



CALIFORNIA'S NEXT GOLD RUSH:

Chilean lithium and California climate policy

Summary: Human-caused global warming threatens to destroy the planet. Governments are beginning to transition economies off of fossil fuels which emit huge amounts of carbon dioxide into the atmosphere. Renewable energy, power captured from sun, wind and water, will replace fossil fuels, but a hurdle remains: storage. California, the world's sixth largest economy, is building huge amounts of renewable battery storage from lithium. The state passed an ambitious goal of reaching 100 percent renewable energy by 2045 and is counting on lithium to get it there. The metal is light and can pack a lot of power. It makes electronic devices like the mobile phones, laptops and electric vehicles portable and possible. It's also being used for stationary storage, what utility companies call largescale batteries that store energy for electric grids. However, the state policy doesn't acknowledge the burden its demand for the natural resource puts on other countries. Lithium is secured through water-intensive mining by large international corporations in the middle of a desert region in South America. The lands where lithium abounds are sacred spaces for indigenous populations near the mines who also consequently rely on mining for employment. There are concerns that lithium extraction is permanently depleting water sources these communities rely upon both spiritually and for survival. This article endeavors to shed light on the complexities of abating global warming for the benefit of richer economies at the expense of poorer, more vulnerable ones.

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Like colossal piles of sifted powdered sugar, freshly-mined lithium glints in the Chilean desert sun with the kind of reflective power snow or ice possess. These flat-topped mountains of metal could be seen—piled against the Andes mountains on a recent April afternoon—from kilometers away at the gates of the US-owned lithium mine called Albemarle.

The raw element is exported to battery manufacturers—mostly in Asia—and used to store power in iPhones, laptops and Priuses.

Increasingly, governments like California are building massive amounts of lithium battery power into the grid to store renewable energy in an effort to combat climate change. So far, lithium is the most affordable and lightweight storage technology available on the market.

The commodity comes at a cost to indigenous communities living near lithium mines, which both rely on mining for employment but believe the water-intensive extraction process is draining the world's driest desert dry. And it's unclear whether the carbon footprint of lithium's petroleum-powered extraction process and global supply chain is offset by the green energy revolution it supports.

Tourism has exploded over the past few years in northern Chile's Atacama region. Wealthy travelers snap selfies at the Mars-like Moon Valley and the Tatio geysers. But they likely haven't heard about lithium mines just south of San Pedro and few tourism agencies offer to educate them.

Claudio Chayle, 37, worked at one of the mines but quit to start his own agency named after an ancient water ritual performed annually in his hometown of Peine. He said kilometer-wide yellowing pools used to concentrate the element out on the salt flats sometimes attract flamingos that filter-feed in nearby lagoons. Concentrated lithium will separate your skin, he said, and can kill a flamingo.

"We had to designate a truck to pull dead flamingos from the pools," Chayle said.

It's a destructive business, like all mining, wrought with layers of local and international political struggle powered by this promising new market commodity. Despite all of this, lithium appears to be a necessary evil and the world's best bet in avoiding catastrophic climate change.¹

However, an ambitious graduate student in a small San Diego-based battery lab is working on a new technology that could help California kick its lithium addiction. The story of her research shows one way the US government investment could help.

"Lithium is far from over," said David Victor, a professor of international relations at UC-San Diego. "There's a lot more running room on the technology; that's what science suggest. But that doesn't mean you don't invest in other technology the same time."

Part I: Unintended consequences of a green grid

California has less than 26 years to figure out how to power itself, the world's fifth largest economy, on 100 percent renewable energy. It's not just a policy goal. The new state law signed in January by former Gov. Jerry Brown states power utilities will be committing a crime by burning fossil fuels after 2045.

But humanity doesn't yet possess the technology to get California there. Capturing enough sunlight and wind isn't the problem: it's how to store that energy when the sun doesn't shine and the wind doesn't blow.

Lithium, the third and lightest element on the periodic table, is the fastest-growing storage technology.

The silver-white powdery substance, sometimes called "white gold," packs a lot of energy for its weight and reliably recharges thousands of times over. (A conventional lead-acid battery recharges only a few hundred times). That's great for the electric vehicle market which requires lighter batteries to make cars travel further more efficiently. However, like all metals, lithium is not a renewable resource.

It must first be mined from rock, volcanic deposits or saltwater brines and then extracted chemically. The ocean is actually the world's largest lithium source, containing just .1 parts lithium per million. The fragile desert ecosystems in northern Chile is the best, where concentrations of 1,500 parts per million can be found.

Today, two foreign companies are mining lithium from one of the highest known concentrations sites on the planet: Salar de Atacama (Atacama salt flat) in Andean Chile. The most popular way to extract it involves drilling wells in the ground and sucking salty, lithium-containing brines from subterranean aquifers through long rubber hoses. Those hoses feed into a series of evaporation pools, the last of which contains the final product of highly-concentrated lithium.

Lithium mining in Atacama is really water mining. Decades ago, mining companies privately secured water and land rights from the Chilean government and convinced indigenous communities to sign off on their projects.

Some companies, like SQM, are permitted to extract 47 billion liters of water from the desert every year. That's a problem for a part of the world that receives just 15 inches of rain per year.

Older generations of the native Atacameño people will tell you an economy based on traditional agriculture is no longer sustainable. The rivers fed by melting Andean snowpack that made growing fruits and vegetables is not as reliable as it used to be.

There have been droughts and, if not droughts, destructive flooding that wipes out entire houses and uproots trees — a sight rarely seen in the region.

Indigenous people say they can see water levels dropping in desert lagoons that sustain the threatened flamingo population. They can't prove it though; the mining companies are in charge of monitoring them.

“To a country with an economy that depends on natural resources, how does the life of a flamingo weigh against a mine site and a thousand jobs?” said Manuel Silvestre, a naturalist at Laguna Chaxa, a nature preserve just north of the two largest lithium mines.

Now, a younger generation of native “Atacameño” communities are organizing demonstrations against mining companies, claiming lithium mining has ravaged the region of its rare water resources. They're hiring lawyers and scientists to build a case against the mines.

“We have laws that favor the company, that favor economic power over the lives of people and indigenous communities,” said Sergio Cubillos, president of the town of Peine and the council of 18 Atacameño communities.

It's complicated, though, because lucrative lithium mining is a primary source of employment in the region. Outside the indigenous community center in Peine a hand-written sign reminds citizens of extra healthcare services coming to town Saturday. Next to it, a printed company job posting at Albemarle—the neighboring lithium mine.

Companies recently started paying for “reparations” projects to make amends. In mining communities, new AstroTurf soccer pitches and colorful jungle gyms stick out among the stone homes and unreliably paved streets the color of the desert sand.

The scale of environmental damage created by lithium extraction is unclear. Lithium companies author their own environmental assessments. A complex system of Chilean government departments evaluates the reports. Some in Chile's legal community acknowledge lithium contracts need more oversight. SQM, one of the world's largest lithium miners, recently suffered penalties for illegal payments to politicians.² SQM was in the Apple supply chain in 2016 when an industry executive told *The Washington Post*.³

It is clear that as more cities, states and nations, most of which are in the global north, approve policies mandating a transition to 100 percent renewable energy, the demand for lithium-based battery storage will only rise. Indigenous leaders want Californians to know this renewable energy plan is not sustainable for the future of their culture.

"We want them to change their methods of extraction as soon as possible," Cubillos, the indigenous president, said. "We don't think it's the United States or Europe or Germany's fault...but we want international pressure on this business."⁴

² SEC v. Sociedad Quimica y Minera de Chile, S.A (2017, January 13). In *Securities and Exchange Commission*. Retrieved from <https://www.sec.gov/litigation/admin/2017/34-79795.pdf>

³ Tossed aside in the 'white gold' rus: Indigenous people are left poor as tech world takes lithium from under their feet (2016, December 19). In *Washington Post*. Retrieved from <https://www.washingtonpost.com/graphics/business/batteries/tossed-aside-in-the-lithium-rush/>

Part II: California goes 100 percent renewable

California has set some of the most ambitious greenhouse gas reduction goals in the United States. On Sept. 10, 2018, California's former governor Jerry Brown signed Senate Bill 100, which put California on a path toward eliminating fossil fuels from its energy sector. It fast-tracks previous timelines set for moving to renewable energy sources, like solar and wind, and requires all retail electricity to become carbon-free by 2045.⁵

When President Donald Trump initiated the process of pulling from the United Nations Paris Agreement on June 1 of 2017, he both fulfilled a campaign promise and galvanized local politicians to fill the gap left by U.S. leadership on climate change. Within days of Trump's announcement, over 200 U.S. mayors committed their cities to uphold the voluntary commitments the Obama Administration—an architect of the agreement — made to reduce greenhouse gas emissions.

Hundreds of organizations doubled down on pressuring leaders to enact climate change policies, like the Sierra Club, which launched a 'Ready for 100' campaign and organized local chapters to support 100 percent clean energy measures in public, private and faith sectors.

California's law has become a model for climate change action in other states as lawmakers in both New Mexico and Washington recently approved similar legislation. Much ado was made over each bill signing with press photos of politicians happily shaking hands over freshly-inked legislation. Environmentalist groups joyously raised placards exclaiming “clean energy for all” and “clean energy jobs now.”

The 100 percent renewable policy trend was the powder keg a puttering market in the in the lithium energy storage market needed.

In February of 2017, California utility San Diego Gas & Electric unveiled what was then touted to be the “largest lithium ion battery storage facility in the world.”⁶ It facility would add 120 megawatt hours of energy, enough to serve 20,000 customers for four hours, reads a press release.⁷ Tesla announced plans in 2018 to build a 1.1 gigawatt-capacity battery system for Pacific Gas & Electric.⁸ It's the largest of a number of projects Tesla orchestrated among utilities in California and Australia to add battery pack storage to grids.

Behind all of those projects is lithium.

⁶ SDG&E Unveils World's Largest Lithium Ion Battery Storage Facility (2017, February 24). In *SDG&E Sempra Utility*. Retrieved from <http://newsroom.sdge.com/clean-innovative/sdge-unveils-world%E2%80%99s-largest-lithium-ion-battery-storage-facility>

⁷ SDG&E

⁸ Baker, D. R. (2018, June 29). PG&E, Tesla team up on big batteries. In *The San Francisco Chronicle*. Retrieved from <https://www.sfchronicle.com/business/article/PG-E-Tesla-team-up-on-big-batteries-13038571.php>

According to the United States Geological Services, global lithium production (excluding domestic production) increased by 23 percent from 2017 to 2018, from 69,000 tons to 85,000 tons. In 2017, production spiked by 74 percent from the year prior.⁹¹⁰

“What we’re seeing today in the market is (that) 95 percent plus of bulk grid energy storage contracted today is lithium,” Mike Kerry, director of Energy and Storage Systems, said at a lithium workshop on the at University of California-San Diego campus in May.

Yet, the impressive growth of batteries on the grid and its consequences are invisible to most Americans.

Even the Chilean people “don’t worry about this topic,” said Cubillos, president of the Atacama indigenous council. There are some environmental groups that empathize with us, he said.

“But we have an environment ministry that contradicts itself,” said Cubillos. “They launch programs for the environment but continue to authorize mines that extract water.”

Cubillos said no one really knows how much water remains in the Atacama Desert since lithium extraction started.

Two companies operate there: SQM and Albemarle.

An environmental impact report submitted by SQM in 2017, the plant began extracting brine at 750 liters per second in 2005. That’s increased, since the publishing of the report, to 1,500 liters per second until 2023. After 2024, water extraction rates hit 1,700 liters per second.

The second-to-last page of the 94-page report ranks perceived environmental impacts from the lithium project. “Altering of the functionality of the hydraulic system” of the salt flat is ranked as either “irrelevant” or “no effect.”

A 2014 study financed by SQM sought to settle the question of how the desert’s subterranean aquifers - the source of lithium - are recharged. The results would determine how and where “environmental protection zones” are drawn and the permitted rate of freshwater and brine extraction.

“Recent studies have shown these ecosystems have not been affected by brine extracted from the Atacama salt flat,” the report reads. But pressure to obtain more minerals is “likely to result in an increased water demand,” it acknowledges.

Little third-party research is being done to verify the companies’ conclusions.

⁹ Jaskula, B. W. (2019, February). Lithium . In *U.S. Geological Survey, Mineral Commodity Summaries*. Retrieved from <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-lithi.pdf>

Manuel Prieto, an researcher at San Pedro's Universidad Catolica del Norte, analyzed archaeological sites along a dried-out river basin to try and prove water-intensive copper mining in the region forced indigenous communities to abandon entire settlements.

He's now embarking on new research to study the lithium supply chain. It's difficult to work on lithium, he said, because the political situation even at the local level is increasingly gridlocked. Some want and need the mining, others are completely against it, other have simply come to terms the way Chile manages its natural resources.

Part III: Worrying over water

Manuel Silvestre, the naturalist at Laguna Chaxa, a national wildlife reserve, preaches the water's spiritual connection to tourists. Protecting this ecosystem is protecting the origin of humanity itself, he believes.

The Atacama salt flat is an endorheic basin, a land depression where water draining from the mountain tops is trapped and cannot reach the ocean. The only way for the water to go is down, filling those subterranean aquifers that have become ever-so important to the mining industry.

Excess water can rise and pool through the porous landscape, creating a series of lagoons in the desert. Trending topics on Instagram show countless pictures of visitors bathing in idyllic neon blue pools the native people call "eyes." Chaxa, however, is extremely shallow, sulfuric and murky.

Its nutrient-rich waters spawn algal blooms, zooplankton and phytoplankton. The teeming biology attract flamingos that filter-feed up to 14 hours per day on the tiny creatures Chileans call "mini-shrimp." The uni- and multi-celled organisms were the first manifestations of life on planet Earth, Silvestre teaches.

"In this ecosystem, we can see the grandfather of our grandfather," Silvestre said.

Guides at the Chaxa say they've noticed dropping water levels in the lagoon but they have no data. SQM, which donated 40 million pesos to the lagoon's official designation as a reserve in 2006, operates the water monitoring station there.

That same year SQM issued its first "sustainable development policy," began a hydrological and biological environmental monitoring plan while winning new rights for increased extraction in the Atacama salt flat, according to the company's 2015 sustainability report.

Wilfredo Cruz, the elected indigenous president of Toconao between 2000 and 2005, said he fought with the government's development bank for two years to secure Chaxa's designation as protected land.

But the Chaxa as only a reserve, with less conservation protections than a national park, for instance.

“A national park you can’t touch. But a reserve, you can,” Silvestre said. “You have to believe in the ethics of those in charge, and that happens all over the world.”

The job of a town president is to guard not only the water and land, but also local employment, Cruz said. The Chaxa draws tourists through town and employs 10 local people, he said.

Cruz formerly worked as an electrician for both copper and lithium mines but gave up that life to start a small vineyard and hostel business in Toconao. In the end, he said, I didn’t like working for the mines because “it’s invasive and destroys everything.”

Sixty years ago, before the world had its sights on lithium, Toconao was a stable producer of vegetables and fruits for the region, Cruz said. Local farmers sold their produce to supply the copper mining town of Chuquicamata, 85 miles northwest of the town.

Toconao sits 2,485 meters above sea level. When it comes to irrigation, gravity was its greatest friend.

A system of ancient canals thread from the Jere River, fed by the Andes mountains, to orchards in the oasis town. Farmers traditionally shared water from the canal using a series of metal shutters to force the flow into each orchard. Irrigation was done by flooding the orchard, Cruz said.

Now just a few traditional orchards remain, mostly as hobby plots or out of nostalgia. Olga Liendro still tends to her grandparent’s orchard, growing cactus fruit, quince, carob and oranges brought by Spanish invaders. The town elects a “water mayor” to oversee the process, a job that really measures up to chatting with neighbors for an afternoon.

“But now there’s too much drought and (agriculture) is no longer profitable,” said Cruz, whose vineyard operates on a modernized irrigation system, a technology most can’t afford.¹¹

Toconao’s elderly residents note a change in the climate, too.

Luisa Zulieta, 80, lived in Toconao for the last half of her life. Her gift shop is a common stop for tourism agencies. Visitors can buy alpaca ponchos made on Zulieta’s loom from the llamas she keeps behind the storefront.

Two of her sons work at the lithium mines. But she’s noticed a change in the climate, in the frequency and force of the rains.

“When it rains, it causes much more damage than before,” Zulieta said. “The water runs and carries orchards, houses and whole trees with it.”

Nowadays, it seems like either there’s too much water or not enough.

In 2012, torrential rains caused violent flooding that ripped down the Jere Valley. Cruz posted a video of the muddy destruction to YouTube. The Chilean government issued a red alert in May of 2014 alerting towns in the region to evacuate stream and river banks.

That same year, Cruz assisted in a ribbon cutting ceremony for a new water treatment plant to remove arsenic from drinking water. Toconao needed more water so it opted to combine its traditional water source with that of another valley, though it carried a concerning amount of the toxic element, he told a reporter.¹²

SQM noted the event in a report but failed to mention the arsenic.¹³

Instead the company cited government statistics: that in 2003, 93 percent of the community had access to the public water system. That's not entirely accurate. The government's full report shows while 98 percent of urban residents in the region had public water access inside their home that year, only 58 percent of the rural population did.

The government's updated 2011 version of that same report fails to mention water access at all.

The world's leading policymaking body on climate change — the United Nations Intergovernmental Panel on Climate Change — published a special report this year outlining the risks of a warming world. Global temperatures have increased almost 1.5 degrees celsius since pre-industrial revolution and use of fossil fuels.

If the world warms to 4 degrees over that level, the United Nations predict widespread food insecurity and loss of rural livelihoods due to insufficient driving and irrigation water access. Though the UN has not accepted a report specifically about the climate risks in the Atacama region, it's considered part of the global "dust belt."¹⁴

Countries in the lower Southern Hemisphere subtropics, that includes Chile, will experience the "largest impacts on economic growth" due to climate change of even .5 degrees.¹⁵

The region's unique topography doesn't help Atacama's situation either.

The Atacama lies in what's called a rain shadow, an area that's dry because surrounding mountains block the passage of rain-producing weather.

¹² Toconao inauguro su nueva planta de tratamiento de arsenico (2014, August 29). In *Region2.CL*. Retrieved from <http://www.region2.cl/toconao-inauguro-su-nueva-planta-de-agua-de-tratamiento-de-arsenico/>

¹³ Anexo I: Antecedentes relativos al area de emplazamiento del proyecto (2003). In *SQM Salar S.A.* . Retrieved from http://bibliotecadigital.ciren.cl/bitstream/handle/123456789/6625/CONAMA-HUM0850_v1.pdf?sequence=1&isAllowed=y

¹⁴ UNCCD. (n.d.). Chapter 12: Drylands. In *Global Land Outlook* . Retrieved from https://knowledge.unccd.int/sites/default/files/2018-06/GLO%20English_Ch12.pdf

¹⁵ Intergovernmental Panel on Climate Change. (2018). Summary for Policymakers. In *Global Warming of 1.5C*. Retrieved from https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

Under a new law, mining companies will have to consider the impact of their industry on climate change, according to Cristian Ruiz, a Chilean environmental law expert at the firm Carcelen, Desmadryl, Guzman & Tapia.

“Indigenous people think the mining companies are the culprit for everything but probably climate change is at fault too,” Ruiz said.

Again, Cubillos doesn't see more reporting from the mines as a solution.

“How can I verify it? The state doesn't have the capacity to do investigations against the mining companies,” Cubillos said. “What the mining company says is the truth.”

Cubillos said without more pressure to limit water mining in the desert, the world is condemning the Atacama a “sacrifice zone.”¹⁶

Part VI: California's intermittency problem

California is using lithium to solve its renewable energy storage problem, called “intermittency” by energy industry wonks. Intermittency refers to periods of time when renewable energy sources, like the sun and wind, aren't available to power the grid. It can be a thick cloud momentarily blocking the sun or the hours between sunset and sunrise.

Economists know this phenomenon as the “duck curve” because when plotted on a graph, the average amount of solar power generated and used over a 24-hour period looks kind of like the outline of the waterfowl.

Here's the problem: The sun produces the most energy at midday, when most people are at work and energy demand is low. When everyone returns home from work in the evening, energy demand shoots up but solar generation drops.

There isn't enough technology to store the sun's energy after it sets. This has utility companies worried.

As California adds more solar power to the grid and writes legislation demanding utilities use it, solar energy goes to waste because there's not enough storage capacity. Like in March of 2017 when California paid Arizona to take the excess electricity its residents weren't using in order to avoid overloading power lines.¹⁷

Meeting evening energy demand requires an army of power plants, mostly fueled by natural gas, that are idling until late afternoon when they have to rapidly inject power onto the grid.¹⁸ That

¹⁷ Penn, I. (2017, June 22). California invested heavily in solar power. Now there's so much that other states are sometimes paid to take it. *Los Angeles Times*. Retrieved from <https://www.latimes.com/projects/la-fi-electricity-solar/>

¹⁸ Sivaram, V. Pg. 75.

means Californians pay for a fleet of generators to wait around until they're needed, inducing wear and tear on power plants that work much better if its producing at a gentle rate all day.¹⁹

If California wants to claim its 100 percent renewable, it will have to cut-out natural gas plants entirely.

Daily intermittency is one problem. There's seasonal intermittency to consider, too. It's not much of a threat for sunny California, but in some regions of the country solar radiation in the winter is less than half of that in the summer.²⁰

Storing solar energy for entire seasons is doubly difficult. It's too expensive, several times the cost of the existing power system. Pumped hydro storage is the only known technology that possesses seasonal storage capacity. Electricity pumps water uphill from a low reservoir to a higher one. The water can be released downhill through a turbine when there is a need for electricity. Still, it's difficult to find new, cost-effective hydro sites that are environmentally-friendly.

But producers can't get lithium out of the ground fast enough to meet that demand, causing uncertainty on Wall Street and higher prices. Meanwhile, new mining companies are scouring other salt flats for more sources of high-grade lithium.

"There are countless companies and very, very few viable projects because the market is so new it lacks the ability to distinguish bad assets from good assets," said Emily Hersh, who closely follows the lithium market for her consulting company DCDB Group.

Before you can start taking lithium out of the ground, you've got 10 years of "extremely high risk, extremely expensive mineral exploration," Hersh said. "The risk of not finding what you hope or that the market shifts... it's unavoidable."

On May 8, Canadian company LiCo Energy Metals announced in February that it would abando plans to explore a lithium project in the Purickuta in the northern sector of the Atacama salt flat. The company cited multiple "delays with exploration plans" which included opposition from the indigenous community.²¹

The company said it "(did) not see any way in which this project or property can be realistically explored or developed in the future by any corporate entity."

Local indigenous political clout is starting to gain a power foothold against these projects.

¹⁹ Sivaram, V. Pg. 76.

²⁰ Sivaram, V. Pg. 231.

²¹ Metals & Mining: Global mining industry outlook, what are the expectations? (2018, November 12). In *S&P Global Market Intelligence* . Retrieved from <https://www.spglobal.com/marketintelligence/en/news-insights/videos/global-mining-industry-outlook-what-are-the-expectations>

A rising mining opposition group called “Atacama Somos Todos,” “We are all Atacamenos,” staged a demonstration May 27 at the 2019 Exponor, an international technology and innovation show for the mining industry in Antofagasta. Indigenous members took over the stage with a huge banner bearing a painting of a dead flamingo next to a lithium battery and a dripping faucet in the salt flat. They sang songs, beat drums and played guitars in front of a rows of suited businessmen and women. Two people were arrested.²²

“We will defend Atacama. We are not a sacrifice zone,” the group said.

Part V: The uncomfortable history of US in Chile

The rush to mine lithium, sometimes called “white gold,” echoes the long and repetitive history of U.S. interests in the natural resources of Latin America.

In Chile, first, it was copper. New York’s Daniel Guggenheim, the son of first-generation Swiss immigrants, obtained rights to the country’s most prolific copper deposits in 1899. Copper mining persists at the original Guggenheim’s site today, now called Chuquicamata a 1.3-kilometer crater in the ground north of the city of Calama. All of the surface copper within the mine’s current limits is gone, so miners are digging tunnels for subterranean copper.

After Guggenheim, U.S. natural resource interests in Chile expanded. Those interests were challenged in 1970 when the socialist, yet democratically-elected leader, Salvador Allende took power. Allende favored policies that kept sectors of the economy under state control.

He nationalized the copper mining industry away from foreign ownership via a constitutional amendment. At that time, the mines, smelters and sales organizations were owned wholly or in part by U.S. companies.²³ It was an unpopular leader change in Vietnam War-era United States. As a 1971 *New York Times* article put it, copper was key to financing Chile’s “transition to socialism” under Allende.

The Nixon administration supported, perhaps even directed, replacing Allende with a militant dictator via a coup d’état in 1973. Despite heinous crimes against his own people, the new dictator, Augusto Pinochet, favored free markets and the privatization of natural resources. Foreign companies swooped in to lease land, mineral and water rights from underneath the Chileans who lived and relied on them.

Raw material exports was and remain the largest source of revenue for the Chilean government.

Chile is the top global exporter in copper ore. It produced about 28 percent of global demand in 2017, according to statistics from the Observatory of Economic Complexity, a lab based at the

²² General, E. (2019, May 27). Dos personas detenidas tras manifestación contra la contaminación en la inauguración de Exponor. In *El Regionalista*. Retrieved from <https://regionalista.cl/dos-personas-detenido-tras-manifestacion-contra-la-contaminacion-en-la-inauguracion-de-exponor/amp/>

²³ De Onis, J. (1971, April 11). Chile: Copper Is the Color of Allende's Mandate. *The New York Times*. Retrieved from <https://www.nytimes.com/1971/04/11/archives/copper-is-the-color-of-allendes-mandate-chile.html>

Massachusetts Institute of Technology. Copper now produces one-third of the Chilean government's annual income.²⁴

It's both a symbol of national pride (copper countertops glimmer back at travelers at the Calama airport) and the quiet source of blame for income inequality and public health crises in mining towns. One resident in Calama—the town where most Chuquicamata workers live— told me the city suffers from the highest suicide rates in Chile. And there has been documented arsenic leakage from mining sites into sources of drinking water.

The International Energy Agency predicts global desire for copper will experience a fifty percent increase by 2030 to meet demand due to the explosion in the renewable energy industry.²⁵ It's a key element in conducting electrical current in batteries, charge ports and wiring.

Conventional cars contain up to 49 pounds of copper while hybrid electric vehicles contain almost double that. Plug-in hybrid electric vehicles, like the Chevy Volt and Tesla's new Model 3, use over 130 pounds. An electric bus contains 814 pounds, most of which is used in the battery.²⁶

Chile is also the top global exporter of lithium carbonates, accounting for a whopping 63 percent of the market. Once again, the U.S and now Canada and China are capitalizing on this resource.

US-owned Albemarle Corporation is headquartered in Charlotte North Carolina. Its lithium mine lies in the Salar de Atacama, just west of Peine, a small indigenous community built along a mountainside. Luther C. Kissam IV, chairman, president and CEO, made a reported \$8.5 million off the company in 2017 including salary, stock options and other earnings.²⁷

SQM, which stands for Sociedad Quimica y Minería de Chile, is a chemical and mining company that has operated in the Atacama salt flat since at least the 1980s. Pinochet, the Chilean dictator, gave control of the company's contracts in the Atacama salt flat to his son-in-law Julio Ponce Lerou. By 2010, SQM was extracting potassium from the subterranean brines.

Strangely, it's historical investment in the Chilean lithium industry is not highlighted in its most recent annual report to the U.S. Securities and Exchange Commission.

However, reports made to the Chilean government by the company show mining rights in Atacama are leased to SQM until 2030. It also holds water leases which allow the company to have a "supply of water from rivers or wells near our production facilities sufficient to meet our current operating requirements."

²⁵ Bennett, N. (2019, January 29). Global energy transition powers surge in demand for metals . In *Mining.com*. Retrieved from <https://www.mining.com/global-energy-transition-powers-surge-demand-metals/>

²⁶ "Copper Drives Electric Vehicles." , Copper Development Association, Inc. , 2017, www.copper.org/publications/pub_list/pdf/A6191-ElectricVehicles-Factsheet.pdf.

²⁷ Corporation, A. (2018). Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934: for fiscal year ended in December 31, 2018.. In *Form 10-K*. N.p.: U.S. Securities and Exchange Commission. Retrieved from <https://investors.albemarle.com/static-files/52140f9d-202c-438b-9833-84728f1c5c2c>

Lithium is protected under Chilean law as it is considered a “strategic” mineral used for nuclear fusion. Thus, SQM reportedly has annual quotas that limit the total tonnage of lithium that can be sold. The Environmental Law of 1944 (amended in 2010 “Ley sobre Bases Generales del Medio Ambiente”) governs environmental protection measures mining must consider. But the company does not specify what “modifications” it has made to “eliminate any adverse impacts.”²⁸

According to its 2017 report to the SEC, there are no international regulations that apply to its lithium production operations.

More recently, Chinese company Tianqui purchased the majority of shares (from a Canadian company) in SQM last year, an effort Lerou pursued in the courts to no avail.

On the ground, it’s obvious SQM operates quite differently from it’s U.S.-owned neighbor Albemarle. Many workers at Albemarle are from the indigenous neighboring town of Peine. They pile on buses or take Chile’s distinct candy-apple red mining trucks from home to their shift at the mine located a few miles west of town in the flat.

SQM, however, built a camp right outside the entrance road to the mine itself. Workers travel by bus between the camp and the salt flat, sleeping and eating between 12-hour shifts behind the camp’s guarded gates.

The company had its share of public legal trouble. In January of 2017, the company settled a lawsuit filed by the U.S. Securities and Exchange Commission regarding accusations that from 2008 to 2015 the company made \$14.5 million in improper payments to Chilean politicians, candidates and other individuals.

The payments were made using fake documents submitted to SQM by individuals who posed as legitimate vendors, court records state. The company agreed to pay \$125,000 to resolve other charges that it violated the Chilean Foreign Corrupt Practices Act and agreed to a “cease-and-desist” order. It also paid another \$30 million to settle parallel civil and criminal charges.²⁹

At the end of that debacle, then-Chilean President Michele Bachelet appointed a commission to consider a national lithium policy. Its final proposal proposed creating a state-owned lithium company, like Chile’s state copper company, CODELCO. It also proposed a new royalties structure and to the dismay of Atacama’s largest companies, a review of the government’s current contracts with SQM and Albemarle.

So far none of these recommendations have moved forward. At least one attorney in Chile has said that the government is working on moving the contract review piece forward.

All of this throws more uncertainty at an already wobbly market for lithium.

²⁹ SEC. (2018, September 25). SEC charges former CEO of Chilean-based chemical and mining company with FCPA violations. In *U.S. Securities and Exchange Commission press release*. Retrieved from <https://www.sec.gov/news/press-release/2018-212>

Part VI: Lithium market troubles

Lithium market analysts write long blogs and produce hours-long podcasts on the unfolding of this mining industry. There are fears of both over production or under supply and volatile prices.

Three companies control over half of the lithium supply: Albemarle, Tianqi and SQM.³⁰ The price of lithium carbonate in October of 2017 reached \$26,000 a ton and dropped to \$11,000 a ton in just one year.³¹ The following year wasn't any better for the lithium market. Analysts said China overinflated prices on some lithium products, while others actually fell. Meanwhile hot electric vehicle sales over-hyped lithium demand forecasts. But lithium stocks were down 50 percent that year and many investors abandoned the market.³²

Investors had tough questions for SQM during a February call.

Joel Jackson, a capital market analyst for BMO, asked SQM to clarify how much lithium the company would produce this year.

“We thought it'd be about 70,000 tons. You said it will be a little less than 50,000 tons,” he said.

SQM's CEO Ricardo Ramos Rodriguez said production would center on the lower end but that the company hopes to more than double its capacity. Rodriguez told investors to think “long term,” into 2025 when SQM believes global market demand will reach 1 million tons.

SQM argues that it is being unfairly held back from producing more lithium by an outdated government regulation. The nuclear commission also restricts the total amount of lithium that companies can produce through a quota; SQM can't extract more lithium from the salar than it agreed in the terms of its lease with the government in 1993. This has led to the bizarre result of SQM pumping lithium back into the desert to avoid overshooting its quota, even as the price of the commodity has been rising.”³³

“I think lithium will grow,” Hersh said. “But from an investment standpoint, it's scary.”

³⁰ Lombrana, L. (2019, February 21). Lithium Market Cheers as Top Supplier Sees Demand Driving Higher. In *Bloomberg Markets*. Retrieved from <https://www.bloomberg.com/news/articles/2019-02-21/lithium-market-cheers-as-top-supplier-sees-demand-driving-higher>

³¹ Lithium price spotlight (n.d.). In *Fastmarkets MB*. Retrieved from <https://www.metalbulletin.com/lithium-prices-update>

³² Bohlsen, M. (2019, March 8). 2019 Lithium Themes To Watch Out For. In *Seeking Alpha: Commodities market outlook*. Retrieved from <https://seekingalpha.com/article/4247506-2019-lithium-themes-watch>

³³ Lithium: Chile's buried treasure (n.d.). In *Financial Times*. Retrieved from <https://www.ft.com/content/cde8f984-43c7-11e6-b22f-79eb4891c97d>

Part VII: New and promising tech's funding problem

The US is languishing behind its competitors in terms of investment in these new energy technologies. A transforming energy mart based on lithium also means US dependence on foreign entities, which is not the political agenda of the Trump administration.

On May 14, a bipartisan group of US lawmakers rather quietly forward plans to take stock of metal reserves within the country's borders and streamline the permitting process for electric vehicles. It's an effort to challenge China's dominance over supply chains in the booming green energy market.³⁴ More domestic production of lithium could reduce the carbon footprint generated abroad, but it would simply shift those burdens home.

Some energy analysts believe the rise of lithium-ion batteries threatens to lock out new contender technologies.

"The production arms race among lithium-ion battery producers is on track to reduce costs through enormous scale and oversupply, while creating a moat around the industry that emerging technologies cannot cross," said Varun Sivaram, a former energy policy advisor to the mayors of both Los Angeles and the governor of New York, in his book "Taming the Sun."

Sivaram envisions two futures in his book: one where governments fail to invest in energy research and good storage technology subsequently fails to manifest in time to save the planet; and another where the United States leads global investment in innovation to stabilize the climate.

There are other, less intrusive, storage technologies out there but they too fail to make it out of the laboratory due to a lack of government investment.³⁵

There are teams of graduate students working projects to make lithium ion batteries more efficient, lightweight and less dependent on rare earth metals mired in social conflict. Shirley Meng's Sustainable Power and Energy Center at UC San Diego recently won a \$2.5 million grant from the U.S. Department of Energy to develop a cobalt-free lithium ion battery.

"There's such a limit on the technology available that there's not really a choice. Every battery that works well has cobalt in it," said Hayley Hirsh, a graduate researcher in Meng's lab.

According to the US Geological Service, as of 2016 the country was fully reliant on foreign sources for 20 mineral commodities, a 250 percent increase in 60 years.³⁶ Seventy four percent of

³⁴ Scheyder, E. (2019, May 14). U.S. Senate moves forward on plan to develop electric vehicle supply chain. In *Reuters*. Retrieved from <https://finance.yahoo.com/news/u-faces-hurdles-push-build-062814097.html>

³⁶ Risk and Reliance: The U.S. Economy and Mineral Resources (2017, April 12). In *USGS*. Retrieved from <https://www.usgs.gov/news/risk-and-reliance-us-economy-and-mineral-resources>

US cobalt is imported by China, Norway, Finland and Japan. It's 50 percent reliant on Chile, Argentina and China for lithium.

Sodium, however, is not on that list and that's where Hirsh's research interests lie. Hirsh is developing a sodium-based battery she hopes could eventually be used for large-scale storage batteries that California's grid needs. But she's an army of one at UCSD's nano engineering lab.

Her research is considered "basic" and funded by the National Science Foundation.

"I think it's considered basic because there's not very much research on it," Hirsh said. "DOE will put money into something they perceive will happen, or they know is possible."

The US has plenty of sodium reserves that could potentially be used for batteries. A mine in Wyoming's southwestern corner is the world's largest deposit of trona, or sodium carbonate that's processed into soda ash or baking soda, as it's commonly known. The mine produced 17.4 million tons of it and employed 2,225 people in 2018. At its current rate of operation, the 40-billion-ton reserve could last 2,350 years.³⁷

Hirsh is a socially-minded scientist, a member of Engineers Without Borders and president of the campus energy club. She cheerily volunteers to give tours of Meng's lab and, in good humor, discusses the hurdles she gracefully tries to clear alone in her research.

For instance, batteries need electrolytes to function. Electrolyte for lithium batteries is manufactured by multiple companies and sold in bulk to institutions. Sodium needs a different type that's not produced commercially so Hirsh has to make her own. Lithium is also sold pre-cut, ready to be placed in the test batteries used in labs. Hirsh's sodium, which is sticky like cookie dough, has to be rolled and cut into the tiny circles necessary for her tests.

"I told a visiting scholar who was struggling with the material that he had to go home and learn to make cookies," Hirsh laughed.

Hirsh hopes to get a grant soon to travel to Chicago's Argonne lab to test her battery recipe. She also hopes Meng's lab will receive enough funding soon to hire a second graduate student on the sodium project.

"There's not enough lithium and cobalt out there to replace all the cars and grid energy storage," Hirsh said. "We'll have to use something else and that's where, I think, sodium will come in."

Lithium could also eventually lose relevance to its neighbor on the periodic table: hydrogen. The colorless, gaseous fuel is the most abundant in the universe and releases energy when combined with oxygen. Its byproduct is—conveniently for a drought-stricken places—water. Though most production of hydrogen fuel today relies on fossil fuels, solar energy could be harnessed to split

³⁷Trona (2018). In *Wyoming Mining Association*. Retrieved from <https://www.wyomingmining.org/minerals/trona/>

water molecules and produce hydrogen, creating a truly renewable fuel with no harmful emissions in production or use.³⁸

Hydrogen likely won't be sufficient to support the transportation sector, Ferry said. But it could replace what's called "stationary storage," the large-scale battery warehouses being built by utility companies switching to renewables. (ASK MIKE FERRY TO EXPLAIN THE PHYSICS BEHIND THIS THOUGH - SOMETHING ABOUT HOW THE PHYSICS OF H DOESN'T MAKE THIS FEASIBLE WITH ELECTRIC CARS, FOR INSTANCE?)

Still, energy analysts like Varun Sivram envision a world powered by tech that converts sunlight directly into hydrogen fuel for vehicles, ships and aircraft and other products like fertilizers and plastics.³⁹ Harnessing the sun—which beams down more energy to the Earth's surface in an hour than the world uses in a year—is the solution to saving the planet from catastrophic climate change, Sivram argues. That will require "sharply increasing investment in innovation," which at the moment is lacking.

There isn't much time to spare.

The world has a dozen years before global warming exceeds a level that doesn't worsen risks of droughts, floods, extreme heat and poverty for hundreds of millions of people, according to the world's leading climate scientists in a report issued for the United Nations last October.⁴⁰

"We are right on the precipice of some pretty bad stuff in terms of global warming," said Corey Gabriel, executive director of Scripps Institution of Oceanography's climate science and policy program. "It's going to get worse unless we very, very quickly find a way to remove (fossil fuels) and transition to renewable energy."⁴¹

³⁸ Sivaram, V. (2018). *Taming the Sun*. Woods Hole, MA: Massachusetts Institute of Technology. Pg. 285.

³⁹ Sivaram, V. Pg. 9.

⁴⁰ Intergovernmental Panel on Climate Change. (2018).

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