Guidance on Lithium Mining and Extraction

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A. Introduction: Connections Between Lithium Mining and Climate Change

Purpose

This document addresses the consequences of increased mining for lithium as would be required for the transition from internal combustion engine (ICE) vehicles to battery-powered electric vehicles. This document attempts to provide background on lithium mining, its use in the energy transition and potential environmental consequences, as well as a discussion of siting processes including a just process.

In general, large-scale mining is environmentally destructive and often disruptive to nearby communities. As such, the process of developing mining operations, including lithium, needs to be approached carefully and with attention to community concerns. Mining operators and permitting agencies must also clarify the likely permanent changes to the region where the mine is located.

The Sierra Club already has a policy on mining, Mining and Mining Law Reform Policy, adopted 2/20/2020. That policy only twice mentions lithium, which is projected to be extracted in increasing quantities for the energy transition from fossil fuels to renewable power in modern technological societies. Other policies to address supply-chain shortages, secondary mineral recovery, and recycling capacities may mitigate these increases. Mining companies and their investors are already paying great attention to this mineral, and analysts for the mining industry are covering lithium broadly. Thus we are tasked with addressing questions such as:

1. How do different lithium mining methods affect the environment?
2. Are there any new or different concerns about lithium extraction, relative to known mining?
3. Are there ways to decrease the need for lithium mining?
4. What are the socioeconomic impacts of lithium mining? Might they differ from those of traditional mining?

Insofar as we are able, we formulate this guidance to assist Sierra Club groups and chapters that are facing new lithium mining.

Background

The Earth is facing a rapid change in climate in nearly all zones due to global warming caused by the impact of human activities on the Earth's ecosystems and the ability of Earth's natural systems to moderate climate. This is due primarily to our overreliance on fossil fuels to supply energy, overuse of energy in general, and the limited ability of Earth's natural systems to absorb excess carbon dioxide. This over-reliance has only recently (2021) begun to be addressed with planning and implementation of a world-wide transition from fossil fuels to renewable sources of energy as in solar, wind, and geothermal installations. The energy transition will bring large changes to the types of infrastructure that consumes energy and how that infrastructure is powered. A just energy transition will involve replacement of fossil-fuel power generation with renewable power installations while addressing the disproportionate effects of the transition itself on frontline communities in the climate crisis.

It is anticipated that there will be an increased need for energy storage to replace fossil-fuel burning vehicles with battery-operated or other alternatives such as fuel-cell vehicles and to compensate for the intermittent nature of many renewable energy sources with battery backups. Battery production will require an increased use of lithium, an essential stock for lithium-ion batteries, which have high energy-storage capacity, among other desirable features. We should, however, resist the broad narrative of inadequate supplies of these minerals, from which it follows that we must mine them where possible without regard to impacts.

Modern mining has a significant environmental footprint. According to the UN International Resource Panel, "Annually, the extraction of metals and minerals has risen significantly, from 11.6 billion tons in 1970 to 53.1 billion tons in 2017, accounting for 20 percent of climate impacts." Mining comes at a significant cost to the environment and the ability of Earth to moderate its climate through natural ecosystems.

As of this writing, Nevada has the only operational lithium mine in the US, which uses a pumped-brine/evaporative-pond type of extraction. However,other lithium extraction methods are being proposed; and one mine in northern Nevada, the proposed Thacker Pass mine, is in the process of receiving permits (and also under legal environmental challenges) to extract lithium by open-pit mining. Open-pit mining combined with onsite leaching is a common method of mining many minerals, including gold, but it presents many harmful environmental impacts, as well as significant positive and negative socioeconomic effects. New technology is being developed to extract lithium directly from pumped brines, but as yet little is known about the environmental consequences of this technology.

In communities where lithium mines are being proposed, the public will be faced with increasing pressure to open them and to expand existing mines. This document is intended to shed light on the expected consequences of lithium mining and to provide information necessary for deliberation on actions to be taken regarding a proposed mine plan. In addition to seeking to avoid or reduce environmental impacts, the Sierra Club supports a just energy transition that recognizes (frontline) communities, which are often low-income communities or communities of color, can be disproportionately affected and seeks to engage with communities to avoid or minimize these impacts.

This document will discuss the status of lithium mining in the US. We will look closely at the potential effects of lithium mining on the environment and social justice, including how those effects differ based on the technology used. We will connect lithium mining to the Sierra Club's Mining and Mining Law Reform Policy, as well as its policies on electric vehicles and battery recycling.

Other metals required in batteries

As demand for clean energy storage grows (e.g., solar and wind farms, as well as electric vehicles), so will demand for the materials required to make batteries; in addition to lithium, these include copper, manganese, cobalt, nickel, aluminum, and iron, plus two non-metals, graphite and phosphorus. Of the materials needed for battery storage, lithium, copper, iron, and phosphorus have large deposits in the US, while the others generally will need to be imported. Cobalt, nickel, and manganese are particularly challenging for US battery producers since they are effectively not mined in the US. Cobalt, in particular, is primarily mined in the Congo under conditions that are unlikely to meet international standards for sustainable mining. Thus, until substitutes are developed, the effects of mining these other minerals are connected to battery production, so lithium does not stand in isolation. The exact makeup of lithium-ion batteries may be changing also; for instance, from a lithium-cobalt-nickel combination to one that uses lithium-iron-phosphorus. Regardless, lithium remains the primary metal needed for transportation purposes. Substitutes such as the sodium-ion battery may appear for stationary energy storage, as for the electrical grid; but a viable substitute for vehicles is unlikely to be found in the near future. Each of these battery materials presents its own challenges beyond the scope of this document, which focuses on lithium policy, and may require additional analysis on sourcing of these materials.

Emerging technologies

Lithium is currently a critical element for transportation batteries, and both battery design and lithium-recovery technology are evolving quickly. Evolving methods for recovery of lithium from all sources (geologic, brine occurrences, recycled batteries, as well as re-mining waste) will likely change as more is processed. Even extraction of lithium from ocean water is being advanced, although the concentration of lithium in ocean water is very low. Thermal treatment of pegmatite ores is likely to continue, but once the lithium is made soluble from brines, pegmatites, or clays, the process of isolating lithium products is generally similar. Selective methods of isolating lithium in a solution containing other ions (e.g. magnesium, sodium, and potassium) is a goal of many research programs around the world, and advances are announced frequently. These emerging technologies may change the impacts and economics of the various mining methods as they become mature. However, replacement of lithium with other elements for transportation batteries appears (at present, 2021) to be unlikely, primarily due to the very high energy density of lithium as a key component of these batteries.

Current uses, production, reserves, and resources

According to the United States Geological Survey's (USGS) 2021 Mineral Commodity Summaries, 71 percent of lithium found its end use in batteries. Rates of lithium usage are expected to grow substantially with the electrification of the transportation sector in an effort to curb greenhouse gas emissions. The rate of growth will be largely dependent on the rate of electrification of the transportation sector, and developments are published seemingly on a weekly basis. Estimates of the increase in lithium requirements also vary widely, but many estimates suggest that it could increase by as much as factors of three to ten by 2030. This need will increase lithium mining, absent policies to avoid new mining such as establishing recycling facilities for the metals in batteries, reducing the quantity of new lithium required to construct batteries, using other sources of lithium, and reducing vehicle miles traveled (particularly single occupancy vehicle use). The Department of Energy (DOE) could be said to be leading this effort with their lithium-battery recycling prize, and their project is already in its final phase. However, because such policies remain in development, an increase in the extraction of new lithium is a near certainty for the near future.

The units used to represent quantities of lithium resources, reserves, and production differ, and are sometimes omitted. In the literature, authors often fail to distinguish between Imperial tons (2000 pounds) and metric tonnes (1000kg). However, there is only roughly 10 percent more mass in a metric tonne than an Imperial ton. Element resources are expressed in terms of metric tonnes (1 tonne = 1000 kg). Bulk lithium is marketed as metric tonnes of lithium carbonate (Li_2CO_3) or metric tonnes of lithium hydroxide (LiOH). In terms of pure lithium, a metric tonne of Li_2CO_3 is not equal to a metric tonne of LiOH. The table below is an aid to understanding and converting the relative masses.

mass of molecule	***multiply***	***by***	***equals***	***mass of lithium***
Mass of Li_2CO_3	***x***	***0.1880***	***=***	***mass of lithium***
Mass of LiOH	***x***	***0.2898***	***=***	***mass of lithium***
Mass of Li_2O	***x***	***0.4646***	***=***	***mass of lithium***

The United States is currently not a major producer of new lithium, but is expected to require large amounts of lithium for batteries as new electric automobiles are manufactured. Where will the lithium that is to be used in these vehicles be produced? The USGS regularly provides an estimate for mineral production from both the US and the rest of the world. Below is a USGS table that provides an estimate of 2020 lithium production, reserves, and resources. These estimates change each year, particularly with respect to lithium reserves and resources. As demand for lithium batteries grows, so has exploration of new sources of lithium. While different entities offer different estimates of each of the numbers below, the USGS estimates have the greatest credibility.

World Mine Production, Reserves, and Resources[1] Each value represents metric tons of lithium metal.

Country	2020 production[2]	Reserves[3]	Resources[4]
Australia	40,000	4,700,000	6,400,000
Chile	18,000	9,200,000	9,600,000
China	14,000	1,500,000	5,100,000
Argentina	6,200	1,900,000	19,300,000
Brazil	1,900	95,000	470,000
United States	900-950 (est)[5]	750,000	7,900,000
World	82,000	21,000,000	86,000,000

[1]Source: **US Geological Survey, Mineral Commodity Summaries, January 2021.** Listed above are estimates of national production of lithium metal. [2] These are the estimated actual national production from natural sources. [3] The reserve base is estimated as the in-place demonstrated (measured plus indicated) resource. [4] Resources are concentrations of naturally occurring material in the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible. [5] From the Albermarle website, estimate of lithium metal produced from brines in Clayton Valley, NV, which is currently the only producing lithium source in the U.S.

At present, Australia is the largest producer of lithium, primarily from pegmatite rock. Also notable is that Bolivia has a resource base of 21,000,000 tons, but not a large current production. The reserves/resources in the US come from clays, pegmatites, and continental, geothermal, and oilfield brines. The clay deposits are primarily located in Nevada where three mines are currently undergoing the permitting process.

Our analysis here will be summarized in a series of guidelines that should be reviewed by local chapters and groups in locations where lithium mining is being proposed. Guidelines are tailored to the differing mineral occurrences and differing methods of extraction. In addition, other guidelines address the needs for responsible extraction, community involvement, recycling design, and a circular economy. The reader must realize that we cannot anticipate all the developments in technology fully at this time and that, therefore, updates to this document will be in order.

This guidance is meant to aid chapters or groups in areas where new lithium mining is proposed and who are considering whether to support or oppose the project. Because lithium mining intersects with the Sierra Club's existing policies and with the Sierra Club's advocacy for a just energy transition in line with the Jemez Principles, chapters and groups should also align themselves with the Club's national conservation office when making any decisions.

B. Lithium Geochemistry, Mining, and Extraction Methodologies

Lithium geochemistry and its relation to deposits, mining, and extraction

Lithium (Li), element number three on the periodic table, is an alkali metal, along with sodium (Na^+), potassium (K^+), rubidium (Rb^+) and cesium (Cs^+). It has three total electrons, one in the outer shell. With its small mass and single outer shell electron, lithium has the highest electromotive potential ("desire to ionize") of any element, making it very favorable for use in batteries because it offers more useful energy for the same mass. However, lithium has a low crustal abundance of just 20 to 70 parts per million (ppm) and is most common in alkali volcanic rocks and in granites, including pegmatites. In seawater, lithium has a concentration of 0.14 to 0.25 ppm, but reaches levels of about 7 ppm in fluids exiting hydrothermal vents.

Lithium is found as a silicate (containing silicon) or aluminosilicate (containing aluminium and silicon) in the continental crust. It may be part of the crystalline matrix, which is shaped like a jungle gym, or trapped within the matrix because of its small size. It may be a primary alkaline volcanic rock or a secondary clay deposited in a lake sediment. Extracting and concentrating lithium from these rocks requires crushing, separation, and concentration of the metal as a solid phase, and use of sulfuric acid (H_2SO_4) to leach the lithium into aqueous solution. What remains after lithium is extracted from the ore is called tailings. Mine tailings (including lithium ore tailings) typically contain toxic substances. In addition, if sulfuric acid is used, the tailings could have acid residue, which can mobilize multiple major and trace metals that may pose specific environmental issues. Both the solid tailings and the residual fluids can and must be neutralized at the mine site prior to disposal so that no acidic environmental contamination is created by mine processes.

Lithium also has very high water solubility as do all alkali metals. High temperatures (as are found in geothermal waters) enhance solubility and leaching. Thus a common mining problem is separating lithium from other alkali metals that are dissolved in the water. As a dissolved ion, lithium can be concentrated in water by the removal of other ions (e.g., sodium, potassium, rubidium, cesium) or by removing some or all of the water in which the lithium is dissolved. If, for example, seawater is evaporated, it first precipitates sulfates (gypsum and anhydrite, $CaSO_4$) and, after removing about 90 percent of the water, it precipitates NaCl (common table salt) and then KCl. These evaporative and precipitation mechanisms enrich lithium in the residual brine, enabling them to become a mineable source of lithium. (Brine means any salty water, from merely undrinkable to more concentrated than waters of the NaCl-saturated waters of, say, the Great Salt Lake.) Rarely can waters naturally become concentrated to the point of precipitation of lithium carbonate or lithium hydroxide. These are instead often the product of mine-site chemical processing and the initial lithium recovery process. Mining lithium in this way carries the risk of contaminating groundwater with additional brines.

The most valuable lithium deposits have the highest concentration and the largest total amounts of lithium. This occurs where (1) acid volcanic rocks, including pegmatites, are common, (2) groundwater or geothermal waters interact to preferentially dissolve lithium, or (3) waters containing dissolved lithium are evaporated to concentrate lithium as a precipitate or in the residual fluid. These mechanisms most often occur in combination to produce a variety of lithium ore types. Some examples are given below. The examples serve to demonstrate the multiple considerations that go into decision-making with regard to lithium mine evaluation.

Silver Peak Mine

Silver Peak Mine (southwest of Tonopah, Nevada), the only producing lithium mine in North America, is operated by the Albemarle Corporation. Lithium mining at Silver Peak Mine is currently accomplished by extracting lithium from residual brine (past the NaCl precipitation point) that the mine pumps from beneath a dry salt lake. To understand the origin and implications of this brine extraction methodology, we must understand the groundwater interactions and precipitation processes of salt lakes.

When rivers cannot flow to the sea, they terminate in lakes whose area represents a balance between inflow from rivers and outflow via evaporation. But what happens to all the dissolved elements carried by the river? They get ever more concentrated in the lakewaters. If the process continues for sufficient time, lakes can evolve to gypsum/anhydrite precipitation ($CaSO_4$) and then NaCl (common table salt) precipitation at 10 times the salinity of seawater, resulting in the creation of a salt lake like Utah's Great Salt Lake. If the water table for the lake basin is below the land surface and it is less concentrated than the NaCl precipitation point, the basin produces a clay playa; when the water table is at/above the land surface and is NaCl saturated, the basin produces a salt lake covered in NaCl precipitates. Because water has been removed by evaporation and because e.g. $CaSO_4$ and NaCl (with accessory elements) have been removed by precipitation, lithium associated with the inflowing rivers will become highly concentrated into the residual lake brines (in this sense, seawater is also a Li resource although the lithium concentration in seawater is low). Additionally, because the residual brines are the saltiest and densest local waters, this residual brine will percolate down and displace any fresher (less salty but not necessarily "fresh") groundwater that might have been in the basin where the lake developed. Salt lakes thus represent a complex system of incoming surface runoff, fresh groundwater inflow (from the surrounding uplands), evaporation and brine development, solid precipitates and a residual brine with a higher concentration of lithium.

At the Silver Peak Mine operation, brines are pumped from depth below the salt lake and placed into man-made evaporation ponds (Silver Peak ref 2). Brine waters can then be further evaporated and mixed with soda ash to precipitate Li_2CO_3 (Silver Peak ref 3). Residual brine solutions, where the lithium has been extracted, may be disposed of most easily by pumping them back into the deep brine via a second wellbore or allowing them to percolate downward naturally using infiltration ponds. However, continued pumping of the brine as a lithium source will lower the water table and create potentially significant reorganization of the varying-salinity groundwaters flowing in the closed basin system. Such a groundwater reorganization may increase the salinity of fresher surface-fed groundwaters in the region. As a result, potentially drinkable fresh water could become undrinkable.

Rhyolite Ridge

The proposed Rhyolite Ridge mine (under development by Ioneer Ltd.) is located 15 miles west of Albemarle's Silver Peak lithium mine in Esmeralda County, Nevada. It contains both ore-grade lithium and ore-grade boron in clay deposits within sedimentary rocks of the kind formed at the bottom of lakes. The original source of the lithium was most likely 6 million-year-old volcanic rocks that were weathered and then concentrated in a closed basin lake by evaporation. Some sections of the deposit have up to 30,000 ppm (3 percent) boron as a sodium borosilicate mineral and 2500 ppm (0.25 percent) lithium in mixed clay layers.

After 70 feet of the unusable covering rock material known as overburden is removed, the lithium-boron deposit would be quarried and trucked to an on-site vat-leaching facility that uses sulfuric acid (H_2SO_4) to put lithium and boron into aqueous solution. The leach fluids will eventually yield lithium carbonate, lithium hydroxide, and solid phase boric acid through industrial refining. There is a need for appropriate disposal and storage of the spent ore (tailings) and any fluids that may enter and/or escape from the spent-ore storage pit. Ensuring that such solid and liquid mine waste is neutralized is an imperative.

As element extraction methods improve, advance and change with time, it is possible that old mine tailings can be re-extracted with greater efficiency and less overall open-pit destructive mining. Rio Tinto is currently studying ways to extract lithium from tailings of old boron mines (lithium from tailings).

Thacker Pass

The Thacker Pass Mine (Thacker Pass ref 2) in Humboldt County, Nevada is 25 miles south of the Nevada-Idaho border. The prospect is owned by Lithium Nevada Corporation, a subsidiary of Lithium Americas Corporation and is currently in the permitting phase. This proposed mine sits in the McDermitt Caldera (Thacker Pass ref 1), a geologic feature at the southwestern end of a series of volcanic features that have spread northeastward to Yellowstone National Park over the past 20 million years. These alkali volcanic rocks are lithium-enriched relative to normal crust. Following a small caldera collapse, the caldera rim was eroded inward and weathered to form a thick sedimentary sequence with especially high lithium content (up to 100 times Earth crustal average). The Thacker Pass lithium deposit (Thacker Pass ref 4) is a sodium, magnesium, lithium silicate clay that will require sulfuric acid (H_2SO_4) to extract the lithium. Leachate materials will be excavated from a two-square-mile open pit mine.

According to a company spokesperson, Lithium Nevada plans to extract lithium from the Thacker Pass ore by suspending it in water, and separating out the non-clay portions of the ore. The resulting clay fraction will be treated with sulfuric acid to remove the lithium from the clay. Then, the fluid containing the clay, the dissolved lithium, and other dissolved substances will be neutralized and filtered to produce the clear aqueous fraction containing the lithium and other constituents removed from the ore. The neutralized and filtered solid material will then be placed in a tailings facility that will be lined using a heavy, water-impermeable liner. However, the heavy plastic liners can still leak from poorly sealed seams,damage from the weight of the tailings, and deterioration from heat and acids. Thus, all of these facilities, regardless of the lining material, are required by Nevada law to have groundwater leak detection systems that are monitored during mining operations and at least 30 years after mining has ended. Leakage of residual dissolved toxic metals and other substances could contaminate the area. All sulfuric-acid leach processes will likely also result in similar contamination issues with some variation, depending on the composition of the ore.

Salton Sea

The Salton Sea Geothermal Field is the result of extensional processes and volcanic intrusion associated with the San Andreas Fault; followed by multiple episodes of ancient Lake Cahuilla filling and evaporation in the Salton Sink depression of California's Imperial Valley. These filling and evaporation cycles have led to a deep NaCl brine pool beneath the valley. These brines are heated by relatively shallow volcanic intrusive processes which interact with lacustrine sedimentary deposits to produce a geothermal brine enriched with iron, manganese, zinc, lead, cobalt, and lithium. This hot brine is currently being used as a source of geothermal power, and there is hope that it can be cost-effective to recover lithium from the power plant's outflow.

When lithium is extracted from geothermal brines as a byproduct of geothermal power production, there is the potential that the waste brines, although stripped of their lithium, might still retain high metal concentrations that would be of concern. It might be possible to mitigate the brine disposal problem by reinjecting the waste brines into the basin brine field to ensure continued geothermal water production. Such an approach is likely to have lesser environmental impact and may have already been evaluated in the geothermal power plant design.

Like geothermal waters, hydraulic fracturing (fracking) wastewater is likely to contain lithium, which could be extracted from those fluids. Projects underway in Pennsylvania and Oklahoma have been exploring this possibility as a lithium source.

Piedmont Lithium Project

Lithium has been mined in the spodumene belt of North Carolina since the 1950s. Piedmont Lithium was recently granted a US Army Corps of Engineers permit approval to restart production. The mine site is located four miles north of Bessemer City, North Carolina.

The ore deposit contains multiple spodumene bodies within volcanic pegmatite dykes. The mine would be an open pit with an on-site concentrator that used a combination of crushing, flotation, magnetic separation, and sulfuric acid leaching to extract lithium. The company also plans to construct a chemical plant to further refine the raw lithium product. The mine ore body is expected to stay productive over the mine's 25-year lifespan.

As with all acid-leach concentrating operations, there are residual leached rock and acidic waters to be disposed of. Such acid waters pose a possible contamination from both the acidity of the water as well as the possible metal and rare earth metals contained in the leachate. Again, acid neutralization of both solid and liquid mine waste is necessary.

Summary of Characteristics of Lithium and Its Ores

1. Lithium is of value to battery manufacturers because it has the highest ionization potential of any element.

2. Lithium prefers being dissolved in water and is very hard to precipitate. In the solid phase, most lithium is difficult to extract because it is usually tightly held in a silicate or aluminosilicate matrix that is resistant to aqueous leaching.

3. Lithium is generally of low concentration in the Earth's crust but can be concentrated in environments where (1) acid volcanic rocks, including pegmatites, are common, (2) groundwater and geothermal waters interact with solids to preferentially dissolve lithium, or (3) waters containing dissolved lithium are evaporated to concentrate lithium as a precipitate (solid) or in the residual fluid. These mechanisms most often occur in combination to produce a variety of lithium ore types.

4. Open pit and hard rock mining require considerable space and terraforming, as does the disposal of tailings and liquids.

5. Valuable lithium deposits can occur as brines. These are commonly associated with salt lakes and closed basin systems, as well as oil and gas hydrofracturing wastewater. Under these conditions, “mining” most commonly occurs by pumping liquids from the ground, extracting the lithium, and reinjecting any residual liquid into the ground by direct pumping or by rapid infiltration basins.

Guidelines

1. Ore-grade solid occurrences of lithium typically require open pit excavation and acid treatment to extract lithium into an aqueous fluid.

a. Acid extraction involves disposal of waste liquid and waste solid, both of which may be highly acidic and contain toxins and metal contaminants. Liquid and solid waste should be neutralized before disposal in lined pits.

b. Considerable tailings (waste solid) will need to be contained for long periods of time such that ancillary toxic elements and contaminants are not leached into a water phase and transported into the environment. As technology improves, tailings may be a valuable source for the re-mining of lithium.

2. Ore-grade liquid occurrences of lithium require pumping and disposal of brine and a process to remove the lithium from the brine.

a. Pumping of any subsurface liquid (in or out) has the potential to alter existing groundwater flows and could result in loss of water quality or quantity.

b. Reinjection appears preferable to rapid infiltration because it can be better controlled and therefore less disruptive to existing groundwater flows and water quality.

c. Residual liquids should be injected back into the ground where existing waters are of poor (and similar) quality. For hydrothermal or geothermal systems reinjection of waters is often necessary to maintain the geothermal field, and therefore reinjection could be a part of locally optimizing both power production and lithium production.

C. Responsible, Just, and Sustainable Lithium Mining

Responsible and sustainable mining is a contentious topic. There are no agreed-upon standards of responsible mining; however, the Initiative for Responsible Mining Assurance (IRMA) has developed principles and a standard through diverse stakeholder participation including the mining sector. The Sierra Club has adopted IRMA's best practices, which ensure responsible mining. The four overarching principles underlying IRMA's standard are:

1. *Business Integrity*

    INTENT: Operating companies conduct business in a transparent manner that complies with applicable host country and international laws, respects human rights, and builds trust and credibility with workers, communities and stakeholders.

2. *Planning and Managing for Positive Legacies*

    INTENT: Operating companies should appropriately engage stakeholders from the early planning stages and throughout the mine life cycle to ensure that mining projects are planned and managed to deliver positive economic, social, and environmental legacies for companies, workers, and communities.

3. *Social Responsibility*

    INTENT: Operating companies engage with workers, stakeholders and rights holders to maintain or enhance the health, safety, cultural values, quality of life and livelihoods of workers and communities.

4. *Environmental Responsibility*

    INTENT: Operating companies engage with stakeholders to ensure that mining is planned and carried out in a manner that maintains or enhances environmental values, and avoids or minimizes impacts to the environment and communities.

A cautionary note is needed here to clarify that (in many if not most cases) when a mining company approaches a community regarding a mine, there is an unequal power dynamic in play. Most communities do not have expertise in the technical aspects of modern mining such as hydrology, geochemistry, and chemical engineering. Therefore, it is essential that communities have access to trusted independent consultants so they can carry out discussions with mining companies and the government on a more equal basis.

Although not unique to lithium mining, there is additional pressure placed on communities that are being asked to host lithium mines because of the urgency of climate-change mitigation. This dynamic can make the siting of a mine even more contentious, and the situation of perceived urgency should not be used to hurriedly approve a poor mine plan.

Some mining companies may try to use IRMA a way to advertise that the company has “social license.” As a result some communities are wary of misuse of IRMA. Therefore it is absolutely vital to be clear that IRMA is an assessment process and not a seal of approval. A mine should not be considered “responsible” by just joining IRMA. The company must further complete the audit process, which will then provide scores on all of the various standards within IRMA. IRMA is a complex system, so a mine can score well in some areas and not in others. Therefore, care must be taken to get the complete audit profile to avoid company greenwashing.

Yet, some communities view the nature of mining as inherently irresponsible and unsustainable. For example the Indigenous Caucus of the Western Mining Action Network (IC/WMAN), which is composed of mining affected indigenous communities across North America has developed a position related to responsible mining, which is briefly summarized by the IC/WMAN as:

> *IC/WMAN has voted against mining, including what is called responsible mining. All of these mines, now and in the future, are on Indigenous lands and/or our sacred sites and national lands. The government and mining corporations have failed us (not that it wasn't on purpose from the beginning!). We are calling for governments and corporations to apply their funds and efforts toward a circular economy that relies on recycling, reuse and substitution of metals and taking back manufactured products for that purpose. This strategy combined with true conservation and mass transit systems could mean we never need new mines. Wind & Solar are dependent on mining and therefore not renewable nor*

> *sustainable, yet. We must utilize wind & solar as "bridge fuels" to future truly sustainable & renewable technologies.*

Community engagement and social responsibility is vitally necessary for a mining project. Therefore, it must be compliant with high-bar environmental and human rights standards. Specifically, addressing communities locally is paramount to foster engagement, equity, environmental sustainability, and economic development. Mining companies and agencies must let the visions of those who are the most affected participate equally in the action by invoking the Jemez Principles for Democratic Organizing:

1. *Inclusivity*
2. *Bottom-up organizing*
3. *Let the community speak for themselves*
4. *Work together in solidarity and mutuality*
5. *Build a just relationship amongst stakeholders*
6. *Commitment to self-transformation*

We need to see mining as an environmental and human rights challenge that must be resolved globally. Where mining is necessary to meet global needs for additional minerals, the operations where mining takes place must all be subject to the highest standards to protect human rights, labor rights, communities, and the environment.

Indigenous people's issues hold a special place in mining and extraction. Their rights, territories and livelihoods are seriously threatened by the world's demographic pressure, compounded by the extractive industries' appetite for resources. A widespread lack of respect of their cultures and rights has resulted in many communities being decimated, dispossessed of their lands and forcibly relocated. Furthermore, what indigenous peoples have been voicing for decades remains true: while holding much of the world's diversity in terms of culture, language and spirituality, indigenous peoples are also the stewards of natural resources and guardians of biodiversity.

Indigenous peoples have lobbied the United Nations for many years for adoption of Free, Prior, and Informed Consent (FPIC) as a prerequisite for any activity that affects their ancestral lands. Indigenous communities need to be full participants in reviewing, rejecting, or approving mining that would impact their ancestral lands and waters and any other areas that hold significant cultural or religious significance. Mining companies should adhere to the standard of Free, Prior and Informed Consent that has been adopted by the United Nations Declaration on the Rights of Indigenous Peoples.

In an FPIC process, the “how”, “when” and “with and by whom”, are as important as “what” is being proposed. For an FPIC process to be effective and result in consent or lack of it, the way in which the process is conducted is paramount. The time allocated for the discussions among the indigenous peoples, the cultural appropriateness of the way the information is conveyed, and the involvement of the whole community, including key groups like women, the elderly and the youth in the process, are all essential. A thorough and well carried FPIC process helps guarantee everyone’s right to self-determination, allowing them to participate in decisions that affect their lives.

Non-indigenous, directly-affected communities and the general public also need access to balanced and clear information regarding mining proposals. This includes community engagement with independent consultants, who have no stake in the mining venture. It is important to advocate for broad acceptance in these non-indigenous communities.

Herein lies the dilemma: climate change action will include vehicle electrification that requires batteries; batteries require lithium (to be effective on the necessary timescale) which is far cheaper to mine new than to recycle. Lithium mining thus contrasts the complexity and complicated nature of climate change needs with the simplistic and linear nature of most current political positions and proposed actions. Because humanity operates within the Earth/human system, there will always be positives and negatives in any choice. It is the decision-makers that must weigh all the evidence and enable solutions for the long term and short term. *Thus, o*ne can only hope that all the applicable information will have been analysed in the decision-making process. This means getting an early start on any proposal in any location with all the necessary participants and information. It cannot be emphasized enough that addressing climate change will require working together, compromise, rational and intelligent decision-making, trade-offs, and recognizing disproportionately affected communities. This guidance outlines the range of information needed for decision-making without prioritizing or weighting how it should be included.

Guidelines

1. Be wary of mining operations’ claims to have responsible mining methods and to have approval of local communities.
2. Seek out the directly affected community and listen to their perspective on the proposed mine or expansion plan.
3. Strongly advocate for Indigenous communities’ right to Free, Prior, and Informed Consent on any projects that may affect them or their territories.

4. The project should have broad non-indigenous community acceptance.
5. There should be an independent analysis of the mine plan.
6. The mining company should be approached to join IRMA and begin the process of certification under IRMA which requires an audit prior to certification. Certification can occur after the mine is operating.

D. Siting Considerations

Commercial-grade lithium deposits are not widespread or common. As a result, it is not feasible to simply move a proposed mine to an area with fewer conflicts. In all likelihood, there will be trade-offs involved and mitigation measures considered as decision-makers, local stakeholders, and advisors (e.g., the Sierra Club and/or other NGOs) weigh the costs and benefits of mining lithium in any given location. However, it is important to be mindful of who decides which trade-offs are acceptable, and whether the directly-affected community members have a say in the decision. There are some categories of lands and waters that are particularly of concern, and where the Sierra Club would usually be inclined to oppose a new disruptive mining operation. These include:

- Areas of Cultural Significance
- National Park System units
- Designated Wilderness areas
- Wilderness Study Areas
- National Wildlife Refuges
- National Conservation Areas
- Areas of Critical Environmental Concern
- Endangered Species Designated Critical Habitat
- US Forest Service Roadless Areas
- State, regional, and local parks and protected areas

In addition, there are areas where Indigenous Nations have sovereignty over their lands and should be the ones to decide if mining should be banned or allowed. Some lands are unceded treaty lands, which the US government does not recognize as having sovereignty, but the treaty is not withdrawn and therefore is recognized under international law.

In addition, there are public and private lands that have important historical and ongoing cultural importance and significance for Native Americans based on their prior occupancy of these lands for thousands of years before displacement by colonial powers. The Native American views on mining proposals on these lands and waters should be respected and considered. It is often not possible to mitigate the damage to a cultural area from a mining project; and thus, in such a situation, siting the mine and preserving the cultural value of the area are fundamentally incompatible. Similarly, if there are significant designated historical buildings and sites, these conflicts should be addressed and avoided if possible.

There is generally a directly affected community that must host the mining operation. These are often called frontline communities because they will be first to experience effects of the mine, and they will also be the most affected. Frontline communities' cultures and ways are likely to be unavoidably and permanently changed by the presence of mining operations. There are numerous examples of conflicts between communities and mining operations that result in cultural fragmentation. A 2020 report from the Brookings Institute showed that mining operations often violated Indigenous peoples' rights. Some conflicts between mining companies and communities have even become violent, with mine opponents facing injury and death.

If mining or its associated facilities and activities pose significant nuisance, health, or safety concerns to local communities and their air and water, those concerns must be fully addressed. Special attention should be paid to additional environmental justice concerns so that low-income communities, Indigenous communities, and communities of color are not disproportionately bearing the adverse impacts of mining development.

Guidelines

1. Areas in or near the mine plan that have public support for special protection should be properly protected.
2. Identify historical-cultural areas that should be protected.
3. Ensure that the mitigation approaches are satisfactory to the affected community, especially with regard to identified special cultural areas.
4. Ensure that concerns of the directly affected communities are addressed to their satisfaction.

E. Reduce, Repurpose, and Recycle: Toward a Circular Economy

At each vertex of the vehicle electrification, battery recycling, and lithium mining triangle there are both positive and negative impacts. These must be considered carefully on the local scale, the national scale, and the global scale to choose what to do where. As in any process, there will be relative winners and relative losers and effort should be made to enable a solution that is fair, equitable, minimally harmful, maximally beneficial, and with special attention to those disproportionately affected.

Large-scale modern mining and resource extraction are destructive to natural ecosystems. Direct disturbance destroys habitats, and mining operations have a zone of influence that goes beyond the distrurbed area. This additional zone will have varying negative effects on the ecosystem depending upon the specifics of the mining operation.

The environmental and environmental-justice concerns with regard to mining point to a need to minimize extraction — reducing demands for materials and energy. It will be beneficial to pursue policies and practices that aggressively support public transportation and other alternatives to individual vehicle travel and that invest in design-level attention to reuse and recycling of vehicle batteries and other products using lithium-ion batteries, such as laptops, phones, and large-scale grid storage. Such policies and practices will mitigate some problems around mining of lithium. Societies should optimize such means of reusing, repurposing, and recycling of materials before additional extraction proceeds, and seek to create systems of ecologically sound recycling within a true circular economy.

Many sources are reporting that the global demand for lithium, and that of related battery materials, could grow by as much as a factor of 10 by 2030. It's difficult to estimate what global demand for lithium will be in 2050, the date many are using for having largely converted to renewable energy across the globe; but factors of up to 20 or more times the global production rate of 82,000 tonnes in 2020 are predicted by one modeling exercise, which includes inherent assumptions such as recycling rates, demand rates, and so forth. Were all of this demand to be satisfied by new mining of lithium resources, the impacts would be substantial. It is also to be noted that research on battery design and components continues to evolve, and so new discoveries could alter the future of lithium.

Circular economy

It is possible that most demand for minerals in the future can be met with substantially less new mining if the world shifts toward a circular economy model for materials. There are two broad movements (p. 10) in circular economic thinking; the first is reformist and seeks to operate within the bounds of current economic thinking while the second seeks a fundamental transformation of the socioeconomic order. Some see this as a disagreement over the capability of capitalism to overcome resource limits and decouple ecological degradation from economic growth. They note that the reformist view is really only talking about the economy; but, because the latter goes “beyond economic considerations and see[s] circularity as a holistic social transformation,” they propose the term *circular society*.

The United Nations defines a circular economy as “...an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized.” In the circular economy, primary extraction of minerals is greatly diminished through various strategies related to recycling. These include reducing, reusing, and repurposing, with recycling being the method when the others are no longer practical. Some are even going beyond the concept of circular economy to a concept of zero waste. The Sierra Club already supports this concept in its Zero Waste Policy, and the specifics of achieving zero-waste are being studied and promoted by numerous groups worldwide. This policy also recognizes “human rights principles” in the application of methods to reduce material waste and achieve the circular economy.

The concept of circular societies involves examining how a deeper societal transition, rooted in the well-being of the planet and people, and on sufficiency, could make a significant difference. This implies scenarios that go beyond current circular economy actions and look, for example, at the potential to reduce our material consumption.

Sourcing of lithium

One means to lessen the impacts of lithium mining is to re-mine mine tailings and get more use out of materials where environmental harms have already been done. This may also pertain to the enormous quantities of coal ash that have accumulated over the past century or more. The mining company Rio Tinto is already experimenting with this approach at an old boron mine in California.

Another means that can be used to reduce new mining of lithium is to blend lithium extraction into brine pumping operations that are already taking place. This idea is being investigated at geothermal power plants, in oil and gas fields, and in the pumping of ocean water at desalination plants. By working within a current operation that has already created environmental impacts, new impacts could be largely avoided.

Reducing the need for lithium, and related minerals

Beginning with battery design and manufacture, producers must continue to improve lithium-ion batteries’ energy density to achieve longer battery life (measured as both time and number of recharge cycles), and to make recycling a design priority. These advances are market driven, and much of the advances will occur naturally in that context. However, as of this writing, it is cheaper to mine new lithium than to recycle lithium, creating obstacles to recycling. Reduction of demand is therefore the first principle in order to avoid extracting new material.

As the International Resource Panel notes: “The largest reductions of life-cycle emissions could be attained by changing patterns of vehicle use (ridesharing, car-sharing) and shifting towards trip-appropriate smaller vehicles. This is mainly because they reduce not only the demand for materials but also the energy use during the operation of the vehicles.” This requires a fundamental rethinking of the increasingly global consumer culture and may require a generational timescale for full adoption.

The need to reduce extraction of “new” materials, such as lithium for vehicles and electrical-grid energy storage, applies across a wide spectrum of current society such as urban sprawl; over-commitment to detached, single-family homes; lack of public transportation in US cities and suburbs; lack of neighborhood shopping, dining, and recreation amenities; and overly centralized community services. There is a need to increase opportunities to walk and bike or use small, low-powered transportation options such as electric bicycles or scooters. Adapting our towns and cities around these modes of transportation can significantly reduce demand for private vehicles or extend their useful lives considerably.

Reusing and repurposing lithium batteries

Reuse is a prominent attribute for many products, and the term “reuse” applies almost intrinsically to lithium-ion batteries because they undergo many recharging cycles, often hundreds, in normal applications. “Reuse” could possibly describe some methods where, for instance, the battery enclosures are salvaged and reused, but we do not consider reusing further here and instead focus on recycling.

Once design factors have been optimized for recycling and before recycling is even considered for lithium-ion batteries, there is an important stream for them after they have reached the end of their “first” life. In the circular-economy terminology, they can be “repurposed” for other applications (sometimes called “reused”). Lithium-ion batteries that power electric vehicles are expected to last 5 to 10 years before they drop to a capacity factor (often expressed as estimated mileage range at a full charge) that inhibits their continued use in the first life. This factor is often quoted as 70 to 80 percent of original battery capacity. For the mobile application as in an electric vehicle, it is not beneficial to continue to carry around the original weight of the batteries while they deliver only partial performance. But there are many situations in which weight and space are not nearly as great a concern. Lithium-ion batteries may have a “second” life in applications such as stationary energy storage at a solar or wind power plant. In this case, the battery-storage footprint will be much less than the solar-panel footprint. Lithium-ion batteries repurposed in this way could serve as many years in a second life as in the first life. Another second-life application could be in heavy machinery, where charging is readily available and newly manufactured, full-capacity batteries are not required.

The repurposing described above will decrease demands for mining new battery material, and it also eliminates the environmental impacts (water, air, solid waste, etc.) of manufacturing new batteries. After the second life, the spent lithium-ion batteries could enter the recycling stream. Another important argument for repurposing now is to keep lithium-ion batteries out of inappropriate recycling streams while the lithium recycling industry becomes more safe, ubiquitous, efficient, and profitable.

Still, repurposing lithium-ion batteries has numerous challenges. Electric vehicle batteries consist of hundreds of individual cells that must be tested and assessed for further use. Refabrication may be required to satisfy the needs of the repurposed application. Again, the technology is undergoing rapid development. With a wave of end-of-first-life lithium-ion batteries looming, it is important that these batteries enter a second life or that recycling becomes nearly universal. Also, the offerings of repurposed batteries will need to compete in cost and reliability with newly manufactured ones. It is hardly desirable that repurposed batteries sit on shelves unsold because they are more expensive or of lower quality.

Recycling lithium-ion batteries

As stated above, recycling should only be done when reduction, reuse, and repurposing options have been exhausted. At present, recycling of lithium batteries is challenging and not yet broadly cost effective; yet progress is being made toward that end with major help from manufacturers, research centers, government agencies, and nonprofit organizations. However, current research rarely emphasizes the importance of battery design for recycling. Given that we are in the early stages of the energy transition, actual recycling rates presently have little meaning since the vast quantity of lithium-ion batteries were just recently manufactured and have not approached the end of their first life. In contrast, the recycling of lead-acid batteries is a mature operation around the globe; in the US it is estimated that as many as 99 percent of these batteries are recycled. No less should be sought for lithium-ion batteries when they are beyond repurposing. The European Union has proposed regulations that aim to increase lithium-ion battery recycling to nearly 100%.

Successful recycling of lithium-ion batteries involves many challenges — technical, regulatory, and cultural. Technical and regulatory changes are well addressed in a recent Berkeley Law publication, which puts the onus on industry and government to create and promote an effective recycling stream in the US for lithium-ion batteries. The Union of Concerned Scientists has an informative roadmap to lithium-ion battery recycling. Kia Motors in South Korea is building lithium recycling around the circular economy concept. However, recycling technology in US industry is developing rapidly also. For instance, in April 2021 a consortium of companies under direction of LINICO Corp. has established a recycling center near the Tesla Gigafactory in Nevada to use advanced methods in recovering cathode materials from spent lithium-ion batteries. Supported by the Department of Energy (DOE) in the US, a Lithium-Ion Battery Recycling Prize is being offered to the company that develops the best robust, scalable recycling method. Also, the DOE has started its own lithium-ion battery recycling program, called the ReCell Center.

The US, along with other developed countries that will embrace the bulk of electric vehicles in the near term, must be careful not to export lithium-ion battery recycling responsibilities to lesser-developed countries where lax or non-existent regulation encourages unsafe and inefficient recycling practices and labor exploitation. These adverse consequences already exist for recycling of many products of developed countries; for instance, e-waste and plastic. The rationale to be applied is the same as for mining: the US should not export environmental and social-justice problems.

The cultural aspect of lithium-ion batteries recycling can't be over-emphasized. At least for small batteries, the current culture is mostly a "throw-away" attitude. This needs to change as we scale up the sizes and quantities of lithium-ion batteries. Due to the immature nature of the recycling industry for lithium-ion batteries, it is difficult to get accurate figures on recycling rates and, more importantly, on actual recovery rates. They vary by country, but the overall global rates are still poor. The EU is setting new ambitious standards for collection rates and actual recovery rates for lithium. Along with making recycling easier for end-users, there needs to be more education on the importance of keeping lithium-ion batteries out of the waste stream because they can present fire dangers.

Guidelines

1. **Sourcing:** New mining of lithium can be minimized if novel sources of this mineral can be developed economically. Monitor the technical progress of re-mining of waste piles created by former mines and of blending lithium extraction into already occurring brine pumping, as at geothermal power plants, in oil and gas fields, and at desalination plants.
2. **Reduce:** The reduction of all material use should be a goal that parallels the energy transition. Without capping and then reducing lithium use, there will be a continual increase in the demand due to an increased number of vehicles on the road and to more energy storage requirements for electrical grids that feed ever-increasing consumption.
3. **Repurpose:** There are opportunities to repurpose lithium-ion batteries to less intense use without sacrificing utility. All means should be sought to repurpose batteries in a second or third life before they are recycled. This also moves the inevitable recycling phase to a more distant time, allowing for technological improvements in recycling to become mainstream.
4. **Recycle:** When there is no more practical added life for lithium batteries, they should be recycled at a high rate of recovery of all the basic materials. This will reduce the demand for “new” mining of lithium. Advocating for thorough recycling of lithium-ion batteries is as important as advocating for quick adaptation of lithium batteries for today’s vehicles and electrical-grid storage facilities. This requires new local, state, and federal laws and regulations.
5. **Circular economy:** Through the intelligent application of reduce, repurpose, and recycle, the realization of a true circular economy is possible. We should advocate for such an economy in order to ideally make lithium mining largely unnecessary by the end of the energy transition, perhaps around mid-century.

F. Regulatory Oversight (Federal, State, Local)

Regulatory oversight of mines

Regulating the exploration, development, operation, and closure of all mines is critical for minimizing their impact on communities and the environment, and mining of lithium is no different. Mines in the US will usually have federal and state oversight, and sometimes local oversight as well. That oversight can vary dramatically, particularly at the state and local level.

The three United States laws that have an impact on mining are: (1) the National Environmental Policy Act (NEPA), which requires a detailed analysis of the environmental and societal impacts of developments on public lands; (2) the Mining Law of 1872, which designates mining as a preferential use of the public lands and often works to prohibit federal agencies from denying mine proposals; and (3) the Federal Land Policy and Management Act (FLPMA), which requires that mines must avoid undue and unnecessary degradation of public lands, although the term “undue and unnecessary degradation” is not well defined. In addition, the Bureau of Land Management (BLM) has the MS 3809 Regulations that describe how mines are regulated and permitted on BLM-managed lands, and the National Forest has regulations (Part 228 -- MInerals) that control mining carried out in national forests. Many states have their own set of regulations for mining on both federal and private lands, and these vary from state to state.

Since lithium is recovered from a variety of sources, the impacts and regulatory oversight will vary, depending on the hazards. The sources broadly fall into two types insofar as laws and regulations are concerned: (1) brines and geothermal waters and (2) geologic resources such as clays and pegmatites. With regard to the source of lithium then, one of the following pertains:

1. Brines and geothermal waters

Mining lithium from brines or geothermal fluids will have primary impacts on water resources through the deposition of the remaining salts once lithium has been removed. In many cases the disposal of the brine waste containing salts is not a major environmental problem because those salts do not normally alter the deposits; therefore, in some cases, the processed brine can be reinjected into the source water without major concerns with groundwater quality, particularly when lithium is removed from geothermal water. For geothermal waters, odors can be a concern due to the presence of hydrogen sulfide.

However, in certain locations, removal of large amounts of brine groundwater creates a zone of groundwater depression that draws in good-quality groundwater from surrounding areas and mixes it with saline groundwater systems, rendering the water unsuitable for drinking or other domestic uses. Lithium from brine deposits is often concentrated by selective crystallization, which requires evaporation of large amounts of water. Processes that selectively remove lithium from water, without adding other substances (e.g. solvents), may prove to be one of the least impactful methods for production of lithium. However, at present, those methods do not appear to be sufficient to supply the world with needed lithium and may not be economically feasible.

2. Geologic resources

Recovery of lithium from geologic deposits is currently being developed in the United States (and other countries) as a major source of lithium. The domestic sources of geologic lithium include both clays and pegmatites, and both are presently being investigated. Lithium clays have an advantage because the lithium can be recovered without a thermal treatment; however, this typically involves an acid-leaching process. Acid leaching has been shown to be problematic in Australia and in the US, requiring long-term management, and the question remains as to the complications of acid leaching for lithium clays. Moreover, mining of geologic deposits is disruptive to surface resources, Native American cultural sites, wildlife, surface water, and groundwater. Minimizing the long-term effects of lithium mines requires rigorous regulatory oversight by both federal and state agencies. Because lithium is classified as a locatable mineral, it falls under the 1872 Mining Law, and will limit the ability of federal agencies to deny any mining proposal on public lands.

Mining is best regulated when both the federal and state regulatory agencies require comprehensive permits to mine, which allows protection of resources from both federal and state perspectives. Not all states regulate mines to the same standard, particularly states that do not have large mining industries. But, in general, the following requirements should exist in either or both regulatory systems.

- Environmental impact analyses: Prior to initiation of a mine, a detailed assessment of how the mine will affect the existing environment needs to be conducted. This will occur for federal, federally assisted or licensed projects , but should also be conducted by a state agency when the proposed mine is on private lands. The requirement for such a private-land study will vary with each state, depending on the laws and regulations in place. State regulations vary in the level of protection provided, and local activists may wish to become involved in the adoption process for regulations by mining regulatory commissions. Maine is a good example of a state with effective state-level mining regulations.
- Protection of groundwater and surface water: Mines will often penetrate the pre-mine groundwater table and then lower the groundwater table by aggressive pumping. When pumping is discontinued, the groundwater level will fill the void and create a pit lake. As the water flows into the pit lake, it can interact with newly created surfaces and release a variety of contaminants. For lithium mines, arsenic, antimony, and a variety of salts can be a particular problem. Those contaminants can migrate with groundwater flow. Any significant degradation of groundwater or surface water should not be permitted. Additionally, the creation

of waste rock dumps and tailings facilities should be designed to minimize release of contaminants with precipitation.

- Protection of air quality: Dust and emission of volatile contaminants needs to be carefully assessed and regulated. Recovery of lithium from clay deposits generally requires sulfuric acid, which is produced by burning sulfur, and will require tight regulatory oversight to minimize release of sulfur dioxide. Regulatory limits exist for release of sulfur dioxide, and these need to be rigorously enforced. Dust is a common problem at effectively all mines and needs to be regulated to protect those living downwind, especially the elderly, children, and others with special sensitivities to pollution. In some states air and water quality, dust, noise, and access issues are regulated by county land use permits in addition to state regulations.
- Regulation of operating mines: Both federal and state agencies need to regulate operational mines with regular visits and with water and air monitoring systems. Data on these monitoring systems should be made public and available online. Emergency reporting systems should be in place for the times when a mine exceeds the amount of pollution it is permitted to release. Mines need to be operated with safety as a central priority to minimize adverse impacts to workers and the surrounding communities. Noise and lighting need to be managed to protect wildlife and those living nearby.
- Closure and reclamation: While operating mines may have the most disruptive impact on communities, the long-term consequences of the mine will be largely determined by whether it is properly closed and reclaimed. The mining industry knows that reclamation begins when the mine is being opened, and plans for closure should be in force throughout the life of the mine. Reclamation of the site should consider long-term safety, create a productive post-mining land use for the site, and create a site that conforms with the pre-mine topography and blends with the surrounding country. Bonding for closure is critical, and the bond should be sufficient for the respective state or federal agency to fund agency staff to oversee the closure, hire a third-party contractor to close the site, and allow for monitoring of the site (especially its water impacts) over the long term, with the scale and time period depending on the risk of contamination. The reclamation bond should be evaluated on a regular basis (every 2 to 4 years) during operation to ensure that it is sufficient to cover the costs of closure.

How the regulation of the mine from start to closure actually functions will depend on the regulatory agencies, and how they interact with other agencies. Mining has created some of the most costly and contaminating sites in the United States, and agency regulators must ensure that lithium mining does not contribute to those long-term costs and land-use disasters.

Sound regulatory oversight of mining both by federal and state regulatory agencies is absolutely required. Certification of a mine through the voluntary IRMA process is a major step forward; but thorough, consistent, and professional oversight is critical for maintaining mineral production that meets clear requirements for environmental protection and minimizes mines' overall impacts.

Guidelines

1. Federal, state, and local regulatory agencies should work cooperatively to protect communities and the environment. The contributions of each agency will depend on the land status of the proposal; mining development on private land may only involve state and local oversight. The agencies need to be appropriately authorized, staffed with competent individuals, and provided with sufficient resources to ensure that operation of the lithium mine site is consistent with the operating permit and the federal, state, and local laws.

2. Those who wish to track lithium mining should familiarize themselves with pertinent federal, state, and local regulations.

3. Regulation of lithium-producing facilities will depend on the type of source being developed. Brines, geothermal waters, produced water from oil and gas wells, and other aqueous lithium sources will be regulated differently than geologic sources requiring traditional mining operations because their impacts are different.

4. New proposals for lithium operations should require the following:

- A detailed plan of operations, followed by a thorough environmental assessment or environmental impact statement.
- Regulatory actions to protect surface water and groundwater.
- Regulatory actions to protect air quality.
- Oversight of monitoring activities with regular regulatory visits to ensure the mine is operating in a manner consistent with the permit conditions.
- A detailed closure plan with bonding that will allow the regulatory agency to hire a third-party contractor to close the facility if the mining company is unable to do so. The closure plan and the amount of bonding should be reviewed periodically (e.g., every 2 to 3 years) as mine operation plans may change.

5. While certification by the IRMA process is a very useful effort, it is not a regulatory program. The public should expect that the various regulatory agencies understand and are actively carrying out their duty to protect communities and the environment.

G. Summary of Guidance

Introduction: Connections Between Lithium Mining and Climate Change [no guidelines for this introductory section]

Lithium Geochemistry, Mining, and Extraction Methodologies

1. Ore-grade solid occurrences of lithium typically require open pit excavation and acid treatment to extract lithium into an aqueous fluid.

    a. Acid extraction involves disposal of waste liquid and waste solid, both of which may be highly acidic and contain toxins and metal contaminants. Liquid and solid waste should be neutralized before disposal in lined pits.

    b. Considerable tailings (waste solid) will need to be contained for long periods of time such that ancillary toxic elements and contaminants are not leached into a water phase and transported into the environment. As technology improves, tailings may be a valuable source for the re-mining of lithium.

2. Ore-grade liquid occurrences of lithium require pumping and disposal of brine and a process to remove the lithium from the brine.

    a. Pumping of any subsurface liquid (in or out) has the potential to alter existing groundwater flows and could result in loss of water quality or quantity.

    b. Reinjection appears preferable to rapid infiltration because it can be better controlled and therefore less disruptive to existing groundwater flows and water quality.

    c. Residual liquids should be injected back into the ground where existing waters are of poor (and similar) quality. For hydrothermal or geothermal systems reinjection of waters is often necessary to maintain the geothermal field, and therefore reinjection could be a part of locally optimizing both power production and lithium production.

Responsible, Just, and Sustainable Lithium Mining

1. Be wary of mining operations' claims to have responsible mining methods and to have approval of local communities.
2. Seek out the directly affected community and listen to their perspective on the proposed mine or expansion plan.
3. Strongly advocate for Indigenous communities' right to Free, Prior, and Informed Consent on any projects that may affect them or their territories.
4. The project should have broad non-indigenous community acceptance.
5. There should be an independent analysis of the mine plan.
6. The mining company should be approached to join IRMA and begin the process of certification under IRMA which requires an audit prior to certification. Certification can occur after the mine is operating.

Siting Considerations

1. Areas in or near the mine plan that have public support for special protection should be properly protected.
2. Identify historical-cultural areas that should be protected.
3. Ensure that the mitigation approaches are satisfactory to the affected community, especially with regard to identified special cultural areas.
4. Ensure that concerns of the directly affected communities are addressed to their satisfaction.

Reduce, Repurpose, and Recycle: Toward a Circular Economy

1. **Sourcing:** New mining of lithium can be minimized if novel sources of this mineral can be developed economically. Monitor the technical progress of re-mining of waste piles created by former mines and of blending lithium extraction into already occurring brine pumping, as at geothermal power plants, in oil and gas fields, and at desalination plants.
2. **Reduce:** The reduction of all material use should be a goal that parallels the energy transition. Without capping and then reducing lithium use, there will be a continual increase in the demand due to an increased number of vehicles on the road and to more energy storage requirements for electrical grids that feed ever-increasing consumption.

3. **Repurpose:** There are opportunities to repurpose lithium-ion batteries to less intense use without sacrificing utility. All means should be sought to repurpose batteries in a second or third life before they are recycled. This also moves the inevitable recycling phase to a more distant time, allowing for technological improvements in recycling to become mainstream.
4. **Recycle:** When there is no more practical added life for lithium batteries, they should be recycled at a high rate of recovery of all the basic materials. This will reduce the demand for "new" mining of lithium. Advocating for thorough recycling of lithium-ion batteries is as important as advocating for quick adaptation of lithium batteries for today's vehicles and electrical-grid storage facilities. This requires new local, state, and federal laws and regulations.
5. **Circular economy:** Through the intelligent application of reduce, repurpose, and recycle, the realization of a true circular economy is possible. We should advocate for such an economy in order to ideally make lithium mining largely unnecessary by the end of the energy transition, perhaps around mid-century.

Regulatory Oversight (Federal, State, and Local)

1. Federal, state, and local regulatory agencies should work cooperatively to protect communities and the environment. The contributions of each agency will depend on the land status of the proposal; mining development on private land may only involve state and local oversight. The agencies need to be appropriately authorized, staffed with competent individuals, and provided with sufficient resources to ensure that operation of the lithium mine site is consistent with the operating permit and the federal, state, and local laws.
2. Those who wish to track lithium mining should familiarize themselves with pertinent federal, state, and local regulations.
3. Regulation of lithium-producing facilities will depend on the type of source being developed. Brines, geothermal waters, produced water from oil and gas wells, and other aqueous lithium sources will be regulated differently than geologic sources requiring traditional mining operations because their impacts are different.
4. New proposals for lithium operations should require the following:

    · A detailed plan of operations, followed by a thorough environmental assessment or environmental impact statement.
    · Regulatory actions to protect surface water and groundwater.
    · Regulatory actions to protect air quality.

· Oversight of monitoring activities with regular regulatory visits to ensure the mine is operating in a manner consistent with the permit conditions.
· A detailed closure plan with bonding that will allow the regulatory agency to hire a third-party contractor to close the facility if the mining company is unable to do so. The closure plan and the amount of bonding should be reviewed periodically (e.g., every 2 to 3 years) as mine operation plans may change.

5. While certification by the IRMA process is a very useful effort, it is not a regulatory program. The public should expect that the various regulatory agencies understand and are actively carrying out their duty to protect communities and the environment.