LITHIUM

By Gary Antonides

The Stanford University Report "World Lithium Supply," by Eric Eason, Nov. 30 2010, describes lithium, the third element in the periodic table, as a soft, highly reactive, silvery-white alkali metal, the lightest of all metals, with excellent heat and electrical conductivity. It is sometimes called "white petroleum."

Lithium has many industrial uses. It is used in the manufacture of glasses, ceramics, pharmaceuticals, and aluminum and magnesium alloys. But the highest potential for growth is in the battery market, where lithium is used as electrode and electrolyte material in both lithium disposable batteries and in lithium-ion rechargeable batteries. By 2009, the battery market had grown to 31% of global lithium consumption. In 2018, the International Energy Agency (IEA) predicted that by 2030, there would be nearly 125 million electric vehicles on the planet. That compares to 3.1 million electric vehicles in 2017. (http://large.stanford.edu/courses/2010/ph240/eason2/#:~:text=Instead%2C%20lithium%20is%20usually%20extracted,at%20the%20Atacama%20Salt%20Flat.)

In terms of energy, Cairn Energy Research Advisors estimates the lithium ion industry is expected to grow from 100 gigawatt hours (GWh) of annual production in 2017 to 800 GWhs in 2027—not only as a result of electric cars, but also of many other things, including mobile phones.

In terms of lithium production, by the year 2025, lithium demand is expected to increase to over five times 2019 levels. Auto manufacturers account for much of this. Volkswagen, by itself, plans to launch more than 70 electric car models in the next 10 years. Also, in 2015, China announced it was prioritizing electric vehicles as part of its five-year plan.

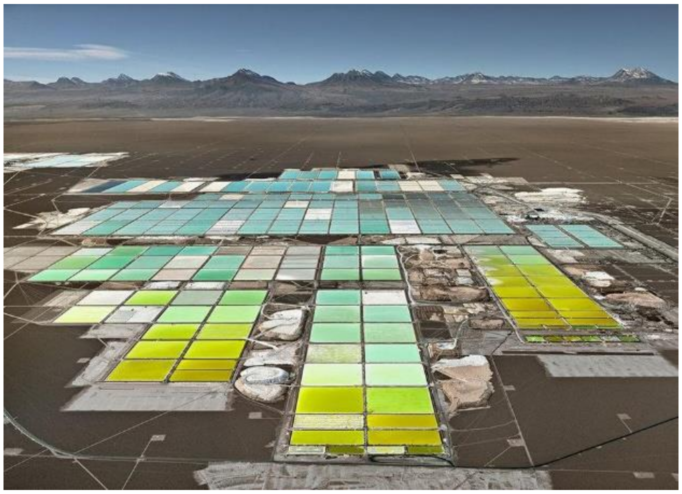
As a result of demand, over the period from 2016 to 2018, lithium prices more than doubled and are expected to keep increasing. Clearly, as the automotive industry begins to manufacture large numbers of hybrid electric vehicles and electric vehicles that use lithium batteries, we have to ask if there will be enough lithium.

Where Lithium Comes From

Lithium is never found in its elemental, metallic form because it is highly reactive, highly flammable, and will even react spontaneously with water. (This high reactivity is why some lithium-ion batteries ignite or explode when exposed to high temperatures.) Instead, lithium is usually extracted from lithium minerals that can be found in igneous rocks (chiefly spodumene) and from lithium chloride salts that can be found in brine pools.

Spodumene (lithium aluminum silicate) is used as a commercial source of lithium(U.S. Geological Survey)

As of 2015, most of the world's lithium production is in South America, where lithium-containing brine is extracted from underground pools and concentrated by solar evaporation. The largest producer of lithium in the world is Chile, which extracts it from brine at the Atacama Salt Flat. Argentina produces lithium from brine at the Hombre Muerto Salt Flat. There is also an enormous lithium deposit in Bolivia at the Uyuni Salt Flat (the world's largest salt flat, over 4,000 square miles), but this resource remains untapped for now due to political and economic reasons. The largest producer of lithium from spodumene is Australia, which has a large deposit near Perth. Other major lithium producers include China, which produces it at salt lakes, and the U.S., which produces it from brine in Nevada. Extracting lithium from brine is currently cheaper than mining it from spodumene, so there are many deposits of spodumene that are not now being mined.



Separation ponds at SQM Lithium mine, Atacama Desert, Chile.
OPEN COMMONS.

As of January 2010, the USGS estimated world total lithium reserves at 10.9 million tons (economically extractable now) and identified potentially economic lithium resources at 2.6 times that. Most of the identified resources are in Bolivia and Chile (35 and 29% respectively).

Some History

According to https://en.wikipedia.org/wiki/Lithium the production and use of lithium underwent several drastic changes over the years. The first major use of lithium was in high-temp lithium greases for aircraft engines and similar applications in World War II and shortly after. Lithium was also used in soaps. The small demand for lithium soaps and greases was satisfied by several small mining operations, mostly in the U.S.

The demand for lithium increased dramatically during the Cold War with the production of nuclear fusion weapons. The U.S. became the prime producer of lithium between the late 1950s and the mid-1980s. Lithium was used to decrease the melting temperature of glass and to improve the melting behavior of aluminum oxide and these two uses dominated the market until the middle of the 1990s.

After the end of the nuclear arms race, the demand for lithium decreased and the sale of Department of Energy stockpiles on the open market significantly reduced prices. In the mid-1990s, several companies started to extract lithium from brine which proved to be less expensive, and many of the mines closed, including the U.S. mines near Kings Mountain in N. Carolina.

The development of lithium ion batteries increased the demand for lithium and it became the dominant use in 2007. Brine extraction efforts were expanded to meet the demand. It has been argued that lithium will be one of the main objects of geopolitical competition in a world running on renewable energy and dependent on batteries.

Lithium in Car Batteries

The maximum realistic energy capacity for lithium-ion (rechargeable) batteries is about 4.6 kw-hours per pound of lithium. Lithium-ion electric vehicles have a large variation of battery capacities, but the Nissan Leaf, as an example, has a 24kw-h battery and it takes about 5.3 pounds of lithium to make it. If all of the world's economically extractable lithium were used to make Nissan Leafs. we could make 4.1 billion of them. If we assume a North American standard of living for everyone in the world (about 1 car for every 2 people), we would need about 3.4 billion Nissan Leafs. That seems unlikely. Perhaps if all the world's cars are going to be made electric, a mixture of battery technologies will have to be used.

Cars and trucks now account for nearly one-fifth of all carbon emissions in the U.S., according to the Union of Concerned Scientists. Fossil-fuel vehicles emit an average of 24 pounds of CO_2 and other hazardous gases for every gallon of gas used. With regard to emissions, electric cars are a significant improvement. Yet some regions of the world will suffer as we transition to electric cars. Mining for lithium is associated with serious environmental problems, as discussed later.

The article "Are Electric Vehicles Really Better For The Environment?," by James Ellsmoor, (https://www.forbes.com/sites/jamesellsmoor/2019/05/20/are-electric-vehicles-really-better-for-the-environment/#643d59b476d2), says that the country in which the batteries are being produced will have a large impact on emissions, even though EVs have considerably lower emissions over their lifetime than vehicles running on fossil fuels regardless of the source that generates the electricity

A range of rare earth metals make up the composition of the battery, and their extraction and manipulation contribute to carbon emissions. A 2018 International Council on Clean Transportation (ICTT) report illustrates that the country in which the batteries are produced has a large effect on emissions .

A comparative study between EVs and internal combustion engine vehicles (ICEVs) in China corroborates the ICTT report. Chinese EV battery manufacturers produce up to 60% more CO_2 during fabrication than ICEV engine production, and they could cut their emissions by up to 66% by adopting American or European manufacturing techniques. In most developed countries, the pollution created through the extraction process and production of batteries remains about the same as manufacturing ICEVs.

In its study, the ICTT also notes the stark difference in emissions between electric and internal combustion over the course of their lifetimes. With no tailpipe emissions, EVs produce essentially all of their emissions through their manufacturing process and the sourcing of their energy. Several studies show that an electric vehicle charged on an exclusively coal-powered grid would have similar lifetime carbon emissions as an ICEV. But, in 2019, only 23.5% of U.S. power came from coal (https://www.eia.gov/tools/faqs/faq.php?id=427&t=21). All other sources, including gas are much cleaner, making EVs markedly less polluting over their lifetimes.

ICEVs have been steadily reducing their emissions since 2000, but electric vehicles still have a marked edge, and, as EVs become more common, as the technology improves, as EV production is scaled up, as recycling increases, and as power sources get cleaner, EVs will greatly reduce emissions.

Energy Storage

As the world moves towards a low-carbon future, energy production, as well as transportation, desperately needs to reduce emissions, and developments in both electric vehicles and battery storage are rapidly changing both markets. Lithium is a key component in energy storage.

Large scale batteries as a storage option for renewable energy on main electricity grids was shown to be feasible when Elon Musk upgraded South Australia's energy grid. It took only sixty-three days for Tesla to build a 100MW lithium-ion battery, the largest in the world, capable of kicking in within a second as the backup power source. With renewable energy as the prime power source, this mega-battery kicks in if wind farms (or coal-powered plants) unexpectedly shut down. In December 2017, a major coal generator in the neighboring state of New South Wales tripped, and the batteries did indeed kick in within a second, avoiding a blackout.

This storage system has cut energy costs for consumers in South Australia, and, by buying and selling power during fluctuating demand, the Tesla battery generates revenue. Its success has led many utility companies to consider using large-scale batteries.

A 2015 study, http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/CONUSGridIntegration.pdf, by Stanford and USC Berkeley, shows how the U.S. could reach 100% of its energy demands through renewable energy. This would necessitate building infrastructure to store power (not necessarily batteries) which could be very costly. Many startups and investors are looking for a breakthrough in energy storage technology. One effort, Breakthrough Energy Ventures, is funded by several billionaires including Bill Gates, Jeff Bezos and Richard Branson, and aims to find solutions for a zero-carbon future with over $1 billion in investment.

Environmental Effects

The subject of lithium mining is discussed in the Jan. 2020 report https://www.zmescience.com/science/lithium-mining-098534/#:~:text=Mining%20starts%20by%20drilling%20a,in%20Salar%20de%20Uyuni%2C%20Bolivia, by Fermin Koop.

It says brine mining in salars (salt flats) is normally a very long process that can take from eight months to three years. After drilling a hole and pumping brine to the surface, they leave it to evaporate for months, creating a mix of manganese, potassium, borax, and salts. That mix is filtered and placed into another evaporation pool. It will take between 12 and 18 months for that mix to be filtered enough to extract the lithium carbonate, also known as white gold. It's cheap and effective, but it takes about 500,000 gallons of water per ton of lithium extracted. This creates a lot of pressure in nearby communities. For example, in Chile's Salar de Atacama, mining has caused the region to lose 65% of the region's water. This has impacted local farmers, who now need to get water from somewhere else.

Also, toxic chemicals can leak from the evaporation pools into ground water. This can include hydrochloric acid, which is used in the processing of lithium, as well as waste products that can filter out of the brine. In the area near Salar del Hombre Muerto in Argentina, residents complain that lithium polluted streams are used by humans and livestock. In Nevada, impacts on fish were found 150 miles downstream from a lithium processing operation.

Hexagonal formations on the surface of the Salar de Uyuni as a result of salt crystallization from evaporating water. Credit Wikimedia Commons

In the U.S., Canada, and Australia, lithium is usually extracted from rock with more traditional methods. This also requires the use of chemicals that can cause environmental problems. Friends of the Earth reported that extracting lithium can pollute the soil as well as cause air contamination.

https://www.forbes.com/sites/jamesellsmoor/2019/06/10/electric-vehicles-are-driving-demand-for-lithium-with-environmental-consequences/#1ab504d962e2, by James Ellsmoor, discusses how electric vehicles are driving demand for lithium and what the associated environmental consequences are.

The drawbacks of the mining industry itself have weighed heavily on the rise of batteries. Mining rare earth and heavy metals emits large amounts of emissions and has a noticeable impact on the environment. Although most lithium comes from brine extraction, some is from hard rock mining, which has more damaging environmental consequences. Getting these resources from brine rather than hard rock helps, along with new eco-friendly technologies that use less energy.

In order to manufacture batteries in a more environmentally friendly way, new alternatives, such as battery chemistries that replace cobalt and lithium with more common and less toxic materials are being investigated.

Recycling

There are also concerns around how to recycle lithium. Nonprofit Friends of the Earth notes that lithium recycling is difficult, because the metal is toxic, highly reactive, and flammable. It tends to be incinerated or end up in landfills. Low collection rates, and the high cost of recycling relative to primary production have contributed to the absence of lithium recycling. In Australia, research showed that only 2% of the country's 3,300 tons of lithium-ion waste was recycled. Unwanted electronics with batteries can end up in landfills and metals and ionic fluids can leak into underground water reservoirs.

The Birmingham Energy Institute in the U.K. is using robotics technology to look for ways to remove and dismantle potentially explosive lithium-ion cells from electric vehicles. There have been a number of fires at recycling plants where lithium-ion batteries were stored improperly.

Unfortunately, manufacturers are usually secretive regarding what actually goes into the batteries, which makes it difficult to recycle them properly. At present, recovered cells are mostly shredded, leading to a mixture of metals that can be separated using pyrometallurgical techniques (using high heat).

A Finite Resource

To create lithium batteries, there is a need for a range of rare earth metals that require heavy mining and manufacturing that emit significant emissions. Becoming more important is the fact that major components such as lithium, nickel, and cobalt exist in a finite amount that is unlikely to meet future demands for batteries.

Studies looking into the sustainability of electric vehicles point out that with the high demand for new electric vehicles, the auto industry will need to adopt economies of scale and more efficient and less polluting manufacturing processes. Certainly, as more batteries are created for these electric vehicles, a market for the recycling of these batteries will have to be created, thereby reducing the need for increased mining.