Utilizing Plants to Control Emissions and Other Detrimental Effects of Lithium Mining

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Abstract:

As the world works toward a sustainable, low-carbon future, there is a growing range of technological innovations expediting the transition away from conventional power sources (like fossil fuels). Transportation and energy are the two highest emission producing sectors in Canada. Advancements in electric vehicles and batteries have radically changed both industries. The lithium ion battery is one of these advancements which has changed the automotive industry greatly in the past few years.

Li-ion batteries can be recharged hundreds of times and are more stable. They tend to have a higher energy density, voltage capacity and lower self-discharge rate than other rechargeable batteries. This makes for better power efficiency as a single cell has longer charge retention than other battery types. Demand for lithium is increasing exponentially, and it doubled in price between 2016 and 2018. By 2025, lithium demand is expected to increase to approximately 1.3 million metric tons. But as the demand for lithium increases, the environment and ecosystems in and surrounding lithium mines around the world are beginning to pay the price. This project focuses on utilizing vegetation to control and prevent many detrimental effects of lithium mining including emissions.

Background:

Lithium is a highly reactive alkali metal that is conductive of heat and electricity. These properties make it extremely useful for the manufacturing of glass, high-temperature lubricants, chemicals, pharmaceuticals, and lithium ion batteries for electric cars and consumer electronics. Lithium, like all alkali metals, cannot be found in nature. Instead it is found as a constituent of salts or other compounds.

Lithium Extraction:

Lithium available in the market can usually be found as lithium carbonate, the raw material which is also used in batteries. Lithium compounds and salts are usually found in underground deposits of clay, mineral ore and brine, as well as in geothermal water and seawater.

Briny lakes, also known as salars, have the highest concentration of lithium, ranging from 1,000 to 3,000 ppm (parts per million). Brine mining in salars is a time-taking albeit effective and cheap process. Mining begins by drilling a hole and pumping brine to the surface. This brine is left to naturally evaporate, first creating a mix of manganese, potassium, borax, and salts which is filtered and placed into another evaporation pool. In total, the filtration process takes between 12 and 18 months to be able to extract lithium carbonate. This process, although effective, requires a lot of water, approximately 500,000 gallons per metric ton of lithium and can only be done in areas with high evaporation rates.

Lithium is found in more than 145 different minerals, but it is extracted only from 5 of them: spodumene ($Li_2O{\cdot}Al_2O_3{\cdot}4SiO_2$), lepidolite ($KLi_2Al(Al{,}Si)_3O_{10}(F{,}OH)_2$), petalite ($LiAlSi_4O_{10}$), amblygonite ($(Li{,}Na)AlPO_4(F{,}OH)$), and eucryptite ($LiAlSiO_4$). Among those, spodumene is the most abundant lithium ore. The naturally occurring mineral contains 8% pure lithium oxide (Li_2O), but commercial ores usually contain only 1–3%. Spodumene concentrate is used to produce lithium carbonate (Li_2CO_3) as well as lithium metal.

Uses of Lithium:

Lithium extractions from brine and spodumene are in the form of lithium carbonate (Li_2CO_3), which can be directly used or processed further. Spodumene and lithium carbonate (Li_3CO_3) are commonly used to lower boiling points and increase resistance to thermal expansion in ceramic and glass applications. Lithium carbonate (Li_2CO_3) can be processed to lithium hydroxide (LiOH) and lithium chloride (LiCl). Lithium hydroxide (LiOH) is used to produce inorganic compounds for absorption of CO_2 or can be further processed to lithium phosphate (Li_3PO_4), lithium hypochlorite (LiOCl), lithium oxide (Li_2O), peroxide (Li_2O_2), among others to be used as catalysts, for sanitation purposes, and photographic developer solutions. Lithium chloride (LiCl) is often used as electrolyte in batteries or further processed to make lithium metal for lead and magnesium alloys, lithium hydride (LiH) for high-purity silane, and lithium nitride (Li3N) to be utilized as a catalyst.

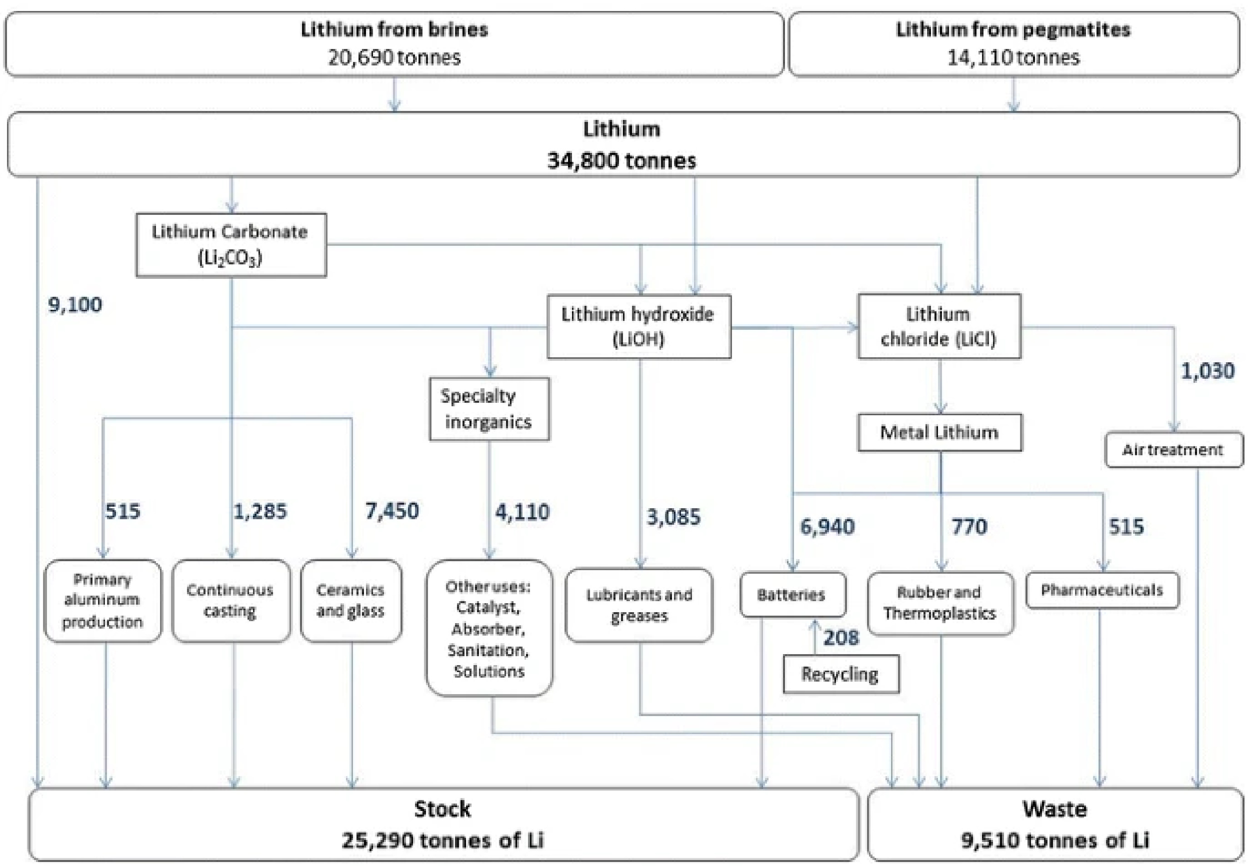

Figure 1: the main applications of lithium-containing chemicals and the quantities used in each application accounted in tonnes of lithium from 2011.

As illustrated in figure 1, nearly 75% of lithium is added to the stock as aluminum, casting, glass and ceramics, and batteries. Based on the lifetime of these products the lithium can eventually be recovered and reused at some point in the future. In lithium batteries, for example, which can have a lifetime between 2 and 10 years, the lithium could be recycled, kept as a product forever, or be disposed of as waste. The remaining 25% of lithium is in one use products like lubricants, greases, rubber, and pharmaceuticals which are assumed to be waste. Of the 180,000 metric tons of Li-ion batteries available for recycling worldwide in 2019, just a little over half were recycled. This is simply not enough - Lithium is a finite resource, and one that we are rapidly burning through.

Li-ion Batteries and Lithium Supply in Upcoming Years:

Right now, and every day all day, li-ion batteries power billions of devices: bluetooth earbuds, cameras, laptops, and e-scooters—anything wireless. But all of the world's gadgets are minuscule compared to the battery power that 3500-5000 lb electric vehicles (EVs) will consume.

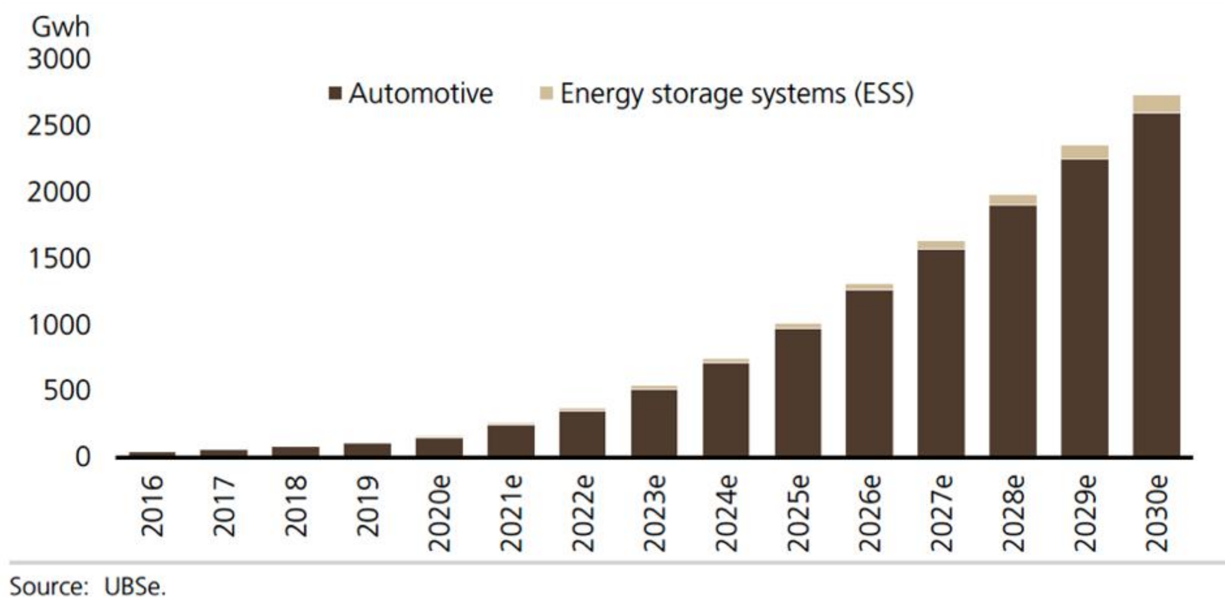

Figure 2: A graph estimating the demand of li-ion batteries in the coming years.

By 2030, EVs will require an estimated 2,700 GWh worth of lithium-ion batteries a year. That is the equivalent of 225 billion iPhone 11 batteries—and nearly 13 times more battery power than we use today.

Detrimental Effects of Lithium Extraction and Use:

South America's Lithium Triangle, which covers parts of Argentina, Bolivia and Chile, holds more than half the world's supply of the metal beneath its salt flats. In the Salar de Atacama located in Chile, mining activities constitute 65% of the area's water use. In a region where annual rainfall is less than 15 millimetres per year, the activity depletes already scarce water resources that local communities and species depend on. 500,000 gallons of water (the amount of water required for extraction per metric ton of lithium) can support 3,500 people for one year.

Lithium mining has also been linked as the cause of several environmental catastrophes in and around the Liqi River in Tibet in 2016, where hydrochloric acid, a chemical used in the extraction process contaminated the water and resulted in thousands of dead fish. Cow and yak carcasses were found floating downstream, dead from drinking contaminated water. This was the third incident in seven years due to a sharp increase in mining activity, including operations run by China's BYD, one of the world's largest suppliers of li-ion batteries. After the second incident in 2013, officials closed the mine, but fish started dying again when the mines reopened in April 2016.

Hydrochloric acid increases the acidity of water in an area, resulting in a drop in pH levels. Most freshwater lakes, streams, and ponds have a natural pH in the range of 6 to 8. When the pH level is lower than 5, fish populations begin to disappear. Below a pH of 4.5, the water is essentially devoid of fish. Also hydrochloric acid runoff from lithium mining areas can cause aluminum ions attached to minerals to be released into bodies of water. This asphyxiates fish by clogging their gills. It can also cause chronic stress that may not kill individual fish, but leads to lower body weight and smaller size and makes fish less able to compete for food and habitat.

The unknown effect though, is the hidden cost of emissions from lithium mining, as well as li-ion battery and EV production. The GHG (greenhouse gas) emissions which in a review by Romare and Dahlöf were reported as a range between the 70kg and 110kg CO_2e/kWh for cell production while material production, including mining, conversion and refining, is between 60kg and 70kg CO_2e/kWh. All major car companies have “green” plans for electric vehicles to cut greenhouse gas emissions, yet their manufacturers are making li-ion batteries in places with some of the most polluting grids in the world. In order to build each car battery—weighing upwards of 500 kilograms (1,100 pounds) in size for sport-utility vehicles—would emit up to 74% more C02 than producing an efficient conventional car if it's made in a factory powered by fossil fuels in a place like Germany, according to the findings of Munich-based automotive consultancy, Berylls Strategy Advisors. As many nations around the world like China, France and the U.K. move toward bans on combustion engines, there are limited regulations surrounding acceptable carbon emissions produced by EV manufacturers.

General Objective:

The objective of this project is to find and discuss methods of combating various detrimental effects of lithium extraction and use. As the demand for lithium increases, especially during this EV revolution, it is crucial that we understand the negative impacts of these technologies and create solutions to prevent environmental pressure on our already declining climate and ecosystems.

Specific Objectives:

This project focuses on specifically utilizing vegetation to control and prevent damage from emissions and runoff in ecosystems surrounding extraction mines. This project focuses on CO_2 sequestration of various tree species and genuses, and their ability to prevent/slow down runoff and grow in various ecosystems around the world surrounding mines.

Methodology:

Calculating CO_2 Sequestration:

A key "feature" of trees is that they sequester carbon – the process of removal and long-term storage of carbon dioxide (CO2) from our atmosphere. The rate of sequestration depends on the growth characteristics of the tree species, the density of its wood, the location's conditions for growth, and the plant stage of the tree. However, there are ways to estimate the carbon sequestration of a tree, one of which is explained below.

1. Determine the total green weight of the tree:

The green weight of a tree is its weight when alive. Calculate the weight of the tree above ground in pounds as follows:

$W_{above\text{-}ground}$= 0.25 D^2H (for trees with $D<11$)

$W_{above\text{-}ground}$= 0.15 D^2H (for trees with $D>11$)

In which D represents the diameter of the trunk in inches and H represents the height of the tree in feet. On average, the root system weight is about 20% the above ground weight so to find the green weight, multiply $W_{above\text{-}ground}$ by 1.2.

2. Determine the dry weight of the tree:

The average tree is 72.5% dry matter and 27.5% moisture so the dry weight is 72.5% of the total green weight.

$W_{dry\ weight} = W_{above\text{-}ground} * 0.725$

3. Determine the weight of carbon in the tree:

The average carbon content is 50% of the dry weight on average.

$W_{carbon} = W_{dry\ weight} * 0.5$

4. Determine the weight of carbon dioxide sequestered in the tree:

CO_2 is made up of two oxygen atoms and one carbon atom. The atomic weight of carbon is 12 (u) and the atomic weight of oxygen is 16 (u). Therefore, the ratio of carbon to carbon dioxide (12:44) determines the amount of CO_2 sequestered. Now to determine the weight of CO_2 sequestered, multiply the carbon weight by 3.67.

$W_{CO2} = W_{carbon} * 3.67$

Results:

CO_2 Sequestration:

Types of Trees	Diameter in Inches (Average)	Height in Feet (Average)	Green Weight In Pounds	Dry Weight In Pounds	Carbon Weight In Pounds	CO_2 Sequestration (pounds sequestered in 10 years)
Maple	13	80	4867.2	3528.72	1764.36	6475.2012
Oak	20	65	9360	6786	3393	12452.31
Sycamore	14	130	9172.8	6650.28	3325.14	12203.2638
Pine	12	100	5184	3758.4	1879.2	6896.664
Fir	17	120	12484.8	9051.48	4525.74	16609.4658
Elm	22	70	12196.8	8842.68	4421.34	16226.3178
Birch	17	80	8323.2	6034.32	3017.16	11072.9772
Cedar	15	120	9720	7047	3523.5	12931.245

Feasibility of Tree Types Based on Average Water Consumption, Temperature Range, and Soil Acidity

Type of Tree	Water (Average)	Temperature (°C)	Soil Acidity
Maple	1260 mm of rain per year	-40 to 37	Maples grow best in soil that has a neutral to acidic pH. This is a pH reading of 7 and under. A range between 6 and 7 is ideal.
Oak	70 mm of rain per year	-35 to 40	The general oak tree pH levels should rest between 3.6 and 7.0.
Sycamore	700 mm of rain per year	-36 to 43	Sycamore has a recommended lower pH range of 4.0 to 4.5 and upper pH range of 7 to 8.
Pine	1320 mm of rain per year	-45 to 30	Pine tree pH levels should be between 3.3 and 7.5.

Fir	1900 mm of rain per year	-35 to 37	Fir trees grow best in soil that has a neutral to acidic pH. The ideal range is between 6 and 8.
Elm	1000 mm of rain per year	-40 to 35	Soil pH levels should be between 5.5 and 8.0.
Birch	800 mm of rain per year	-55 to 30	Birch trees prefer acidic soils with a pH less than 6.5.
Cedar	1200 mm per year	-50 to 40	Cedar trees prefer a soil pH of 6.0 to 6.5, but will grow well in soils up to 7.5.

Analysis and Discussion:

Of the eight types of trees studied in this project, elm and fir trees are the most effective in terms of CO_2 sequestration. These trees can be planted anywhere to reduce the amount of carbon dioxide in the atmosphere and prevent negative impacts of greenhouse gases like global warming. By planting trees in areas surrounding lithium mines, we are able to slow down and temporarily store runoff, which reduces pollutants by taking up nutrients and other pollutants from soils and water through their roots, and by transforming pollutants like hydrochloric acid into less harmful substances. This is particularly useful in areas like the Liqi river, where hydrochloric acid has adverse effects on the surrounding ecosystems. Trees planted along riversides also provide habitat for flora and fauna and increase biodiversity. They act as wildlife corridors between fragmented habitats, keep river water cool and improve habitat conditions for aquatic animals. When branches or tree stumps fall into the water, this also creates new habitats and provides new energy sources for organisms.

Viability of Planting Trees to Mitigate Climate Change

"The global tree restoration potential" report found that there is enough land available on Earth to increase the globe's forest cover by one-third without disturbing existing infrastructure. The study found that Earth's ecosystems could support another 900 million hectares (2.2 billion acres) of forests.

According to the authors, we could capture about 205 gigatons of carbon (a gigaton is 1 billion metric tons), reducing atmospheric carbon by about 25 percent. This would negate any emissions in the next 20 years at the current rate and is equivalent to half of all emissions since 1960. Reforesting 1 billion hectares doesn't come without its challenges though. It could take more than a hundred years to add enough mature forest to get sufficient levels of carbon reduction. Meanwhile 40 billion tons of carbon dioxide (CO2) from burning fossil fuels are being added to the atmosphere every year. To protect Earth from global warming and the extinction of many endangered species which will affect our livelihoods, food security, and health, we must cut down on emissions. This means that new fossil fuel-using infrastructure can't be built, and some existing power plants need to shut down immediately.

Conclusion:

As demand for lithium increases, interest in recycling and regulations are also expected to become more prominent. One solution to reduce lithium use, especially in the coming years is a new concept for an aluminium battery that could offer a greener way of storing energy than what's available in today's market. Researchers in Sweden and Slovenia say it has twice the energy density of previous aluminium batteries, which could lead to reduced production costs and a smaller environmental impact compared to today's lithium-ion rechargeable batteries. For consumers like ourselves, it is essential to reduce lithium consumption, reuse all devices and products, and recycle to prevent additional lithium extraction and its impact on the environment. As for reducing emissions, weigh the environmental cost of all your actions and rethink the 'necessities' and 'wants' in your life. Reduce your carbon footprint by eliminating waste whenever possible and eating, shopping, travelling, and using resources sustainably and efficiently. Vote on policies that protect the environment and use your voice to make others more aware. And remember that anyone can plant a tree and we can start doing it tomorrow. Reforestation can buy us all time to cut our carbon emissions and helps reduce the impact of environmental damage.

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