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Carbon Footprint of Lithium Mining and Refining Processes in Nevada

Introduction

As we are experiencing the effects of climate change and global warming today, there has been a lot of pressure to reduce our reliance on fossil fuels. However, fossil fuels surround us. They are used in the manufacturing of our phones, to power our cars, to produce the food we eat, to package the products we buy, and so much more. The ways that we produce, manufacture, and generate these necessities in our life have a heavy reliance on energy intensive extractions and manufacturing processes heavily relied on coal, oil, and natural gas, which emit CO₂ and other GHGs that have a greater global warming potential in our atmosphere. Around the world, we are seeing innovative approaches to combat our reliance on fossil fuels and transition our energy sources to more sustainable alternatives. Lithium has been associated with the sustainable energy transition and thus, its demand has increased dramatically due to the widespread success in electric vehicles and energy storage to harvest renewable energy. However, lithium is not the answer to all of our transportation and energy storage needs. It has a substantial impact on various natural environments such as groundwater and water resources, desert environments, and more. Nevada, known for its sources of lithium, is the focus of this study. The state has the largest operating lithium mine in the United States, Silver Peak in the Clayton Valley, producing 5,000 metric tons of lithium carbonate equivalent (LCE) annually (Gattie & Duncan, 2024). Nevada does not just encompass the mining extraction of lithium, but it is also home to lithium-ion battery manufacturing and recycling such as the Tesla-Panasonic Gigafactory near Sparks, Nevada (Jowitt et al., 2024).

Part 1-Background information

Historically, lithium has been extracted for the production of ceramic and glass, pharmaceuticals, and lubricating greases (Jowitt, 2024). In recent decades, cell phones and computers boomed, creating a slightly larger demand for lithium. However, these lithium batteries are much smaller than the lithium batteries for an EV or an energy storage battery. Now, lithium has been largely integrated into the renewable energy transition, with an emphasis in extraction and refining to power electric vehicles (EV's) and produce energy storage batteries. Lithium is seen as a suitable candidate in the energy transition mainly due to its relatively high energy density, its lightweight property, and the ability to be found in many areas around the earth. Globally, lithium production is increasing. In 2024, Australia holds the largest production capacity of lithium, with Chile and China following. In the United States, Nevada holds the largest lithium production capacity, in Silver Peak, with plans and agreements to expand lithium extraction to Thacker Pass. Thacker Pass has the potential to produce 449 million EV's if all resources and reserves were extracted (Jowitt et al., 2024).

Lithium accumulates in closed, sedimentary basins in extremely salty groundwater. When water flows in from mountain-front recharge, it can only exit by evaporation, allowing the concentration and accumulation of lithium and other minerals. In other words, the water does not reach the Atlantic or Pacific ocean from a river, it is trapped within the enclosed basin. In Nevada, specifically at the Silver Peak mine in Clayton Valley, lithium is extracted from salar or continental brine deposits from wells in a closed sedimentary basin, distributed out over large pools, and concentrated lithium brine as well as other elements such as magnesium and boron are the end product once the water has evaporated (Salazar, 2021). The concentrated lithium brine then is pumped to a recovery or treatment plant to remove the excess elements and is chemically treated with sodium carbonate to produce lithium carbonate (Flexer et al., 2018). To obtain the

desired form, the lithium carbonate is often redissolved and precipitated to reach the needed battery grade (Flexer et al., 2018). This process evaporates an average of 500,000 litres of brine per ton of lithium carbonate, making this very chemical intensive, incredibly slow, and location specific (Flexer et al., 2018).

Part 2-Benefits, Drawbacks, and Applications of Lithium in Today's World

Although there are many concerns with the extraction of lithium, the refining processes, and the manufacturing of batteries for a variety of transportation and industrial uses, there are many advantages that lithium provides. The transportation sector alone is responsible for 27% of global energy demand, and thus, contributes to a variety of GHG emitted, such as CO₂, CH₄, CO, N₂O, and chlorofluorocarbons (Albatayneh et al., 2020). These GHG have a large global warming potential (GWP), as nitrous oxide is 265 times stronger than CO₂. Thus, the release of these GHGs are contributing to the rise in global warming and driving climate change. There is motivation to combat these emissions through lithium-ion batteries for cars, trucks, buses, motorcycles, etc. The electrification of the transportation sector has been proved to be very efficient. Lithium-ion batteries used in electric vehicles, the efficiency is much higher than a standard combustion engine. The efficiency of an internal combustion engine vehicle of gasoline ranges from 11-27% and diesel ranges from 25-37%. On the other hand, the efficiency of an electric vehicle charged by a natural gas power plant is 13-31% and the efficiency charged by renewable energy ranges from 40-70% (Albatayneh et al., 2020). Due to Newton's second law of motion and fundamental energy analysis, aerodynamic drag reduction is the main energy saving factor in electric vehicles (Han et al., 2019). It is achieved at low and steady speeds, in which the reduced braking saves the wheel energy and can have the potential for even greater energy efficiency when speed limits and varying road grade are known prior to breaking (Han et al.,

2019). Additionally, the power within an EV is transferred to wheels through a single, simple channel and thus, reduces the mechanical losses of energy (Poornesh, 2020).

Since many renewable energy alternatives such as solar or wind energy are very inconsistent, a battery is needed to store the energy when energy is not being produced from a solar panel or a wind turbine. The storage of electrochemical energy in the form of a lithium-ion battery is capable of storing energy with an efficiency of up to 95% (Bresser, 2020). In addition to the high efficiency of an electric vehicle, lithium-ion batteries for energy storage are also very efficient, allowing for the growth of renewable energy.

While the emissions of an electric vehicle are very minimal when it is being driven, the manufacturing and waste management of lithium poses a major disadvantage to the so-called sustainable alternative to transportation and energy storage. For example, the manufacturing impact, which includes the mining and refining of lithium for an electric vehicle, is much higher than the manufacturing impact of an internal combustion engine vehicle by about 80% (Del Pero et al., 2018). Specifically, the processing methods of concentrated lithium brine to lithium carbonate emits between 17-81 kgCO₂eq/kg of lithium carbonate, based on the process (Nikfar et al., 2024). Thus, the carbon footprint of the mining, processing/refining, and manufacturing of an electric vehicle is substantial as the energy required for the process is heavily dependent on fossil fuels.

Lastly, a major problem with the widespread production of lithium-ion batteries is the lack of efficient waste management. The global rate of lithium recycling is less than 1%, dismantling the motivation to a circular economy (Swain, 2017). When lithium batteries are no longer useful, they are dumped in landfills, which can spontaneously ignite or release hazardous chemicals in the landfill, causing pollution in the soil and water supply (Winslow et al., 2018).

Part 3-Environmental and Ecological Impacts

The environmental impacts of the mining and refining/processing of lithium for the production of electric vehicles and energy storage batteries are sufficient. First, Nevada is a hypo-arid region which in turn, already suffers from limited water availability due to small precipitation rates and high evaporation rates. Additionally, there is large agricultural activity, which also requires large amounts of water. The high consumption of water and competition for water resources between these uses imposes significant threats to the groundwater resources.

Additionally, the carbon footprint and the release of anthropogenic GHGs into the atmosphere alter the natural environment and contribute to climate change. When processing concentrated lithium brine to lithium carbonate, there are different processes that can separate the brine consisting of various elements and the lithium. Solvent extraction, adsorption, nanofiltration, and membrane electrolysis are some of the ways that processing/refining is being done in Nevada as well as some other locations in the United States. However, these processes emit carbon dioxide during the process. Solvent extraction emits 52.7 kg CO₂eq/kg of lithium carbonate, adsorption emits 47.9 kg CO₂eq/kg of lithium carbonate, nanofiltration emits 17.7 kg CO₂eq/kg of lithium carbonate, and membrane electrolysis emits 80.57 kg CO₂eq/kg of lithium carbonate (Nikfar et al., 2024). This may be due to the use of propane and diesel in the process facilities in Nevada. The propane is used for heating and drying in the process facility through a 800 horsepower (hp) Donlee boiler, a 150 Johnston boiler, and a carbonate rotary dryer (srk consulting, 2023). A 15,000-gallon diesel storage tank is used to fuel a decommissioned boiler and a 10,000-gallon storage tank located in the playa portion of the mine (srk consulting, 2023). The diesel is used to power fuel equipment and vehicles on-site (srk consulting, 2023).

Lastly, the mining and processing of lithium in Nevada has substantial impacts on the surrounding ecosystem, impacting the abundance and distribution of organisms. This is mainly due to land use. To obtain a substantial amount of lithium, large amounts of water are required to be pumped, making the evaporation ponds very large at around 4,000 acres. When the water is distributed over the evaporation ponds, leakage can occur, polluting the freshwater groundwater underneath. When the soil and vegetation are disturbed by the pumping and the evaporation ponds on the surface, plants and soil biota may be directly killed due to land disturbance, as well as the organisms that rely on the fresh groundwater (Parker et al., 2024).

Part 4-Solutions?

A significant disadvantage to lithium-ion batteries is the lack of waste management. When lithium batteries are no longer useful, they are dumped into landfills, without proper waste management. This can lead to the release of contaminated leachate into the groundwater underneath, leading to highly contaminated water (Winslow et al., 2018). A potential solution to this is to manage lithium-ion batteries as hazardous waste, instead of a general solid waste (Winslow et al., 2018). This could decrease the potential for the materials to ignite or cause other damages, resulting in the release of GHGs.

Another possible solution to the GHG emitted in the processing/refining of concentrated lithium brine to lithium carbonate is the investment in renewable energy to perform the process, instead of the cheaper, unsustainable use of diesel and propane. This can significantly reduce the amount of CO₂ released into the atmosphere during this stage of the process. Additionally, when lithium-ion batteries are charged with natural gas or diesel, their efficiency lowers. When the batteries are charged with renewable energy, their efficiency increases significantly. Tesla, as

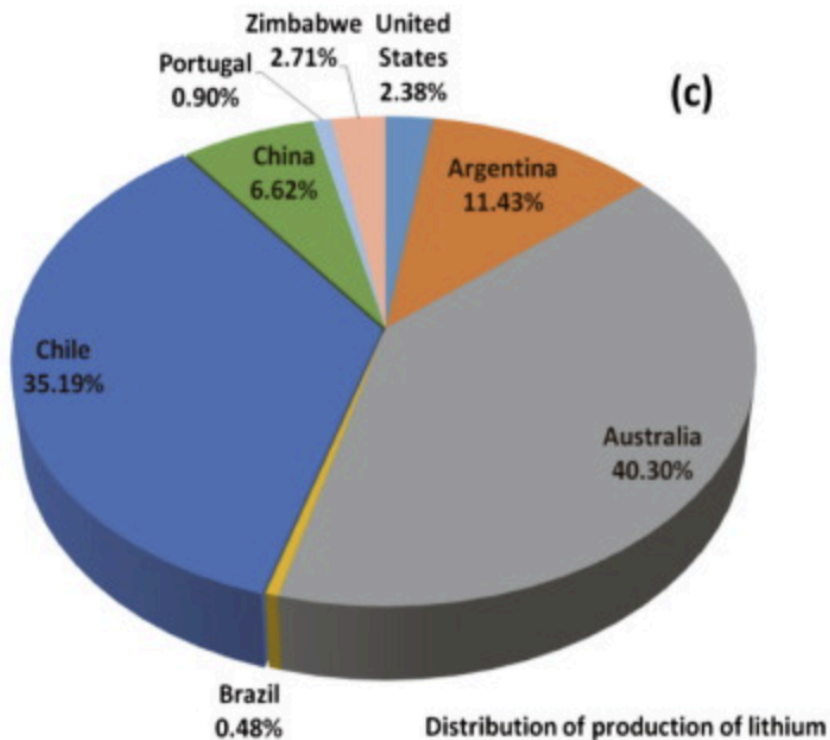
well as other car manufacturers who are producing hybrid and electric vehicles need to invest in renewable energy to optimize the energy efficiency of their vehicles.

Conclusion

In conclusion, although lithium is seen as the answer to many of our climate issues, its extraction, refining, and disposal release substantial amounts of CO₂ and other greenhouse gases into the atmosphere. The carbon footprint of lithium battery technology is currently about 70 kg CO₂ per kWh (Diouf & Pode, 2015). Additionally, these processes impose significant threats to groundwater resources and their availability in already water depleted regions. Lastly, the lack of efficient waste management further exacerbates these environmental issues. However, as the price of renewables such as solar and wind start to decrease, there is hope to invest in these renewable energy sources to power the manufacturing and refining/processing of lithium. The successful integration of lithium in the energy transition hinges on our ability to evaluate all of the potential impacts to the surrounding environment, and implement ways that these impacts can be minimized to preserve the natural resources, ecosystems, and the surrounding communities.

Images

1. Image One:



Caption: The production of lithium on a global scale. Australia remains the country with the highest production at 40.30% and Chile follows at 35.19%.

Source: [#4 on sources list]

Swain, Basudev. "Recovery and Recycling of Lithium: A Review." *Separation and Purification Technology*, vol. 172, Jan. 2017, pp. 388–403,
<https://doi.org/10.1016/j.seppur.2016.08.031>. Accessed 27 Feb. 2020.

2. Image Two:

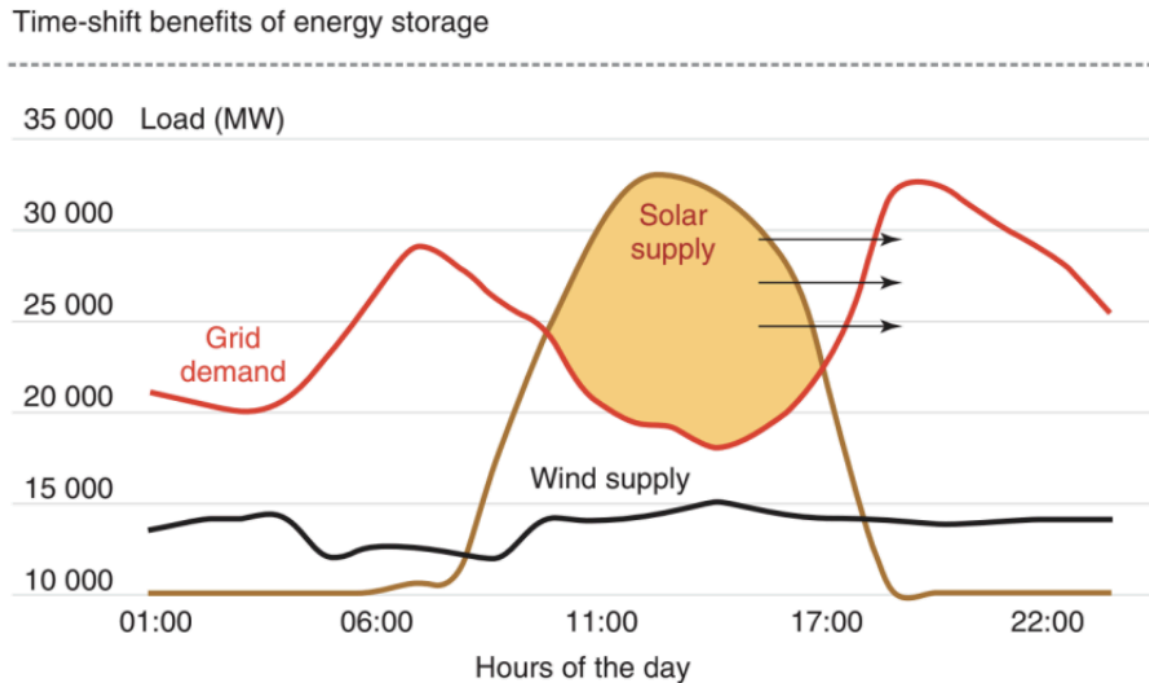


Caption: Typical hypo-arid region of the Clayton Valley while also showing the Silver Peak lithium evaporation ponds.

Source: [#2 on sources list]

Jowitt, S.M., Henry, C.D., Crespo Mena, J., Lindsey, C.R., Darin, M.H., Saftner, D.M., Heintz, K.M., and Hershey, R.L., 2024, Lithium in Nevada—origins, extent, role in the energy transition, and implications for economic development and national security: Nevada Bureau of Mines and Geology Special Publication 40, 48 p.

3. Image Three:

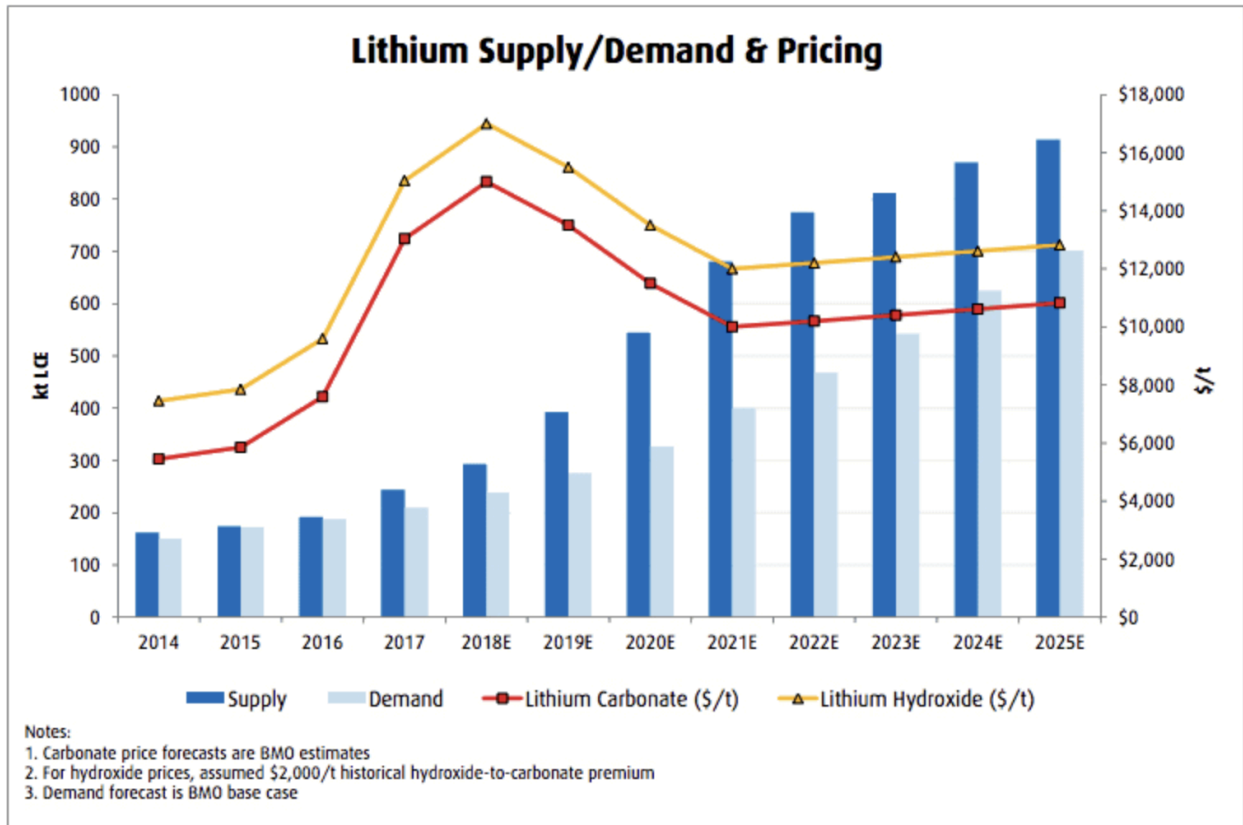


Caption: Variation in the energy supply of renewables and the grid demand throughout the day. Solar supplies the most mid-day, peaking at around 33,000 MW while wind stays fairly steady, peaking at 15,000 MW.

Source: [#1 on sources list]

Bresser, Dominic et al. *Batteries Present and Future Energy Storage Challenges*. Newark, John Wiley & Sons, Incorporated, 2020.

4. Image 4



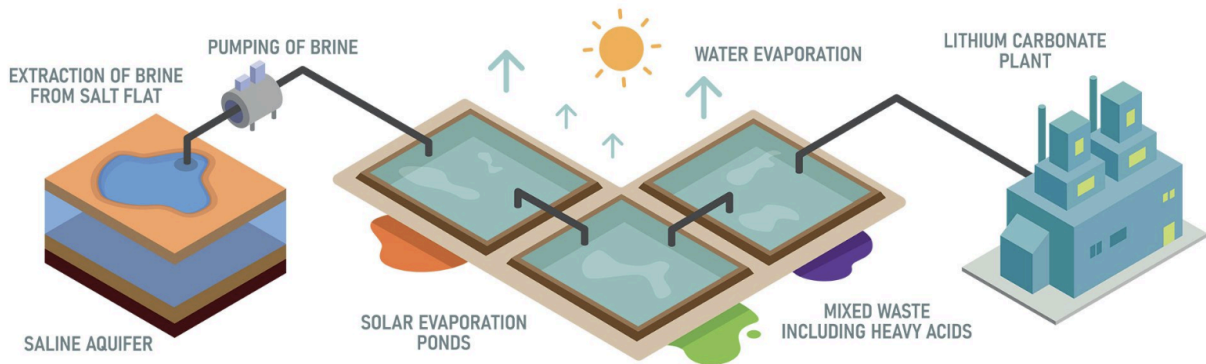
Caption: Lithium supply and demand is increasing as we are discovering more locations to extract lithium and the demand for electric vehicles and energy storage is increasing.

Source: [#3 on sources list]

“Lithium Demand from Battery Makers to Almost Double by 2027.” *MINING.COM*, 25

June 2018, www.mining.com/lithium-demand-battery-makers-almost-double-2027/.

5. Image 5:



Caption: The extraction/mining process as well as the refining/processing process associated with lithium recovery. This process is energy intensive, water intensive, and geologically specific.

Source: [#5 on sources list]

Traviss, Megan. "Ion-Targeting Direct Extraction Technology for Commercial Lithium Extraction." *Innovation News Network*, 28 June 2023, www.innovationnewsnetwork.com/ion-targeting-direct-extraction-technology-commercial-lithium-extraction/32979/.

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