315/w29315.pdf.

Karim, Naimul. “U.S. Says Chinese Lithium-ion Batteries Are Made With Child Labour as Trade War Spills Into EVs.” *Financialpost*, 17 Oct. 2022, financialpost.com/commodities/mining/china-lithium-ion-batteries-child-labour-us-trade-war.

Carlier, Mathilde. "Battery Electric Vehicles in Use Worldwide 2016-2021." *Statista*, 27 July 2022, www.statista.com/statistics/270603/worldwide-number-of-hybrid-and-electric-vehicles-since-2009.

Wang, Cong, et al. "Carbon Footprint Analysis of Lithium Ion Secondary Battery Industry: Two Case Studies From China." *ScienceDirect*, 11 Feb. 2016, www.sciencedirect.com/science/article/pii/S0959652616002341.

Flexer, Victoria, et al. "Lithium Recovery From Brines: A Vital Raw Material for Green Energies With a Potential Environmental Impact in Its Mining and Processing." *ScienceDirect*, 18 May 2018, www.sciencedirect.com/science/article/pii/S0048969718318746.

Izquierdo, Andrea Elisa. "Side Effects of Green Technologies: The Potential Environmental Costs of Lithium Mining on High Elevation Andean Wetlands in the Context of Climate Change." *Repositorio Institucional CONICET Digital*, 6 Feb. 2017, https://ri.conicet.gov.ar/handle/11336/12578.

Wanger, Thomas. "The Lithium Future—Resources, Recycling, and the Environment." *Society for Conservation Biology*, 23 Mar. 2011, conbio.onlinelibrary.wiley.com/doi/full/10.1111/j.1755-263X.2011.00166.x.

Scheyder, Ernest. "To Go Electric, America Needs More Mines. Can It Build Them?" *Reuters*, 2 Mar. 2021, www.reuters.com/article/us-usa-mining-insight/to-go-electric-america-needs-more-mines-can-it-build-them-idUSKCN2AT39Z.

Scheyder, Ernest. "Rare Flower to Get Protected Zone Near Ioneer's Nevada Lithium Mine." *Reuters*, 3 Feb. 2022, https://www.reuters.com/business/environment/us-regulators-preserve-acreage-near-ioneers-lithium-mine-site-2022-02-02/.

Scheyder, Ernest. "U.S. Advances Plan to Protect Nevada Flower Near Lithium Project." *Reuters*, 4 Oct. 2021, www.reuters.com/business/environment/us-advances-plan-protect-nevada-flower-near-lithium-project-2021-10-01.

Braga, M., et al. "Alternative Strategy for a Safe Rechargeable Battery." *Energy & Environmental Science (RSC Publishing)*, 18 Jan. 2017, pubs.rsc.org/en/content/articlelanding/2017/ee/c6ee02888h.

Zhang, Wenli, et al. "Sodium-Ion Battery Anodes: Status and Future Trends." *ScienceDirect*, 28 July 2019, https://www.sciencedirect.com/science/article/abs/pii/S2589778019300156.

Carey, Nick, and Paul Lienert. "EV Battery Makers Race to Develop Cheaper Cell Materials, Skirting China." *Reuters*, 15 Nov. 2022, www.reuters.com/business/autos-transportation/ev-battery-makers-race-develop-cheaper-cell-materials-skirting-china-2022-11-15.

Parker, Joseph, et al. "Rechargeable nickel–3D Zinc Batteries: An Energy-dense, Safer Alternative to Lithium-ion." *Science*, 28 Apr. 2017, web.archive.org/web/20190501093000id_/https:/science.sciencemag.org/content/sci/356/6336/415.full.pdf.