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Research Paper

Lithium and its role in the new energy transition

Bachelor Thesis

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List of Abbreviations

LIB	Lithium-Ion Battery
EV	Electric Vehicle
ICE	Internal Combustion Engines

List of Tables

Table 1 The hierarchy dependence behind the energy transition, lithium, lithium-ion batteries and electric vehicles

Table 2 Time dedicated (in minutes) by each interviewee explaining the biggest challenges of the lithium industry based on keywords

Table 3 Number of times that keywords related to the opportunities that the lithium market will bring

List of Figures

Figure 1 Depiction of the “lithium triangle”

Figure 2 Quick facts of the LiTas lithium recovery system being developed by the company Energy x

Figure 3 Image displaying the supply chain of lithium-ion batteries with the companies inside each stage and location.

Figure 4 Table displaying the advantages that lithium-ion batteries have over lead acid batteries

Table of Contents

Declaration of Authorship	2
Acknowledgements	3
List of Abbreviations	4
List of Tables	5
List of Figures	6
Table of Contents	7
Abstract	9
1. Introduction	10
2. Literature Review	12
Current energy transition:	12
Lithium overview and extraction :	13
Biggest reserves and producers:	14
Importance of lithium-ion batteries:	14
Environmental impact of Lithium mining and lithium batteries:	15
Socio-economics related with lithium mining:	16
Supply Chain:	16
Financial history performance and future:	17
Energy Storage:	18
3. Model:	18
Picking a research methodology:	19
Qualitative research Vs Quantitative	19
Research Strategy	19
Data Collection	20
Interview process:	20
Interview insights:	21
Teague Egan:	21
Daniela Sanchez :	22
Chris Berry:	23
Data analysis and limitations	23
4. Findings	25

5. Conclusions, Limitations, and Recommendations	28
6. References	31
7. Appendices	37
Full interview with Teague Egan, Energy X CEO:	37
Full interview Daniela Sanchez Professor at Cambridge University	41
Full interview with Chris Berry lithium supply chain consultant.	48
Email template sent:	56
Questionnaire	57

Abstract

Climate change has been a persisting problem for society for many decades now. It is an issue that is deteriorating the world's ecosystems and disrupting human civilization. It is not until recently that governments and private companies have started to implement and set solid goals to mitigate this effect. Two major areas of improvement are the electrification of the world's energy supply and decarbonization of the economy, and the way they are being done is by shifting from internal combustion vehicles (ICE) to electric ones and implementing energy storage systems used to harvest clean energy. This enormous change depends heavily on the mining and sourcing of one element called lithium. Lithium is a raw material that is currently gaining more relevance in the world economy and it is forecasted to become a major player for a clean energy transition. Lithium is a constituent of lithium ion batteries (LIBs) which are used for the mobility and energy storage sectors. As it stands right now the entire lithium industry is in its infancy compared to oil and coal companies and in order to cope with the future demand this entitles an incredibly fast evolution of the lithium industry. This research paper will talk in detail what the role of lithium is in the energy transition, analyze the shortcomings that the industry is facing and identify future opportunities that will arise during this transition. Additionally, the true environmental impact of lithium mining and LIB usage will be discussed.

“Companies that don’t adapt [to the low-carbon economy] – including companies in the financial system – will go bankrupt without question. [But] there will be great fortunes made along this path aligned with what society wants.”

-Mark Carney, 2019

former governor of the Bank of England

Keywords: [Lithium, Lithium-ion, Electric vehicles, energy storage systems, clean energy, decarbonization, climate change]

1. Introduction

Climate change has been a persisting problem for human society for over three decades and every year it becomes an even greater problem (Andrew Revkin, 2018). It is not until recently that many governments and corporations have taken this issue more seriously. Before companies would think on how their operations affected the world but now they think on how the future of climate change will affect them. This has sparked a need for an energy transition, which consists of leaving behind the traditional oil, carbon, and gas based energy sources and changing them for clean and renewable energy (Bloomberg,2020). Governments have also made this shift by creating regulations and goals into the future to ensure decarbonization in several industries like farming, electricity and heat, mobilization, and manufacturing. This whole process is extremely complex as it requires a big change and enormous collective effort to make it possible, but as climate change is becoming more prominent and hazardous for human existence these entities have started to take steps in order ensure decarbonization. An energy transition has begun.

The main sources of greenhouse gases which cause climate change are the following: heating (31%), agriculture (11%), transportation(15%), forestry (6%), and manufacturing (12%) and energy production of all types account for 72% of all emission (World resources institute, 2017). These industries produce around 36 billion tonnes of greenhouse gases every year (Hannah Ritchie, Max Roser, 2018). There is one element present in the periodic table that is able to mitigate, on a great level, two of these sources of pollution, transportation and energy production. That element is Lithium. Lithium is a common metal that can be found on many places on earth, including sea water (Kyle Pennel, 2018), and it has the potential to disrupt the energy storage and mobility sector on a global scale. This metal is one of the main ingredients used to produce LIBs present in electric cars and the ones used to store energy produced from renewable sources. Many industry professionals forecast the demand for lithium ion batteries to rise in the next decade as technology has made the production of these batteries economical. Lithium has the potential to change two immense industries: mobility and energy storage.

Although the forecast for the demand of this element is on the upside there are still many factors and problems that need to be tackled in order for that rise to happen. One of the most relevant ones is the current infrastructure needed to cope with the soaring demand that is forecasted (Chris Berry, 2020). The current supply chain of lithium ion batteries is global, meaning that their production requires a joint effort from people and companies all around the world which is a weakness thanks to Covid-19 (Berry, 2020). The main sources of raw materials are concentrated in South America, specifically in Chile, Argentina, and Bolivia (Andrew Fathrope, 2020). This area of the world is often referred as the “lithium triangle” (See figure 1).Then this material is then shipped to China where 90-95% of the anodes and cathodes needed for batteries are produced and then they are shipped to either renewable energy companies who use the batteries to store energy or to original equipment manufacturer OEMs (Berry, 2020). Some of the additional problems are the

extraction, decentralized sources of raw materials, socio-political issues and environmental impact.



Despite all of the problems that Lithium faces, as mentioned before, expert's forecasts are still rooting for a high demand for this element and there are clear signs that support that claim. For example many OEMs have made their entire line ups of vehicles with either hybrid or fully electric variants with future plans to fully shift their cars to fully electric as early as 2022 (Piers Ward, 2020). Also there are many governments stating that they will ban ICE vehicles by certain dates. Additionally there are huge efforts to shift all public transportation to battery powered vehicles.

All these future plans and regulations rely on things alone, and that is the production of lithium ion batteries(LIBs). The relevance of this element is already starting to rise and will have an even greater boom in the following decade (Berry, 2020). The change that this shift will bring to the world is big and an incredible step in the right direction to mitigate climate change. Furthermore, it will bring a huge opportunity to individuals and investors.

This paper will cover what is the current energy transition that the world is facing and what governments and corporations are doing to mitigate climate change. This will include changes that companies are currently making to achieve their goals, specifically in regards to decarbonization. Actions like OEMs shifting to EVs and governments placing higher budgets to address decarbonization and electrification are clear indicators of what the future will bring. Although this change is positive the requirements that are needed to achieve the ultimate goal of a clean world come at a cost. The paper will be divided into the most important factors that need to be taken

into account during the mining, production, and implementation of LIBs. It will begin by providing context and explaining in detail what the available literature sees at the biggest challenges and opportunities of the lithium industry. The main questions that this research aims to answer are the following: What is the role that lithium will play in the energy transition? What areas of the industry present the biggest challenges? What is the future of lithium? What opportunities will it bring? and will lithium really help mitigate climate change?

The type of research that will be used in this paper is qualitative method. It will use primary and secondary sources. For analyzing the data content analysis will be used to compare and contrast the information gathered in the literature review with the data collected in the interviews to correctly identify the most relevant topics needed to answer the research questions. The main limitation of this research is the small sample size of interviews, three professionals were interviewed but this weakness is overcompensated by the high profile that these participants have in relation to the lithium industry.

2. Literature Review

This section of the document will, firstly, give some background on the literature available on the current energy transition along with basic facts about lithium. Consequently, all the implications related to the creation of lithium batteries will be explained along with the arguments presented by available literature. The main goal of this section is to unite all the research that is available on the wide array of sectors that lithium has to go through in order to form part of the energy transition. The world's shift from fossil fuels to renewable energy is an extremely intricate and complex process and in order to fully understand how lithium will take part in this process and to identify the opportunities and threats the entire landscape is needed.

Current energy transition

It is clear that modern society depends heavily on fossil fuels in order to power its energy needs. Since 1971 up until recently around 80% of the world's energy consumption came from fossils ([Akshat Rathi, 2017](#)). This has created a serious imbalance for the environment mainly due to the greenhouse effect. Though this phenomenon was first discovered in 1859 ([Megan Darby, 2016](#)) there has not been any major effort to overcome the problem just until recently. One of the first steps signaling change was the creation of the Paris agreement which, according to the United Nations, has a goal of keeping the world's temperature below 2 degree celsius above pre-industrial levels. This agreement was signed in 2016 and despite its diplomatic success, the overall efficacy of it has remained under heavy observation ([Raiser et al, 2020](#)). Now, within the past couple of years big investment firms and companies like S&P Global and International renewable energy agency (IRENA) have established a term called energy transition.

In the words S&P Global (2020) “Energy transition refers to the global energy sector’s shift from fossil-based systems of energy production and consumption, including oil, natural gas and coal to renewable energy sources like wind and solar, as well as lithium-ion batteries.” The main factors that this company has identified that have caused an increase in adoption of these clean sources are: creation of investors’ confidence for the future, new technological advances and reduced cost for these new clean energy sources compared to its carbon alternatives. Additionally three big shifts they foresee in the future are the transition to electric vehicles, electrification of public transportation, and energy storage from clean sources.

IRENA’s definition of the energy transition is the pathway towards transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century. They see this as an active and ongoing movement.

Based on recent trends and analysis it wasn't until around 2018 that companies and governments have really started to take this issue seriously and even more so now in 2020. For example many countries inside the European Union (EU) like Denmark, Iceland, Ireland, Spain, Sweden, France and many more have established a goal to eradicate the sale of (ICE) vehicles between 2032 and 2040 ([Sandra Wapperlhosrt, 2020](#)). Most of the countries that joined this motion did so between 2018 and 2020. Additionally, in the United States, the west coast democratic party recently introduced a federal legislation that aims to ban the sale of ICE vehicles by 2035 ([Breana Noble, 2020](#)). Similarly, private companies and markets have also been getting on board this sustainability trend. This newly adopted energy transition comes both from companies and governments and it can be identified by looking at a series of new goals and regulations which have been born between 2018 and 2020.

Lithium overview and extraction

Terence Bell (2020) stated that lithium is part of the alkali metal group and it is characterized by its low weight and soft texture. It is a fairly common element that can be found in many places around the world. Due to its high reactivity with air and water it is not found in pure form in nature, which is why it needs to be processed (Bell, 2020). The most common places where lithium can be found are in salt brines, mineral springs, and igneous rocks. The most relevant use of this metal is for the creation of LIBs which can be found in mobile phones, tablets, laptops, and electric vehicles (Bell, 2020). Its other uses include creation of industrial glasses for special uses, multi purpose high temperature lubricants, air conditioning systems, and in drug form to treat manic depression (Bell, 2020). The processing of this element depends on the extraction method. As mentioned before it can be found in salt brine or rocks. The extraction process of the former consists of extracting mineral rich brine from high salinity surfaces such as the salar de Uyuni located in Bolivia. The extract is then placed in a large evaporation pond where it is then exposed to sunlight over a period of months. Once the solution reaches a specific concentration it is then moved to a filtering plant where unwanted minerals such as boron and magnesium are removed. Finally, it is chemically treated to create a solution called lithium carbonate which is a

stable and thin white powder which can then be processed into several forms depending on its intended final use (Bell, 2020). The latter method of extraction is rock mining. This technique is characterized by its higher energy demands and additional material required to conduct the processing, even though rocks contain a higher concentration of lithium. The reason why this alternative needs more energy is due to a double heating process that the rocks have to thru. First they are heated to 2012 degrees fahrenheit then crushed and mixed with sulfuric acid and heated once again (Bell, 2020). The last steps consist of adding one last chemical, sodium carbonate, then one last heating process and finally filtering the solution to be left with the end product.

Biggest reserves and producers

The US Geological Survey (2019) stated that there is an estimated total of 80 million tons of lithium reserves worldwide. The countries with the highest amount of lithium in the world are Bolivia, Argentina, Chile, United States, Australia, and China with 21, 17, 9, 6.8, 6.3, 4.5 million tons respectively (Andrew Fawthrop, 2020). The first three countries represent a well known area of mineral rich brine that is titled the “Lithium Triangle” It is important to note that the biggest reserves, located in the first three aforementioned countries, require extraction through brine. When it comes to the producers of lithium Australia takes the lead, despite it being number four on the previous list. In 2019 this country was responsible for a total output of 42,000 tonnes (Shankra Besta, 2020).

Importance of lithium-ion batteries

The reason why lithium-ion batteries are so relevant is due to their unique characteristics and properties. Tennat Company (2019) wrote an article stating the five main advantages of these batteries. They are: low maintenance, longevity, easy and fast charging, safety, and higher efficiency and when compared to a traditional lead acid battery the advantages are clear (see figure 2). This makes them extremely useful for the use in EV and clean energy storage systems.

Benefit Categories	Lithium-Ion (Li-on)	Lead Acid (Water Based) Battery
Maintenance	X	
Longevity/ Lifetime Value	X	
Charging	X	
Safety	X	
Sustainability	X	
Cost		X

Environmental impact of Lithium mining and lithium batteries

As the energy transition moves towards electrification the demand for lithium-ion batteries will rise, meaning that more raw materials will have to be mined out of the Earth's surface. As mentioned previously the two main ways to extract lithium is through brine or hard rock mining. Flexer, Baspineiro, and Galli (2018) have stated that this electrification trend will only be viable if there is sufficient supply of raw materials. Additionally, in their observations, they mention that it would be an inconsistency if this additional supply for a more sustainable world would be done through non-sustainable mining procedures. Flexer et al (2018) focus their study on the brine lithium extraction method. This process is characterized by highly demanding water needs and its chemical intensive procedure and slow processing.

Currently most of the world's lithium supply is located in the lithium triangle. Mie obbekaer (2019) conducted a study that looked into the water needs of lithium extraction. Her findings showed that mining companies use from 400 to 2 million liters of water per kilogram of lithium. The US company Albermale submitted the lowest figure of 400 liters, while most of the South American companies, located in the triangle steered towards the higher figures. This is especially worrying as most of the local communities where these lithium mines are located also depend on the same water supply that is used for mining purposes. Furthermore, this creates an additional risk for the surrounding wildlife and ecosystems.

Another relevant topic that needs to be addressed is the environmental impact that EV adoption has on the world, specifically the carbon footprint. Nolan Sykes (2020) conducted extensive research to address the overall carbon footprint that an EV has in relation to an ICE powered car. This takes into account the manufacturing process and all throughout the lifespan of said vehicles. Initially the manufacturing process of an EV has a greater carbon footprint than its ICE counterpart, mainly due to the mining and shipping process required to build batteries. On average it takes approximately 8-10 metric tons of CO₂ emissions to build an EV, conversely an ICE powered vehicle takes 7 metric tons (Sykes 2020). Nonetheless, when comparing the overall carbon footprint, along the entire lifespan of both vehicles, the EV ends up being less detrimental to the environment. During the entire life of an ICE vehicle it produces a total of 57 metric tons of CO₂ and an EV 28 (Sykes 2020). This shows that despite the relative infancy in which the EV industry is at there is a positive result when it comes to the overall carbon footprint.

Waste disposal or recycling is another factor to take into account when mentioning LIBs in EVs. 2017 marked the first year EV sales reached a total of global sales of more than 1 million (International Energy Agency 2018) and by taking into account the average 10 year lifespan of an EV that means that the number of waste originating from EVs will be substantial. The recycling industry of LIBs is small; there are not many facilities available worldwide to dispose of these batteries in a feasible way. Gavin et al (2020) consider that this waste will create a sizable social impact in the future if it is not addressed correctly. Currently one of the best options is not to

recycle LIBs in EVs but rather reuse them. Over the years LIBs lose their ability to hold charge and after some time it becomes inefficient to continue their use in a vehicle. Nonetheless those batteries are still able to hold a substantial amount of energy and this represents an opportunity to use these batteries in energy storage facilities given them even more usefulness.

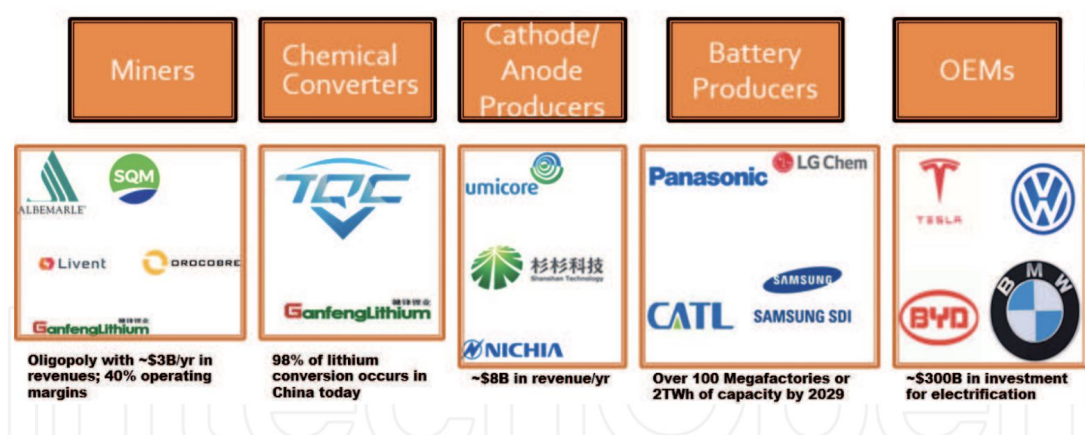
Socio-economics related with lithium mining

Datu Buyung Agusdinata et al (2018) have studied the overlooked aspects of lithium production. One of the biggest areas of concern is the socio-economic impact that this industry will have on the local communities of Chile, Bolivia, and Argentina. There are many ancestral tribes living in the andean region which have already started to suffer from the exploitation of resources. This is slowly revealing the one sided benefits that only provide profit for the government and international companies . The mining industry has already presented detrimental effects in these areas, especially in the salar de Atacama, where mining has used 65% of the region's water supply(Sykes 2020). Some local communities have been forced to move to other sites due to the water scarcity and the deterioration of the surrounding ecosystem (Datu Buyung Agusdinata et al, 2018).

Supply Chain

Chris Berry (2020), wrote an article comparing LIB's supply chain to the mythical creature of the Hydra. In Greek mythology the Hydra was a 9 headed creature that when decapitated two more heads grew back. The reason behind this comparison is due to the enormous complexity of LIB's supply chain. Similarly to the Hydra this supply chain has multiple stages and each one with its unique complexity. These stages are: mining, refining, cathode and anode production, battery cell and pack production (see figure 3). Lithium demand is set to grow in the following years as the energy transition continues. Berry (2020) predicts that the demand for lithium chemicals is set to increase to three times what it is now. This means that the entire supply chain needs to be injected with capital in order to make the transition possible. According to his calculations this sector needs an injection of 10 billion USD to ensure an efficient and timely supply. Additionally, two recent factors that have detained this capital from being injected are the USA and China trade war and Covid-19. As seen in figure 3 the whole task of creating LIBs is a globalized process with a high dependency on China in terms of adding value to the raw materials. China controls most of the chemical treatment process along with cathode and anode creation. The trade war that was ignited during US president Donald Trump's term and has slowed down the development of the LIBs chain. Nevertheless, now with a new president in play this trade war might be headed towards an end. Moreover, moving to the global health crisis that the world is currently undergoing due to Covid-19 globalisation is now seen as a threat. It is clear that interdependence between countries creates weakness in situations like the current one. This crisis has caused investor's confidence to go down and the supply chain has suffered from it as

no capital is being injected to avoid risk.



Financial history performance and future

Matthew Jhonson (2019) wrote an article last year explaining the decrease in stock price of lithium related companies and the price of lithium carbonate per tonne from 2016 to 2019. It was considered a counterintuitive behaviour from the markets as the EV production was set to increase in the following years. Ultimately, what happened was an oversupply of raw materials that was picked up by analysts and caused this price drop.

On the other hand the future of lithium as a raw material and stock prices should experience a rise in demand and thus price, while taking one big assumption in mind. That is that the prediction of increase of EV penetration formalizes (Berry 2020). This assumption should not be something hard to believe taking into account all the joint efforts being done by several nations and companies to decarbonize the economy. Currently there are clear examples of these efforts. There are major projects for the near future in Europe and the US to localize the lithium mining process to avoid being dependent on other countries to be able to keep up with the future demands. In Europe the company Infinity Lithium Corporation (ILC) is working with the Spanish government to create a rock mining project that aims to supply enough lithium to build 10 million EV (ILC, 2020). Additionally, the European commission (2020) is releasing one of the biggest recovery funds to all its members to address the economic recovery after Covid-19. This stimulus package, titled Next Generation EU, will total 750 billion euros of which 30% will be destined to address climate change and electrification. In the USA, in California specifically lies an immense lithium reserve that has the potential to bring 600,000 tons of lithium a year (David R Baker, 2020), the deserts area is being studied heavily to find a way to extract the material in a commercial way.

By analyzing the current market it is clear that it is full of opportunities. Two major factors that were bringing insecurity to this sector were the US election with the tantrum that President Donald Trump was giving by denying his loss and the global

pandemic (Jonathan Ponciano, 2020). Nonetheless, these two areas have presented major advances as the White House transition has been moving forward and the rollout of the Covid-19 vaccines. The Dow Jones industrial index showed the confidence that these advancements gave to the market by hitting a historical milestone on November 22, 2020 (Ponciano, 2020). Additionally green energy companies such as FuelCell Energy INC presented an incredible rise in stock price as President Joe Biden appointed John Kerry as his head of climate change (Investopedia, 2020). Furthermore, lithium ETFs such as Global X Lithium ETF's price have been rising rapidly during this year (Morningstar, 2020). This rise in price has also been accompanied by a rise in stock price of major the big three lithium mining companies: Sociedad Quimica y Minera de Chile, FMC Corp, and Albemarle Corp.

Energy Storage

Aside from EVs, energy storage systems are going to be another area which is going to be affected by the energy transition. As technology advances clean energy sources like wind and solar are becoming cheaper than carbon based energy. In some countries these clean sources are already cheaper (S&P Global, 2020). A report from Navigat research (2020) estimates that 85% of the energy storage systems are going to be using LIBs. This will also represent a sizable portion of the demand for lithium. Additionally there are big projects undertaken by private companies to decentralize the energy supply by transforming buildings into energy harvesters and allowing owners to store this energy with possibilities of reselling and becoming self sufficient. In Spain the company GreenWard is looking to implement a similar model, with many more companies doing it world wide.

3. Methods

The aim of this paper is to analyze the role that lithium will play in the energy transition and to answer all of the research questions mentioned in the introductory chapter. This is a very broad and intricate topic that spreads throughout many aspects of society. In the first section of this chapter the thought process behind picking qualitative and quantitative methods will be explained, followed by the creation of the research plan and the data collection method.

Picking a research methodology

Two of the main research methodologies in social sciences are qualitative and quantitative research. There are significant amounts of arguments to weather which one to use in specific situations. In the section the thought process behind picking a methodology will be discussed.

Qualitative research Vs Quantitative

The main focus of quantitative research is to focus on standardized methods with aims to measure a social phenomenon, pattern, or hypothesis based on numerical data. Earl

R. Baddie (2010) describes this method as a way to objectively measure data through statistical, numerical, or mathematical analysis data collected through polls, questionnaires, or surveys. Ideally in a method like this the goal is to determine the relationship between an independent variable and a dependent one. In order to successfully conduct a research using this method large amounts of data are needed.

On the other hand qualitative research can be defined as “a type of social science research that collects and works with non-numerical data and that seeks to interpret meaning from these data that help understand social life through the study of targeted populations or places.” (Ashley Crossman, 2020). The main thing to focus on in this definition is that it seeks to gather non-numerical data, when compared to quantitative research. Additionally, this is the research method that is best fit for an interview process, which can be conducted through several channels such as phone, online, or face to face. (Virginia Tech, 2018)

For this paper the decision was made to use qualitative research as one of the main goals was to gather information from industry professionals through interviews and compare their thoughts with the available data.

Research Strategy

From the start the decision was made to use both primary and secondary sources of information in this paper. This was done to ensure that sufficient relevant information was gathered. For the primary source of data the plan included conducting interviews with industry professionals that would be able to provide high levels of insights and value to the paper. To secure these interviews a process was thought out which included scouring the web for articles, books, and theses listed in renowned sites. This was done with the intentions of creating an excel sheet to write down the names of the authors and their contact information. The goal that was set for this part was to obtain a total of 50 possible candidates with a 50% reply rate and 10% acceptance rate. The last step of the process was to send them an email explaining the purpose of the meeting and paper. As for secondary sources the idea was to use the list of articles, books, and theses mentioned before as a base. Reputable business sites such as Bloomberg, Investing news network, and S&P Global were used.

After analysing the information that was gathered online it was clear that the research questions in this thesis required covering many factors and sectors to ensure a successful result. The desired profile of the individual consisted of people that were deeply involved in the lithium world. This included investors, advisors, journalists, company executives, professors, analysts, engineers, and suppliers. Not much emphasis was placed on gender, ethnicity, or age. Nonetheless the database did have diversity in mind, but in terms of their involvement in the supply chain of lithium, due to the broadness of the topic. The information gathered in these talks would then be compared and contrasted with the already studied information. By looking at the literature review there is a clear division of the most important topics that are related to the lithium in the energy transition. They are: current energy transition, lithium overview and extraction, biggest reserves and producers, importance of LIBs,

environmental impact of lithium mining and LIBs, socio economics related with lithium mining, supply chain, financial history performance and future, and energy storage.

Data Collection

The data that was ultimately collected in this thesis was the same as what the plan stated. For the primary sources three individuals were chosen to be interviewed. The goals for the contact database for possible candidates were much lower than the goals set in the plan. For the total number of possible candidates only 18 out of 50 were obtained, yet the reply rate was much higher than expected with a total of 72.2%, meaning that 13 individuals replied to the email. Lastly, the final number of people that agreed to the interview were only three.

For the secondary sources all the information was gathered from reputable sources and compared views and insights from many sources. Since the topic covers many areas no one specific criteria was chosen in terms of sources. The data came from other dissertations, car journalists, governmental websites, articles, private companies websites, market analysts, and business magazines.

Interview process

Previous to the interviews research was conducted to ensure the adequate interview process was chosen for this specific paper. Among the options were structured, semi-structured, and open interviews. The decision was made to use semi-structured. William Adams (2015) describes that a semi-structured interview can be conducted conversationally with one responded at a time and that the format employs a blend in close ended questions mixed with open ended questions, which are oftentimes accompanied by follow whys or hows. Additionally, all the interviews were done over the internet using online platforms such as Zoom and Google Meets. In order to obtain volunteers a well written and coherent email template was created with a lot of thought behind it. This template explained the purpose of the email, and the topic that the thesis was covering along with sample questions. As far as the creation of the questionnaire, a total of ten questions were created. Part of the semi-structured interview process includes preparing beforehand (Adams, 2015). These questions were a mix of seven open ended questions and three closed ended. The questions were designed to see what area these experts gave more importance to.

Three individuals were chosen, each one possessing a different profile regarding their involvement in the complexity of the lithium supply chain. Teage Egan is the CEO of the American company Energy X, which is a private company that is in the process of revolutionizing the brine lithium extraction by creating a nanotechnology membrane that will increase the lithium extraction rate to 90% and require minimum amounts of water to do so. Some quick facts about his lithium extraction technology can be seen on figure 4. Daniela Sanchez is a Bolivian professor at Cambridge University. She has over a decade of experience in public research which has been mainly focused on the geopolitics of renewable energies, with a focus on lithium extraction in South

America. Lastly, Chris Berry has been an independent analyst providing advice on the supply chain of lithium to companies and now he aims to build his own advisory company relating to the metals in the energy industry such as lithium, cobalt, graphite, copper and nickel. All three possessed considerable knowledge on the lithium industry and their profiles were diverse in terms of their involvement in the supply chain. In their answers, special emphasis was placed on the lithium supply chain, socio-political side of lithium extraction and the importance of the energy transition. The duration of each interview was between 30 to 35 minutes and allowed the interviewees to answer all the questions. This duration was made following Adam's (2015) research to avoid extending over an hour to prevent fatigue. Two of them were conducted via Zoom and one on Google meets. The three of them were recorded with consent from their part. To ensure their conformity in the participation of this research a consent form was explained to them beforehand. This form was also sent to them and required an online signature in order to use their data in this thesis. To be able record their signature an online software called JotForm was found that allows people to sign documents online.

Quick Facts	
RECOVERY RATE	CONTINUOUS PROCESS
~90% Lithium	1-2 days
FRESH WATER REQUIRED	OPERATING CONDITIONS
Minimal	20-40% high salinity

Interview insights

Teague Egan

According to Teague Egan the sustainability of EVs is considerably better than an ICE power car, but he recognized that EVs require a mining process which is detrimental to the environment. The main goal of his company is to improve towards the mining process. Additionally he states that the main demand of lithium will be from EVs and the reason why currently there is a surplus in supply of lithium is due to the pandemic. His explanation is that the world economies have been slowed down and EV buyers have gone down. Moreover, the supply chain of lithium has also been a weakness during this pandemic due to the globalized nature of it. The mining process mainly happens in South America and Australia and then it is shipped towards China, which is the nation that controls the majority of the cathode and anode creation. Despite all this he sees a promising future for the EV industry as more and more vehicle manufacturers introduce new EV models to their line ups. A great example he mentioned was the introduction of GM's electric Hummer, which was a vehicle first introduced to the public in the 1992 (History Editors, 2020) and was considered to be

one of the biggest gas consuming vehicles in its time. He describes this drop in demand for EVs caused by the pandemic as “a short bleap” and once it is over there will be an exponential growth for the demand of EVs and lithium. To him domestic supply is needed to make the process more efficient and avoid quality control issues. Then with regards to the future he mentions in the energy storage sector there might be possible replacement for lithium batteries as technology advances. On the other hand, he stated that energy storage just places 1% of their budget into R&D which means there is a huge potential for improvement. Conversely, his thought on LIBs in cars is different, he thinks there won't be a replacement for lithium batteries in this sector. This is mainly due to the light weight characteristic of lithium, which makes it ideal for transportation. One thing that he said might change is the chemistry of these batteries, meaning mixing lithium with other chemicals, but in his words “lithium is here to stay”. Lastly, when looking at the big picture he believes that lithium can be a possible replacement for fossil fuels, but it is a process that will take time due to its complexity. In terms of economic impact he said that there are going to be losers and winners as jobs are going to change from oil and coal companies to clean energy sources. In general he sees a net positive impact on society.

Daniela Sanchez

In the words of Daniela Sanchez the socio-political side of lithium mining is one of the most worrying factors of the lithium industry. In general she foresees a boom of lithium demand in the following decade, and this will require close observation to the sustainability side of things inside the triangle. One of the biggest issues she sees is the water supply of these regions as they are at stake and the mining adds risk to the ecosystem. These ecosystems also have cultural and touristic value. This risk is mainly added because of the old and outdated technology that mining companies use. On a more international level she recognizes that the shift to green energy and batteries is an ongoing movement and the world is coincios that it is a must in order to avoid irreversible damage. Due to the enormity of the change that is currently happening, she says it will be a slow one, and the region that is going to be the dominator of this change is Asia, while poor areas like South America will be the least benefitted. She considers this imbalance to be a type of modern day colonialism, as rich countries exploit poor one for raw materials and keep most of the benefit.

With regard to the composition and sustainability of batteries themselves current LIBs need to address not only the sourcing of lithium but cobalt as well. Cobalt is a big issue because it is harder to find and brings ethical dilemmas due to the poor areas in which it is mined. This battery transition also needs to have a circular economy in mind to ensure that it is a truly environmentally friendly movement. She mentions that if this is not taken into account we would be replicating the previous oil movement that has taken Earth to tipping point because the amount of minerals that are going to be mined will be historical. Currently lithium has a low recyclability rate mainly due to the fact that it is cheaper to mine than to recycle. As the industry progresses she mentioned that government incentives and subsidies will be needed in order to ensure recycling and avoid massive waste production.

Chris Berry

Chris Berry's view on the industry is that he foresees an increase in demand for lithium as a raw material and in LIB form mainly for EV usage. But as a financial oriented person he realizes that this increase in demand will require gathering capital and deploying it along the entire supply chain of lithium batteries. According to him companies are now more concerned with the carbon footprint that their products have along the entire supply chain, this means that inefficient ways of mining lithium will lead to OEMs not wanting to use that specific source. An incredible amount of capital will be needed to ensure the entire production of LIBs is done in an adequate manner. Based on his calculations, with an EV penetration rate of 10% will require 10 billion USD to sustain the demand, and to make the process as efficient as possible. A specific area of concern is the lack of education, infrastructure and transparency from the government in the developing countries in which most of the lithium reserves are located.

In terms of the current climate on the lithium market he states that the world is currently experiencing an oversupply of lithium which has led the price down and was worsened by the pandemic. His calculations say that there is currently one more year of oversupply in the market meaning that after that price and production of lithium should increase. Nevertheless, an important point he makes is that companies need to start gathering capital now in order to prepare for the future spike in demand as these types of lithium mining projects time between 3-5 years to solidify. In his mind the gathering of capital and its deployment in the supply chain is the biggest issue being faced by the industry.

Data analysis and limitations

As mentioned above the research plan of the thesis was to compare the information gathered from secondary sources and compare it with primary sources. It is because of this that content analysis was used to interpret the data. In the words of Downe Wamboldt (1992) "content analysis is a research method that provides a systematic and objective means to make valid inferences from verbal, visual, or written data in order to describe and quantify specific phenomena". This description matches very well with the intentions of this paper as articles, theses, books, and interviews were used to answer the phenomenon behind the research questions. Additionally this type of analysis focuses on comparing several sources of information to obtain conclusions. In this case the literature review, which is created from secondary sources, was compared with the interview insights from the industry professionals.

The process behind the analysis portion was the following: once the literature was adequately grounded and the relevant factors listed in the literature review were clearly understood the data was compared with the response given by the industry

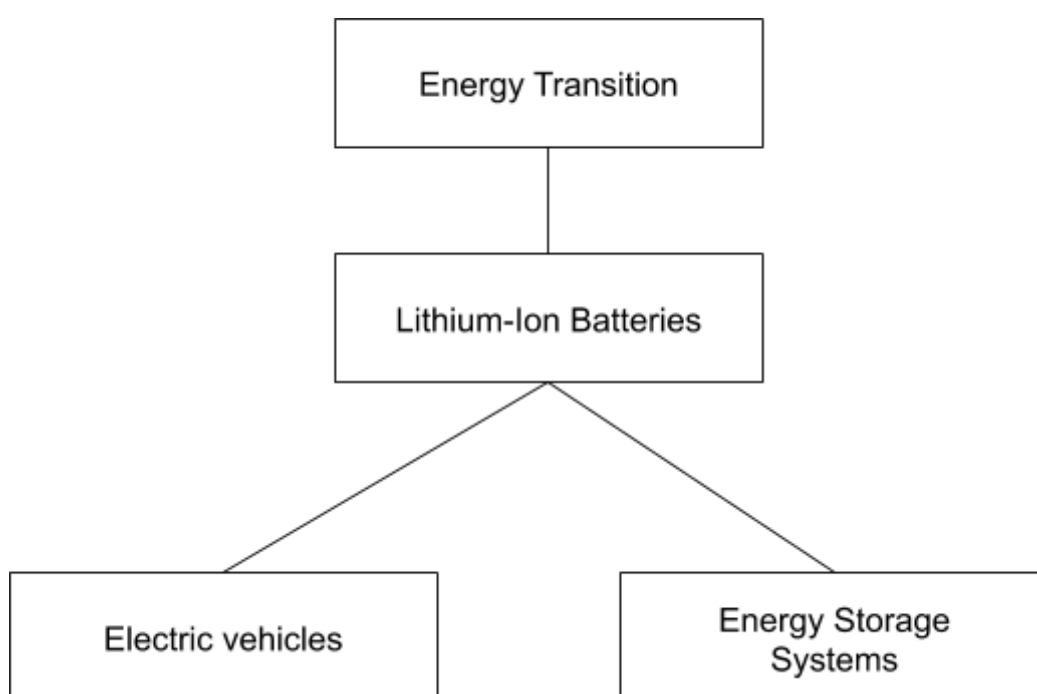
experts. The goal was to find the importance that each interviewee gave to specific factors. Additionally, the topics that were mentioned the most were analysed. The process included validating the available information found online with interviews and identifying what areas were of higher relevance. The recording of the meetings were transcribed to pinpoint which of the topics listed in the literature review were mentioned the most and how much time was dedicated to each of them during the talk time. All of the topics were individually separated and the interviews were divided into how much time each participant dedicated to it (Table 1). This was also done to see if the information in the literature review was really relevant. Additionally special attention was given to how many times keywords were used by them to have another metric (Table 2). This included words like decarbonization, socio-political, LIBs, EVs, sustainability, boom, demand, supply, china, supply chain, energy storage among others. The interpretation steps were the following: firstly the number of word repetition was gathered using the criteria mentioned above. Subsequently the data and insights gathered in the interviews were compared with the literature review to highlight the topics of higher relevance. Lastly, all the areas that received more attention by each of the interviewees were united to create a diverse pool of information that allow the adequate answering to the research questions.

One of the most limiting factors of this study is the small sample size of interviews. Currently lithium is an emerging topic and relatively small industry. Getting a hold of people that were really knowledgeable on the subject presented a challenge. The number of replies that were received surpassed the 50% aim that was mentioned before but most of the individuals did not consider themselves professionals in the lithium field despite having released books or articles on the topic. This also limited the total number of people that the contact database was set to have. It was originally planned to have 50 possible contacts but only 18 were obtained. Aside from that language barriers were a big limitation. China is a major player in the lithium industry and due to language there was no possibility of contacting professionals from that part of the world. The complexity of the industry also held back the potential of this paper as many technical terms are required to understand many of the things mentioned by interviewees. Furthermore, the data analysis was partly done through software and partly manually which is more prone to errors. When transcribing the interviews a free software titled Happyscribe was used. This converted the three interview recordings into text but the precision was not the best. Then the analysis of comparing the interview data with the existing literature was done manually. Many different areas of knowledge had to be studied including some chemistry, politics, finance, and logistics. Moreover, there are many more factors that are extremely important towards the energy transition, many other components and metals have to be inside the batteries that will lead the transition. This paper just focuses on one small aspect of a much larger picture.

4. Findings

What is the role that lithium will play in the energy transition?

After comparing the data collected through both primary and secondary methods the trends with regards to this question were climate change, LIBs, EVs, and energy storage systems. These four things are the most mentioned during the interviews when talking about the role of lithium. These trends are also visible in the literature that was reviewed. Aside from those trends there was a clear relationship between all of them, meaning that each of those topics are interconnected. The way the relationship goes is the following: climate change was the general topic. This was the reason why the other topics were created and why there is so much study and research on them. Then the following topic is LIBs. These batteries are what gives so much importance to lithium as a whole. Then comes EVs and energy storage systems. These two factors influence directly the role of lithium in the energy transition. The best way to describe this is a hierarchy with climate change on top, LIBs below, and EVs and energy storage both under LIBs (Table 1).

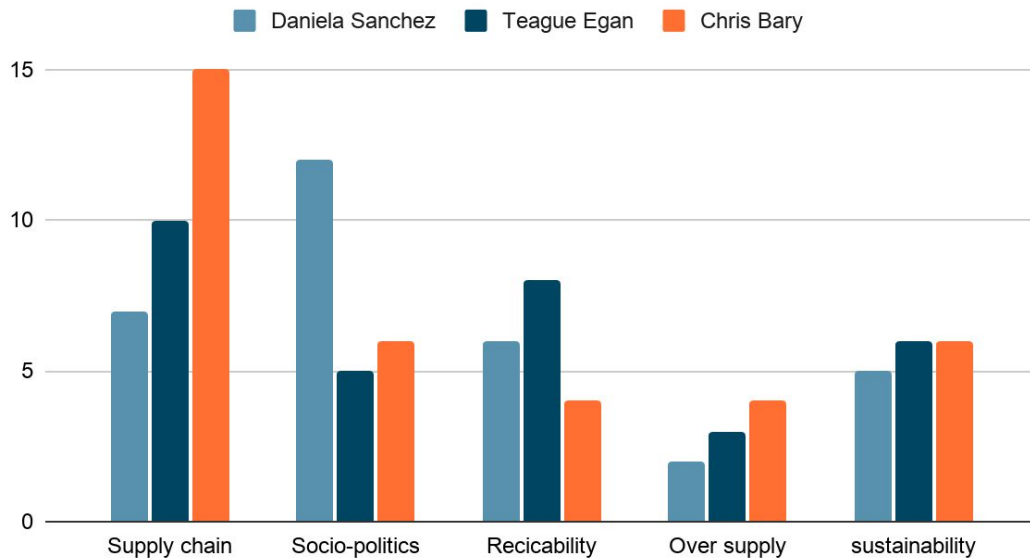


What areas of the industry present the biggest challenges?

In the literature review it was found that the most recurring key words when referring to issues in the industry are: supply chain, globalization, oversupply, and socio-political. With regards to the interviews the key words that were highlighted were recyclability, oversupply, supply chain, socio-political, and sustainability (Table 2). In this section it was clear that the most prominent problem that the industry faces is the supply chain. In literature review most of the problems regarding this chain are mainly attributed to supply of raw materials but industry professionals dig deeper and mention that it is an infrastructure, funding, communication and educational issue. As far as unexpected results go most of the literature only mentions the positive side of

lithium but in the interview it is shown that recyclability of LIBs and sustainability side of the mining industry also pose a threat to the environment mainly due to oversights in these two areas.

Time dedicated



What is the future of lithium?

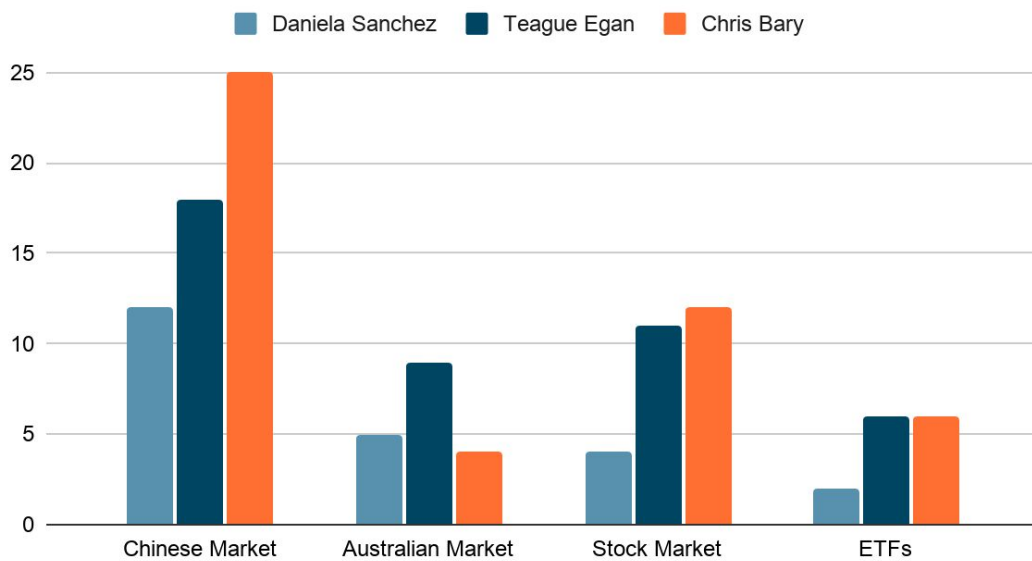
This section is where the literature review and the interviews shared the most. The keywords for this question were: EVs, energy storage, and decade. In both parts the future of lithium is related to the production of EVs and energy storage systems. Moreover the time frame in which lithium is set to be relevant for society is within the next decade.

What opportunities will it bring?

In the literature review there is not much information in regards to the possible opportunities that the energy transition can bring. The key word in the presented literature that related to opportunities was: stock market. Most of the available information just presents data of the market as a whole with not much emphasis on the lithium industry itself. On the other hand the key words from the interviews were: ETFs, stock market, Australian market, and Chinese market (Table 3). Due to the specific knowledge that the individuals in the interviewed have on lithium they were

able to identify more opportunities.

Times mentioned during interview



Will lithium really help mitigate climate change?

This section also presented very different keywords. In the literature review the main ones were: clean air and reduced emissions. In the interviews: mining processes, extended periods, cleaner air, and imbalance. This demonstrated that the literature review focuses more on the absolute net impact that lithium will have on the world, conversely the interviews show that there is much more behind the lithium industry aside from the visible clean results that it aims to have. Despite the discrepancy in key words, both resources concluded that the impact of lithium will ultimately help climate change.

5. Conclusions, Limitations, and Recommendations

In conclusion, the energy transition is a movement that is currently on its way. The shift towards cleaner energies is a trend that will be of high relevance for the next decade or more. Governments and companies are now taking real action to avoid irreversible consequences caused by climate change. The objective of the transition is to reduce the greenhouse gas emissions at a global scale and lithium is being used to achieve this goal. There are two main drivers that will make lithium a high relevance material, the adoption of EVs and energy storage systems that will be used to gather energy from clean sources. These two things are currently being done by creating LIBs. This movement will make lithium one of the most important raw materials in the foreseeable future.

As of right now the lithium industry is minuscule in comparison to other fossil fuel based energy sources. To put things into perspective the entire lithium industry is a 3

billion dollar annual industry and just the annual research and development budget of Shell is 15 billion (Berry 2020). This number just goes to show how much the lithium industry needs to evolve in order to cope with the soaring demand that the future holds. Sadly the development of this industry has been held back greatly by the US and Chinese trade war and the Covid-19 pandemic. The supply chain of lithium is globalized and underdeveloped and in order to be able to get ready for the future massive amounts of capital need to be injected to make the infrastructure and process effective and efficient. In addition there are many secondary issues like socio-politics and the impact that lithium mining and LIB waste will have on the world. Due to the infancy of the industry there is not much focus placed in these areas. For the sociopolitical part the problem mainly arises from the mining stage of lithium as more than half the world supply is located in developing countries and oftentimes local communities are affected negatively while governments and international companies receive the benefit. On the other side of the spectrum, the waste coming from LIBs will be massive as the number of EVs rise without having a proper recycling plan or waste disposal system in place. A movement that is aimed at a cleaner world might become the opposite.

For the opportunity side of things the current markets are presenting a positive view on the future and with the EU, US, and Chinese government's goal to electrify the mobility sector lithium stocks and ETFs present a great opportunity if timed right. Although past performance of an asset is not an indicator of future (John Brown, 2020) it is a good point of reference and most of these financial instruments have been rising in price.

The overall process of this research paper focused on identifying relevant information from secondary sources and comparing it to data gathered from primary ones to identify trends. The main strength of this paper are the profiles that the participants of the interviews possess, they are truly experts on the topic. Teague Egan is CEO of Energy X, Daniela Sanches is a research fellow and professor at Cambridge university and Chris Berry has been a lithium advisor for the past decade. As far as limitation the number of interviewees was low. It was a true challenge locating individuals that were willing to discuss the topic in hand. Additionally, the analysis of the data was partly done by software and partly manually due to the high cost that using qualitative software has. The digital part of the process consisted of transcribing the data in the interviews, furthermore the software was not the most accurate one. The manual part of the process consisted on dividing the data and analysing the relevance given to keywords and measuring how much time the interviewees dedicated to each topic. Another extremely important limitation that this paper will have is how rapid the industry is evolving. Most of the data gathered might become outdated quickly as more and more information is fed as lithium becomes more important. It will be likely that this paper will become obsolete within the next two years as the problems mentioned above are tackled and new ones arise. The point of this paper was to provide a comprehensive picture of the lithium industry along with where it stands right now and future predictions. In a sense it is a very general overview on a complicated topic. Each of the points listed in the literature review can be developed much further and include more details. The word limit on this document

held back the potential of the research as explaining and elaborating more on the topic in hand would have required much more writing. Aside from that lithium is just one of the many components that go into the production of LIBs, another possible connection to further research is the overall impact that mining all the metals and components of LIBs have on companies and on the world.

Recommendations

On the recommendation part it would be ideal to gather a large amount of volunteers for interview purposes. This would make the paper richer and grasp the landscape better and add different points of views. It has been mentioned extensively that the supply chain of LIBs is extremely complex and it requires knowledge on different subjects to make them possible. A major contribution that would provide a better context is the opinion of engineers, people in the chinese market, or locals of the lithium triangle. More time would also benefit the study as gathering information from primary sources is timely and this would also allow a deeper look at the information used to create the literature review. Moreover, expanding to the other components and metals inside LIBs such as copper would provide a better picture as well. Lastly, using high end qualitative software to analyse the information gathered in the interviews would be a great way to ensure an adequate response to the research questions. High end softwares offer a great number of features and intuitive interfaces that would speed up the process and guarantee great results. In short this a list of the recommendations:

1. Gather a larger number of interviews
2. Conduct the study over a long period of time
3. Expand more on the additional component of LIBs
4. Usage of high quality qualitative software for analysing results

Strategies for implementing recommendations

Some strategies for implementing the previous recommendations would be to spend more time generating a detailed database and try finding individuals within your personal network that might be willing to help. Also, taking advantage of the resources available in your surroundings like government offices that might be related to the topic. Setting a timeline with specific goals and adhering to it would also aid a lot in terms of time management. This would ensure that all the time available is used efficiently and generate a superior outcome. Then for volunteers in terms of interviews a great manner of obtaining different opinions is by looking for articles related to the main topic but with different purposes. Finally, to be able to get a high quality qualitative software it can be funded personally or via a learning institution or public library.

1. Spend more time creating a detailed database.
2. Setting a timeframe for the study to set goals and to try to captivate any evolution of the industry in your work

3. Try to find individuals with a profile more oriented towards the specifics behind LIBs construction and chemistries
4. Obtain a licence to one of the many qualitative software analysis tools either through personal funding or via your learning institution

Possible challenges and solutions

The creation of a database is a highly time consuming task. To avoid problems with this everything should be done with time and planned in detail. To avoid losing time this process can be done simultaneously with the research process for other parts of the paper. The database is just one part of the research process meaning that it can be done simultaneously with other parts. For example, it is possible to gather information from secondary sources and at the same time create a contact database. Then to save time in general having your topic before the thesis is assigned is a great way of saving time. Planning way ahead can provide incredible scheduling advantages that will allow the researcher to focus more on other areas. By doing this it would also be possible to start working on the thesis as a whole, but it is important to have the risk of getting the research topic denied in mind. On a different matter, referring to the following recommendation, LIB chemistry and composition is a very specialized topic thus funding someone willing to contribute ideas in this field might be hard. The best way to obtain interviews with people like this is by first finding someone that can reference you to that person. It is easier to approach a stranger and get helped by him or her by first mentioning a name they are familiar with. To conclude obtaining a qualitative software license for personal use comes at a high price. If buying it is not an option there are libraries that have this software available. Also seeking help from your institution might be a solution.

Future research

The lithium industry will start to evolve at a rapid pace in the near future. Many new stakeholders will form part and it might even get more complicated than what it is now. Some recommendations for future research is to be on top of the news regarding the industry, also the market as a whole needs to be taken into account to analyse the opportunities and threats that the energy transition might bring. Currently the future of lithium is based solely on predictions and future plans from governments and companies. It would be great to conduct a follow up of the industry in the next year or two to analyze the results of these predictions. The pace at which this industry is forecasted to change is extremely fast. Lithium production and LIBs will change many times in the following decade thanks to technological advances and governments and private companies.

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7. Appendices

Full interview with Teague Egan Energy X CEO

I'm interested to know, how did you get into the lithium industry? What brought you to it?

I just thought that it was, you know, I really wanted to be in something that was meaningful and impactful. And I started out my career as an entrepreneur in the entertainment world. But I decided that I wanted to have a career change and focus on renewable energy. I just didn't know what. And as I started thinking about asking, I felt like I pinpointed lithium and said, I want to do this, I kind of stumbled upon the opportunity. When I went down to Bolivia, for the first time, I was, I had an aha moment. And I saw a huge opportunity in Bolivia to help extract the natural resource. Because, you know, we're gonna need a lot of lithium. Yeah. So that's kind of how I ended up there.

Do you think that the current lithium batteries that are in the market are really sustainable? And how does that lead us system from your company will help improve sustainability?

Yeah, I mean, look, they're more sustainable than attacking gas. And gas, King and gas burns four times once, and it's a bunch of co2. So yeah, they're 1000 times more sustainable than the life in the car. Using a gas internal combustion car when it comes to printing production. Yeah, I mean, of course, there's gonna be some there's gonna be some co2 emissions. You're taking stuff out of the ground or extracting it from the earth. And we try to improve upon that process using our technology in a controlled environment. But electric vehicles using lithium batteries are just a step change over internal combustion cars. And Tesla has done all those kinds of comparisons and analysis. And yeah, significant.

How long until we see a boom in the demand for lithium?

Okay. So I think that the demand primarily is driven by the electric car revolution. And the sale of EBS, and the manufacturer of EBS is slowed down. And the demand for lithium is slowed down. And it's on such a, the supply chain is currently on such a global level. Right now, the biggest. So lithium is predominantly used in the cathode, the battery, and the biggest cathode manufacturers are in China. So when the route when the raw material of lithium is produced and shipped to China, and then China

makes the cathode, and then that cathode is shipped to the cell manufacturer, whether that's in store in China again, or in Taiwan, or in South Korea. So, the whole supply chain, I'm good, thank you. The whole supply chain is very global. And you know that the shit that that kind of was slowed by the pandemic. So I think that now, you know, all these car companies are obviously planned far into the future and can take years together as the budgeting for a car, but I think just yesterday or today, GM announced or came out with their unveiled Hummer pickup truck, which has 350 miles of range. So I think it's coming back. I think that every car company wants to buy their fleet. And I think it'll be a short blip in the overall timeline of seeing car companies transition to electric vehicles, and the same thing for the demand of lithium will steadily continue to rise exponentially.

Do you think that the supply chain of lithium represents a problem?

Yeah, absolutely. And that's a big item for the Department of Energy trying to Create domestic supply for a lot of our battery materials. It's super expensive having to ship all this stuff around the world. It's timely. Yeah. There's there's a lot of quality control issues there. Yeah. So obviously made, making it, making it closer to home. You know, that's one thing that we're working on is trying to find domestic supplies of lithium ion battery manufacturing facilities here. Do you

Do you have any comments with regard to the Chinese 2025 initiative of China wanting to get a hold on the intellectual market of electronics?

Haven't heard of that specifically. But like, I mean, that's, that's a really smart thing to do. I know about China's One Belt, or what's there I mean, China's China plan for the future. And that's, that's a really smart thing for them to do. They understand how global economies are shifting, and they already control a lot of the manufacturing. And they obviously follow our lead on intellectual property, and innovation. But once we innovate, you know, we outsource a lot of the manufacturing to them. And that's why they become so powerful. So for them to understand things, their electric vehicles, you know, like, they're trying to create a lot of electric vehicle companies, but they're obviously following the lead of Tesla that started in everybody's found in Tesla and started in the US. And that's, that's, that's smarter than what can I say? I hope that we put as much resources and government support behind that same initiative that they are.

So the next question is, do you see any possible replacement for lithium batteries in the near future, and other battery technology that might replace lithium in the near future?

Yeah, I think that the lithium, the lithium ion battery is going to evolve. I think that is very good as it is right now. You know, the transition has happened, or it's happening and now we have to make 2 million cars a year. matters. I think that if you care, e. g, storage in the battery industry refers to something like pharmaceuticals, and healthcare. The pharmaceutical industry has 50 and has a r&d budget of 15% of their revenue that goes towards r&d for creating new types of chemical compounds and stuff like that. The energy storage industry only invests from 1%. Until now, I think that if we increase that r&d budget, there's going to be huge advancements in energy storage and battery technologies. I think that the lithium ion battery will evolve, but there are inherent fundamental laws of physics and chemistry. I need that, for instance, lithium is the lightest metal on the periodic table. Yeah. So unless unless somebody discovers lighter metal, lithium is an ideal material, or electric mobility, I mean, it's an equation of energy density, right? You need batteries and cars to be light so that they can propel that you're talking about stationary storage. And you can use other materials, because it doesn't matter how heavy they are. But I think for electric mobility, lithium is here to sway and you've been in the action generations and batteries that people are thinking about are working on like solid state batteries, or lithium, lithium sulfur batteries or air batteries they are. So I think that battery technology will have lithium ion, but lithium as an element, and it will be here to stay for the foreseeable future.

That's, that's nice. That's good news. Okay, so the next question is, do you see a possibility that lithium could replace fossil fuels?

Yeah, absolutely. I mean, it's already happening. Everything always takes time. You know, I think that lucky lithium. So before fossil fuels or before, like oil and gas, people use coal. And coal is like the big method of transportation, like you'd have with coal trains, right? Yeah. And then oil and gas was discovered that you could use that slide and refine it into gasoline, etc. But even though that was way better than he will still use coal for like, several decades, even still today. And then, with the batteries came along, even though that's 100 times better for the environment than gas. People still use oil, things that things are on that scale, that macro scale, always take a lot of time to transition. I think that we could be looking at, you know, also, there's so many, like factors like politics and political regulation. They were moving towards banning co2, emitting cars, and stuff like that, and then California just passed. I think by 2035 they don't want to sell anymore. permitting cars. Yeah. So we're definitely moving. You know, I see. I see all of 2014 2015 where nobody makes internal combustion cars anymore. They'll still exist, that people will have old versions or something like that. But like, transitions like that take a long time. I

absolutely think that lithium and battery storage is replacing things and hopefully will be generated by renewable sources like wind solar. Yeah. thermo.

What impact do you think this current energy transition is going to have on the world economy?

I think it's going to be fantastic. I think that like, I think that, I think actually, that it's, it's all cyclical, you know, people that have routine and create a lot of jobs repeat, they're also going to lose their jobs that are working in more conventional energy. It's like gas, but overall, like employment and stuff like that. It's all cyclical, so people will get new jobs and continue to be more jobs. I think that overall, reach a much larger territory. started looking at remote places in Africa. Renewable Energy constrained a lot of jobs as places. Overall, it'll be a net positive in terms of I mean, it has to be net positive in terms of the economy.

What do you think is the best way of investing in lithium today?

would be vigorous with introducing public companies. So Albemarle traded on the New York Stock Exchange, or several other market caps, like hundreds of millions or billions. Some of these are traded on the Australian stock exchange or the Toronto Stock Exchange. And then, you know, obviously, you'd invested in Tesla a couple years ago, you'd be doing pretty well right now. So Sure.

Do you have any comments on the political side of lithium mining in bolivia?

Louis Arce is going to be a great leader for that country. In terms of his lithium strategy, he had an announcement with Mars benchmark minerals on this strategy to help push forward the production of lithium and is going to open up the waters for foreign companies such as ours.

[Full interview Daniela Sanchez Professor at Cambridge University](#)

I'm interested to know how you get into lithium? Yeah. How did you get into lithium?

Okay I'm a research fellow at the University of Cambridge. I work on the geopolitics side of renewable energies, specifically solar, mostly wind and how batteries will be used for these lithium ion batteries. So I'm looking at the lithium triangle, Chile, Bolivia, Argentina, to see how these three countries have concentrated more than half of the world resources around 60% of the world production will actually benefit from the boom that is captured. That is coming. If you The technologies will actually be applied in these countries if there will be an internal energy transition. And of course,

what will be the role of the new geopolitical map that is coming with China, mostly Asia and China in the region? So that is my broad area of work. How can we live here? Well, I did my PhD on lithium in the case of Bolivia, so many years ago now, almost six, seven or something, there was nothing about very little research being done at the time about lithium in Bolivia, in particular. So I felt like okay, this is an interesting gap. This is going to be the next big resource in the country, why things are happening. And the project at the time, the state project in Bolivia was about to start. So I was in a very interesting moment of time doing fieldwork, talk to people. So I had to, like, exam the picture of what happened then. And then yeah, the project just continues. So let's see what happens next. I think you hit the jackpot with this, because there are so many aspects that can be developed from different angles, market angles, socio ecological analysis, I mean, a lot of stuff. So it's a really good topic.

So how many years do you think it will take until we see a real boom in the demand for lithium?

Well, it's an interesting question. The boom has been delayed, delayed and delayed, but I think that we are going to see a boom in the next decade, for sure.

So what do you think is this the biggest challenge when it comes to lithium extraction and processing?

Well, a big challenge for whom that is the key question. If you're talking to someone from industry, they will tell you to secure cheapest resources for as much time as possible, it depends who you ask this, but from my own personal perspective, I think sustainability in terms of environment should be one of the biggest priorities. In the specific region of the lithium triangle, lithium resources are located in places that water is an issue, there is a scarcity of water there, that you have a lot of ecosystems surrounding the salt flats that need to be in consideration, because they also offer cultural and economic value for the communities in the surrounding areas. So you have different aspects, that should be part of what you understand that sustainability in terms of the production itself, I mean, you have different technologies that were in here 2030 years ago. So the lithium triangle is using all the technologies. So should that be updated? Maybe that would be a better way to recover water. I mean, you have different aspects that will be part of a debate of what sustainable is, in the case of lithium.

So my next question is, do you really think that the lithium batteries that are currently out in the market, are they really sustainable?

But I mean, you need to under turn the battery in itself, lithium is a key component, but it is one of the most important but you have others. So in terms of sustainability of the battery industry itself, cobalt is a key issue, because cobalt by far is way more complicated. Where is Congo, a very difficult area to work with different issues in terms of how you mined cobalt. So you have ethical and economic issues there. You

have a constant race, to find the better chemistry for the batteries, NMC, LFP different types of compositions are being researched in order to be improved. So you have a constant rate for that. And I think the holy grail of that will be to reduce the cobalt, the cobalt amount in batteries because it's too expensive, too conflictive too unpredictable of where you get cobalt. And then we go to the other topic, which is about the circular economy. This is a key issue that we should be discussing right now. This applies also for solar panels, wind turbines, I mean, you are using huge amounts of minerals for the so-called Green transition. So you're still digging a lot of the minerals. Most of these minerals are located in developing countries. So what we're talking about here, we are actually reproducing a system that has led to the collapse of the planet in a way. So we really need to talk about recyclability circular economy and how to reuse the resources in a better way. Lithium unfortunately, has a very, very low rate of recycling, even from a car I was reading that about half of the lithium use can be recycled. So we have a problem that we need economies of scale. So we need to have a lot of batteries in order to make these a part of our business. So probably, we will be talking about circular economy and the recyclability of lithium in 10 years time. If according to prediction, we have a massive increase in electric vehicles, the production of batteries, also the use of volt battery storage. So we don't have like two industries that in a way will feel in 10 years time and industry of recyclability for lithium, but that will take time. It's a matter of cost so far is way much cheaper to extract lithium than to recycle it at the moment. That's how it is. So it will require a combination of incentives, government policies, so you need to think these in a circular way. And that will require different incentives from different actors in order to make it possible that lithium is recyclable. Yeah, that's true. Every single piece of cobalt that can be recovered, it is recovered. So that is a different thing. You do recycling of batteries? Because you want the cobalt No, so much.

The next question is, do you think there's another battery technology that does not contain lithium that can replace it in the near future?

Talking about hydrogen, that can be I mean, we are in a constant race that is for sure they've raised for more efficiency, like they're better, they're better and for them with better charging rates is constant. I don't think you will have a mature technology in the next 20 years at least. But I know that hydrogen could be an option could be an option. But I'm not sure if that will be a concern in the next 20 years for sure.

Okay, so you see, you see lithium being like the main, the main element that's been there's going to be used for the batteries aside from from the other elements like helium?

I think lithium will be a key component, what might change is the chemistry, you might buy my use nickel, cobalt, does the thing you are replacing cobalt. For me, that is the most important thing for the industry. Lithium, not so much because you have. Lithium is not scarce in itself and is a strategic resource. But it's not scarce; you have a distribution of lithium all over the planet. The problem is that it's economically

feasible to do it in a profitable way. It can only be done on the brines mostly and hard rock in Australia. But spodumene

Do you see, do you think lithium lithium could be a possible replacement for fossil fuels?

Oh, I will say yes. But I wouldn't say that this is going to happen very soon, it's going to be a process of replacement. I think the oil industry is not just about a commodity that provides energy and moves the world. It's more it's more a time of policy. It's not, it's more a political issue. So they do have a lot of power, they have different interests. So I think this is going to be a gradual change, which of course has been accelerated due to the climate change crisis that we are living now. So the fact that we need to replace a combustion engines by by electric vehicles, it's now a priority, it's not something that should be done, or it will be nice to do it, it's just it has to be done in the next 30 years, we need to reduce the co2 emissions by half, we need to start using renewable energies around 70 to 80% of the whole energy matrix of the world. So in summary, a huge dimension of change that is already happening. You have the global commitment for this, you have local commitment in terms of different governments in different parts of the world. Some are more committed than others, you need to consider the impact of replacement of oil in the producing countries, what it is going to look like, who is going to win, who is going to lose with that. And I think batteries play a central role in all of this because you need on the one hand to transform the transport sector and electric vehicles are going to be the key issue in this. And energy storage. Of course, you need to install the energy when the wind is when the wind is not blowing and the sun is not shining. So how do you do that? You need to store this energy in these batteries. So I think the change is already happening. It might be more aggressive that I might imagine. It could Be an option that these actually have simulates the whole recession that we're leaving because of cobit might actually, we might get out of it with a green with a green economy. That might be the case. I think it's a narrative that is quite strong in some parts from governments. So this could be an accelerated process. But if, of course, it will take so many years, it won't be easy, won't be fast, but it will happen.

The next question is, you mentioned that it's true that oil companies have a huge amount of resources and political power, you think that these companies that are starting to feel threatened by this new technology might do something to to slow that change down or, or avoid, avoid it from happening?

I mean, if you have a look at I don't know, shell, some of the big ones, they have already realized the three new renewables are here to stay. The technology now has reduced so much the cost that it's actually profitable to have a solar panel and sell that energy, which didn't happen five or seven years ago. So I think they realized that this technology now has gone so fast. And so far away than what they could have imagined that I think they are diversifying. If you have a look, they have now these green green programs and stuff, so I mean, yeah, I mean, I'm always skeptical about

transnationals, especially oil transnationals. But I don't think they can stop this. Yes, it's one one thing. I don't think it could be stoppable, because the whole, there is a global narrative that admits now that we need to reduce co2 emissions. So either we go the Trump way, and we just ignore this, these scientists are crazy. And climate change is not happening. Or we go the other way, like we really need to move forward in the energy transition. And I would like to think that we're going that direction, not the other way.

Yeah, I think I think we're going. I think it's a better way to think because if not, we'll have terrible consequences, I think for humans.

yeah, I mean, it's irreversible. If we don't do this. Now, in the next two decades, we are doomed. The planet will be here. It's as though they're going to disappear. So I guess most people might actually get this. But as I said, if this is a process, I think it has already started, which is a good news for everyone. But, it might take some time. And yes, how all companies will react to this? Yeah, this is a big question, how I don't think they might have as much power as they used to in the past. And that is because energy is power. So whoever controls energy, whoever controls the technology for producing the storing, distributing energy changes everything. So I think that has already changed with renewables being with batteries.

Okay, the next question is, What impact do you think this energy transition might have on the world economy?

Well, as I said, we might choose to go with a green economy, when I mean, it could be a complete new paradigm. And again, even if we go with the green paradigm, you always have winners and losers. So the whole point will be to have a just energy transition, where those who are providing in this case, the huge amount of minerals, are going to dig minerals as we have never, ever done in history. So yes, how are we going to do that? How is it going to be sustainable? What kind of environmental concerns we will have will be the impact for the producing countries, which happen to be most of the time developing countries, for example. So these kinds of things are questions for adjusting energy transition. And the impact will be that we might have a completely new economy, new types of jobs, maybe we might actually get things better if we go that way. If we do it right properly. And for sure, this is going to change the way energy is generated, distributed and consumed. And that for me, that is what blows my mind about batteries. Just thinking that you can actually store a solid palette on your home, store that energy in your care or in an energy storage battery in your home and then sell it if you are completely changing the system. It can be a decentralized system, you will no longer need them a natural monopoly of someone generating electricity and so you can actually generate it in neighborhoods. So this could change the whole game of energy. how close we are to that I don't think we have that far. German is a good example. Japan is really on the way on this. I mean, everyone suddenly becomes generating their own electricity, storing it and selling it. It's, it's completely unbelievable, but it's happening. Yeah, you might

change the whole game, because the way we consume electricity is something completely outdated right now to what might happen in the next five or 10 years. Where it happens. That's another question. Of course, this will always happen in rich countries, because they have the infrastructure, you have the incentives, how do you do that in the rest of the planet? That is another question. Question. Yes.

So this comes to my next question, you know, Bolivia is facing terrible political problems right now. Do you think the new president will facilitate the extraction of lithium or will make it harder for companies to come to Bolivia and extract?

Ah, well, I mean, these, the new president was the Ministry of finances for 14 years with the Morales government. So what you could expect is the same line of work in terms of lithium. Lithium in Bolivia was a State Initiative. And it has three different phases, the pilot phase, where you start doing trials, industrial extraction, and in theory, they add enough value in this industrialization of castles, at least they wanted batteries, but the cathode industry was the first step. So that was the initial conception of this project, I don't think that is going to change. You can only have public private partnerships in the last stage, which is the face of industrialization, but in reality with a government of moralez. Last year, they signed an agreement with a German company, for example. So many will argue that they weren't adding value there, we're just extracting from the residual brain to produce lithium hydroxide. They claim that the German company will contribute with the technology to do that, and they will secure a market. So yeah, the debate was is this adding value or this is just, we are selling some sort of raw material. So that was one aspect of the debate at the time, then it came all day, all the conflicts because of the alleged froth in the election. And of course, the people in the region where lithium is located, Potosi protested against the signing of this contract. So this is what really happened. I have some very crazy stories on the internet that had no clue what happened. Lithium is a state control and the government in itself signed this agreement with the German company. So whatever you might think that a foreign company wanted to take over and Morales was nationalized in it is completely broken. From the very beginning. Lithium is a state owned and has always been an IT WILL BE So in any case. I don't know. I think they will follow a similar line. They might be more pragmatic. I think they, over the years the government has changed the initial idea that we don't want any foreign partner to let's open these we have let's do a public private partnerships, even created a law for this. So they were trying to encourage I think, in a way foreign investment and leave him of course, it's an attractive option. how feasible it will be, I think the investors will have a look at how stable this government is. How legitimate is well, yeah, how the region where lithium is located reacts to these new governments. So I don't think Yeah, you have a lot of political issues in a way to define who is going to be the next partner in this because you need one. I mean, there is no question that leaving you alone is not going to do it. You really need a foreign partner with the technology that will open markets for you to be competitive.

Do you think membrane extraction technology could revolutionize the mining process in Bolivia?

Yeah, I read about it. I think it's interesting. If you need to, to have a look at the Test. I mean, you need to try it on to see if it works. Yeah, in theory, it seems to be feasible. I think I'm not a chemist, or an engineer myself, but I understood that it could be done in a very efficient way. I would like to think that it might be an option for sure.

What would you recommend someone to invest in lithium whether it's in the stock market or ETFs? around the world? Do you think that's gonna be an attractive investment?

Well, right now, at least here it's not like a, it's not like oil, for example. So you don't have like a market for, for trading. And it's, everything is on the spot, the spot price, which is basically how you sell it to China. So I think it has a different market structure compared to other commodities is not considered a commodity in itself is considered a chemical product. So that makes a difference of how you trade it. There were ideas on the one hand to get a price, for example, you don't have access to information about prices. So they were trying to do the London metal exchange and were trying to do some sort of, I don't know, price, more information on transferring information about the price and that could be a fair step in order to make it like a more. Yeah, Wall Street type of commodity that could be sold and traded. But so far, I don't see this happening in everything depending on who is the bigger player here, which is China. I know how interested they are in having transparency on the price, because they are the big buyers of this. So no one knows what the real price is, you just get a glimpse of how with what this company sold little hydro sang off of LSC? I don't know. I'm not sure how interested they are going to be on that.

Why do you think the price of lithium is so strict, secretive?

It's I mean, lithium was like a chemical curiosity until 2015 years ago, when it suddenly became a key component for the massive Revolution of mobiles and tablets and laptops. When it was more like a chemical curiosity was using pharmaceutical uses in industry, glass ceramic batteries were just a tiny component and suddenly became like more than half of what the lithium is demanded goes to batteries. So again, it's a matter of how they market the structure and how the supply chain is divided between China, and I mean, Asia in general, but China in particular, controls most of the supply chain. So they have the power basically, to determine the price, I think.

Do you think that will make it better and more attractive to the market?

I think it is attractive enough. The problem is that I think the short term is not. I mean, yeah, you if you are an investor, you should think in the mid to long term to invest in lithium, because that is when it's going to be like a huge, massive resource. So far, the price has gone crazy in 2017, I think it reached \$14,000 per ton. I mean, that was crazy. And now it came back to around 8000-7000. So you can see the blood fluctuation is huge, but it reflects the fact that many investors are like this is a big thing, we're going to invest a lot. So suddenly, you had a lot of projects in Australia, for example, that now you have an A lot of supply. So the price went down and then you had cobit on the top of that. So of course the industry has slowed down the whole value chain has slowed down. So this is a contextual aspect in the short term, that of course will affect investors' decisions. But if you think in a medium and long term, you might think that this is an interesting area to invest and actually digging in a company or digging in somehow the technology, the different aspects of the battery technology have kept some sort of power there. But I think that For sure that Asia will dominate this, the whole market of batteries, different chemistries, wherever you might think might be dominated by Asia is not only China, but China is the key player. They're the big player there. So yeah, I think that is what is happening and how you make a more transparent market. It's a very complicated matter. And China needs to see a useful lesson that will be useful for them to have a more transparent liquor market. Yeah.

My last question is, as you mentioned in the interview with BBC, that you fear a little bit about going back to colonialism, with big companies in China or Germany, targeting Bolivia and Argentina and Chile. Do you still think that's a possibility that that might happen?

Yeah, I mean, ideally, I think lithium could be a window of opportunity for the producing countries to actually start an industry in the countries. So that could be in an ideal world, that silently This is a window for Technology Innovation Research, you have a whole new infrastructure, backed by this date, in order to form people who have professionals in this app value that will be in an ideal world. But what I see right now is that China is taking over not only the lithium, triangle countries, different countries with different resources that are valuable for the battery industry, in different forms, investments or loans. This is what happens in China and South America, in particular, you make loans, you don't make investments, you give money to the government. So yeah, I do think this is a serious risk, you have a new geopolitical map coming out, it's very easy. For me, it's very clear who is going to be the leader on this. And yes, we are, in a way repeating an old story within a green paradigm within a green panel that is supposedly to be good for the planet, but not necessarily will be good for the countries that are given all the minerals for this. So that is a question to be aware of.

Full interview with Chris Berry lithium supply chain consultant

So I just want to know, how did you get into lithium. So what attracted you to this industry?

I have been an independent analyst and an advisor to companies along the lithium ion supply chain for about the last 10 years. I've actually, I've been based in New York, for about the last 20 years. And like I said, with with roles in different financial institutions, and then about 10 years ago, broke away from that with the intention of building my own independent research and advisory platform focused on this idea of energy metals, okay, so any metal or mineral used in the generation or storage of energy, so that's lithium, cobalt, graphite, copper, and nickel. And, you know, I'm not, my background is not in the sciences. I mean, I'm not a geologist, or, you know, a battery chemist or anything like that. But I do find it fascinating. I've always had an interest in how these macro dynamics around sort of global growth, emerging market growth, technology, and then raw material usage kind of collide, to create opportunities. And 10 years ago, I looked around, and I felt like there was a need in the market for, you know, a research platform or just an advisory business that focused on this energy transition and the role of raw materials in it. Okay. And, you know, back at that point in time, because battery economics were not competitive with traditional internal combustion engine car economics. You know, the big banks would really not cover lithium or lithium stocks, it was just a tiny market. And it still is a small market, but because of battery economics, and just small markets, the banks didn't care. And so I thought, well, gee, maybe that's my opening. And so the business for me has really grown over the last 10 years, I'm doing less and less kind of independent research and more advisory business. So I will work either on kind of a one off basis or more involved, projects with investors, like hedge funds and sovereign wealth funds, who are trying to understand, you know, where the opportunities and the threats are, with respect to electrification. Also, work with the government and academia, again, just want an advisory basis. I will and also have done a fair amount of work in lithium ion battery recycling. So I really try to focus on the technologies, the actual raw material supply and demand and then government and academia which really craft policy. And what I have found is over the last 10 years, each of those three groups don't understand what the other group does, if that makes any sense. So you know, I can talk to a hedge fund analyst and he will understand of course, you know, I know how to put a convertible bond deal together and what that means and yeah, but he or she may not understand the challenges with dendrites and batteries, and how that can affect economics. And similarly a battery chemist will understand those nuances but doesn't have any idea about, you know, I don't know just how to raise capital, things like that. And of course, government and academia are really, really focused on policy. And, but don't necessarily understand, have the same depth of knowledge with finance as an example. So I just try to sit in the middle of that triangle, if that makes sense. And help each one of those three groups get to where they need to be. And so in addition to that, I've actually served on a couple of company boards, one of which was a lithium development company, we had an asset in Namibia and an offtake agreement with a Chinese lithium converter, and also with

a privately held lithium ion battery recycling company. So I've had a chance to see, you know, both sides of this business, how the companies are built, and how they interact with each other. And then how the individuals, the stakeholders along the supply chain, you know, our positioning for this transition?

Do you think there's gonna be another boom of, of lithium prices or lithium demand in the upcoming years?

Definitely, would be my short answer. And just to maybe go back just to give you a little context of what happens. So you know, when you're talking about lithium with respect to batteries, okay, there are really two chemicals that you want to focus on lithium carbonate and lithium hydroxide. And we don't need to get into the details about how they're produced or where they're produced unless you want to, but you're absolutely right in sort of late 2015. I think it was a combination of Elon Musk, and announcing the Giga factory and making that a reality. And, of course, the Chinese and their view of electrifying their economy, electrifying their transportation sector, really scared the lithium market and end users and said, Wow, we really, we can see what's coming down the pipe. So we better know, start accumulating as much lithium as we can. So the price of lithium hydroxide, excuse me, the price of lithium carbonate went from around \$6,500 per tonne to a peak of around \$20,000 per tonne. And that was in probably late 2018. Give her to read around then. And then hydroxide went from around 8000 \$8,500 a tonne to around \$24,000 a tonne. So, you know, these prices, they went parabolic. And, you know, there's an argument in the lithium world or in the battery metals world that? Well, these are specialty chemicals because, you know, they're as opposed to commodities, right, because it takes a long time to produce them. And they have to be produced to spec. But lithium behaved and continues to behave like a traditional boom and bust commodity. And so what happened was lithium pricing spiked and an enormous wall of capital flooded into the lithium development space. And so you had a situation where a number of hardrock mines in Western Australia actually got funded and started to produce in a very short window of time. And that led to oversupply. And that led to us where we are today, which is with carbonate at depending upon who you speak with, you know, I don't know sextiles back back where we started essentially maybe six or \$7,000 a ton in hydroxide at the same, the same levels previously, maybe at 500 or \$9,000 a ton. So you know what's going to happen in the next couple of years? Well, I think that here we are in 2020. You have an oversupply issue. Of course, COVID was the shock that nobody could forecast. So that really killed any growth this year. And so I think that it's going to take at least another year to get through this oversupply issue. So I wouldn't see any pricing spike before 2022. I do think that we're at the bottom when you look at lithium cost curves and kind of what's feasible right now and what's not feasible but you know, You do have at least four or five months of excess supply in the marketplace right now. And so that has to be consumed. And we're just coming out of COVID, hopefully. And Evie sales do look like they're starting to ramp back to where they were maybe like a year or so ago. So it's sort of last year a little bit. But I think that, you know, I hope you actually don't see a price spike, because that attracts speculative capital, that's not patient that is here one minute and gone the next and what you need to go from, you know, a situation today, where we're at 300,000 tons

of lithium in terms of the size of this market that's on an LC or lithium carbonate equivalent basis. Do you know, I think it will be at 900,000 tons by 2026. or so. You know, you need a lot of capital, you need 10s of billions of dollars to make that happen. And that needs to be raised and deployed now, because it can take anywhere from three to five to seven years closer to five to seven, to build and and to fund and to build a new lithium mine regardless of whether or not it's Brian or hard rock and work out those kinks.

Do you think that the biggest challenge that lithium is facing right now is that a supply chain issue?

yeah, I'm sorry. I didn't mean to interrupt. I do think that's the biggest issue. I think funding will get solved. That's the good news. Okay. The question is, who is going to step in? Is it going to continue to be the Chinese with their enormous checkbooks? Because that's what it's been thus far. Or, you know, I'm hopeful that the oil and gas business will start to step in here and diversify their business models a little bit. I mean, just for the sake of perspective, if lithium is a \$3 billion a year business that's in US dollars, you know, look at the r&d budget of some of these oil and gas supermajors, right. Like, I think Shell's r&d budget per year is 15 billion or something like that. I mean, it's outrageous. So they could literally buy the entire lithium market and not have, you know, lots of money left over. I'm not suggesting that that's a wise thing to do. But I think you know, the way to think about it is yes, the funding to me not just the raising of the capital but the deployment of the capital is also crucial. You've had one greenfields lithium mine, one greenfields lithium brine operation, come on stream in the last 20 years, that's or a Kobe's operation in Argentina. And it's been plagued by technical issues. Okay. And it looks like that's going to continue. So I guess my point there is that raising the capital is one thing, but deploying it properly in building these operations. You know, this is why it takes seven to 10 years for a new brine operation. You know, it was easy in 2017 2018, for the hard rock players to raise capital, but they're not vertically integrated. And that's really the key. That's kind of my point, my paper, which is great, you know, raising capital is crucial, but vertical integration is what saves you and protects you from that volatility. It's not just producing the hardrock spot you mean in Western Australia and then selling it to China? It's producing the hardrock spot, you mean, and then ideally, having your own lithium conversion facility where, you know, you're not just selling spots? You mean at, you know, \$200 margin, you're now selling lithium hydroxide at a 2000 or \$6,000 margin depending upon when we're pricing it.

Aside from electric batteries, what sector do you see lithium going to? Because right now, that's the main source of demand, you know, electric car batteries and for energy storage, do you think that's going to be the main points of demand?

Totally, totally, I think that other NDS is for demand like pharmaceuticals or grease. Those are businesses that are going to grow in line with global GDP. So I sort of assume a 3% growth rate, year over year for those businesses. Who knows, maybe that's aggressive. I don't know. I mean, you could really get granular if you wanted to, but I just assume those businesses from a demand perspective aren't going to grow

greater than 3% per year. Whereas batteries when however, you wanted to find that energy storage, mobility, batteries, lithium juice and batteries is going to grow at 1516 17% per year through 2025. And, you know, that's certainly that's me saying that, but everybody in this space is saying the same thing that the shock, the demand shock is basically right now. And of course, without COVID. You know, it would be business as usual. So the industry is just sort of suffering from oversupply and getting back on its feet. But the real driver of demand for lithium is batteries and the story.

Do you think there's another possible replacement in the near future that could replace lithium ion batteries? And they could disrupt the industry completely?

No, would be my short answer. I think that, you know, when I think of the battery business, or when I think of energy storage, I am divided into two camps. Number one is mobility. And the other camp is traditional energy storage, or SS is sometimes sort of referred to, on the mobility side, I have zero concerns over lithium's role, I do not see it getting substituted or displaced anytime in the next 10 to maybe even 15 years. I know that's a lifetime in terms of battery development, but certainly in the next 10 years. So you know, if you are going to build a Giga factory or build a mine, and you've got a 10 year visibility on demand, that makes total sense. And that makes raising that capital much, not much, well, it makes it easier and not much easier. Now on the energy storage side, there is a lot of competition, you have vanadium redox flow batteries, you have zinc air, you have a number of different chemistries that quite frankly, are better suited to get kind of that wave of energy storage and or electricity storage and electricity deployment. So you know, the sun is shining during the day, getting the solar panels, and you know, your energy storage is going like this, and then we all come home at night and plug in our phones and turn on the TV or whatever. And then you start to see that drop down like that, you know, that sort of wave is? Generally speaking, I mean, I'm talking at a high level here. You know, lithium ion is not the best option for that, because as we all know, if any of us have a cell phone, the battery degrades over time. It is a much different scenario and proposition, for example, with vanadium redox. So I think that lithium ion is going to take the lion's share of the entire energy storage business, okay, for the foreseeable future. But you know, there will be specific niches or specific areas where, for example, vanadium redox, makes a lot of sense. There's a lot of discussion out there now about Second Life lithium ion batteries, you may have heard of that. So, you know, I've got my battery in my Tesla, you say it's eight years old, or something like that, and the battery still has 60 to 70% of its capacity, you know, that's still usable. And I think there is going to be a transition phase or a transition period where Second Life lithium ion make sense. But when we get to that point where a new brand spanking new lithium ion battery is cheaper than a used lithium ion battery, because of scale all of these Giga factories, and also just overall capabilities of the battery, right? higher energy storage, it won't make sense to use, why would you use an old Second Life battery when I can just buy a new one at I'll make up a number, you know, \$90 a kilowatt hour or something like that, it makes more sense to do that. So that's why I think ultimately, recycling is going to become a much bigger deal because you're going to have this utter tsunami of use batteries. And also scrap is another big piece of the puzzle here.

Do you think a lithium could be a substitution for fossil fuels?

You know, I don't. I'm certainly hopeful, to be honest. Because that's my career, but I think I don't think so. I don't think that for now, for the next few decades, I don't see lithium replacing fossil fuels. It's possible. Okay. It's I mean, it's conceivable if the charging infrastructure is there. And, you know, you sort of phase through this question, but I wouldn't think you'd see anything close to that before 2050. You know, if you just go just to demonstrate or think about how not important oil is to the economy, but how entrenched oil is in the economy, if you go back to April of this year, when at least here in the West, you know, the pandemic code was really, really raging, it was hitting the US hard in particular, when, with most of the Western world locked down, you know, no, flying everyone's home, the global economy still used 70 million barrels of oil per day. Okay, so it was like a 30% drop, it was a total shock to the system. But even with nobody working, you know, nobody commuting, and nobody flying and doing things like that. We still use 70 million barrels of oil a day. So the idea that we go to zero fossil fuel use, I just don't think it's realistic anytime in the next few decades.

I'd have to go back and double check and see how, what percentage of oil demand comes from transportation? I don't think it's 40%. I could be wrong on that. But, you know, it'll be a transition. You know, I don't think it'll be all electric anytime soon, even though that seems like it makes the most sense long term. And yeah, you know what that's going to even if you never mind 40%, I would argue even if you cut oil demand, even if you kept oil demand flat for the next couple of years, right? And we've already seen that happening, these oil and gas supermajors are all cutting their capex budgets. In the first quarter of this year. Again, maybe some of it was COVID. related, but there were 50 billion US dollars in Project write downs. Okay, basically, these oil and gas companies like BP saying, you know, what, we paid, I'll just make up a number, we paid \$1 for this asset. Now, it's worth, you know, 50 cents or something like that, because we're at a situation where w ti is, I don't know where it is today, like \$38 a barrel, and Brent is maybe slightly higher. I mean, it's really hard for Saudi Arabia, for example, even with their low lifting cost, like \$10 a barrel. It's hard for them to not make money, but to balance their budgets. At \$40 oil. I've seen stats where they need \$80 oil to basically balance everything. So you know, it goes way beyond Can I just make money doing this? And I think that's that's the interesting kind of geopolitical wrinkle here, but it's decades away. Yeah.

What impact do you think this energy transition will have? Well, especially in the mobility sector, shifting from internal combustion engines to electric vehicles? What impact do you think that would have in the world economy? Because it's, it's going to be a big shift, in my opinion.

I agree. I think Well, I mean, look, better health, better air quality. is one thing I do. I do my current theme now that I'm working on so if you know taming the hydro was the first theme. The next theme is, is what I call the paradox of green growth. And it's this idea that okay, well, decarbonisation, whether or not it's of the transportation

sector or the global economy, it makes total sense. And because battery prices are crashing, and because you have very supportive government policies, whether it's in the European Union in China, you know, those are those are incredibly powerful tailwinds. But to electrify the transport sector, it's not going to take less lithium, it's going to take more, which requires more extractive industries. Now, one of the encouraging things I guess, to look to keep an eye on is to focus on ESG. You know, that is a theme that is even as rich As a couple of years ago, we all paid attention to it and took it seriously. But now it's like, it's incredibly important. And these OEMs, like VW and Tesla and Daimler don't want anything to do with cobalt that's mined in the DRC, for example, or lithium, that is mined in an unsustainable fashion where your co2 emissions are above a certain level. So if we're talking about decarbonizing the economy, you have to decarbonize the supply chains first. And I think that it's actually going to increase costs. Overall, I'm not saying that's a bad thing, I'm just saying those costs are going to increase. And that's going to have to get passed on down the supply chain. And that's, of course, so that's absent some sort of technological leap in lithium mining, refining or processing. So I just see the paradox here, where decarbonisation makes total sense, the benefits are cleaner air, more efficient transportation system, so on and so forth. But, you know, we're gonna have to triple lithium production in the next six years to do this even at a 10% Evie penetration rate, okay. Which means 90% internal combustion engine, so we're not talking about like, 100%. Evie, that's why I don't think it's going to happen for decades. But that's clearly where all the growth is.

Do you think modern day colonialism can be a possibility in the lithium industry?

Um, I do. I do. And I only hesitated because, you know, I don't, I don't want it to be that way. I just, I just think that I can see how that is, it is perceived that way, I think that, you know, with respect to Libya, it's no secret that the country has the largest lithium assets in the world by tonnage. It's also an extremely complicated deposit to produce lithium from Yeah. Which is one of the reasons honestly, a lot of people have tried and failed to work in Bolivia, nevermind the political aspects of nationalization, and so on and so forth. And asset expropriation, it's a very tricky deposit to produce lithium from so you know, the Japanese had been there, the Germans had been there. I think, from my view, a lot of people meaning a lot of Westerners will stay out of Bolivia, because of the geopolitical issues. Number one, but also number two, and maybe maybe, I don't know if more importantly is the right word, but it it's just a really, really tricky deposit to to produce lithium from and you know, if there's one misunderstanding about lithium, it's that, you know, lithium is not rare. Okay. It is literally everywhere, in brine, in hard rock, and even in clay. And even in seawater, you know, if the lithium price goes back to 25, or \$50,000 a tonne at a point, it becomes economic to produce lithium from seawater. I'm not recommending that I'm not even forecasting that but my point is, lithium is not rare. So if you have a situation like Bolivia, where there's a lot of political instability, there are worries about colonialism and worries about nationalization, both of which are completely legitimate in my view. Why bother? Why not try to do business in Argentina or almost any other country?The just, it's like instead of it's the opposite of a win win,

right. It's a lose lose. So I don't know. I just don't see Bolivia really factoring into the landscape at any time in the near in the future?

I don't know if you've heard of the company energy x is an American company. Yes. Do you think they're their extraction system, the one they're working on right now. It's called leaders, which claims to reduce the extraction time by a huge margin. Also they will extract much more The brain. Do you think that's it? Do you think that's a promising technology?

I mean, I think that, you know, energy x is one of about a dozen companies, at least, that are promoting and trying to perfect their own. what's called de la direct lithium extraction technology. I think in the case of energy x, I know the company I've met with them. I think it's too early to tell, quite honestly, I think that one of the challenges with these technologies is that, you know, it might work optimally or might work very well for one brine or one type of deposit, but might not work well for another. As an example, maybe energy x is perfect for that. Bolivian brine, which is, you know, loaded with magnesium. But it might not work in the Atacama Desert, or you know, what might not work the same way with Chilean or excuse me, with the Chinese Bruns and in Tibet, so, you know, not slamming energy acts at all, I mean, I'm actually really happy to see these technologies out there, because I, it's one of the ways that I think it can help lithium kind of bridge this ESG gap that it has historically faced, in terms of water usage, and extraction and all that kind of stuff. So, you know, energy x standard lithium, there are at least a dozen, if I sat down and thought about it, I could come and they've all got their own little spin on it. The problem is, these technologies are all blackbox technologies. So they're never because they're not patented, they're never going to tell you how they work. So, you know, unless you could find a large resource that is having production problems on the Brian side. You would never, you're never really going to know. And so Look, I know energy x is partnered up with Oracle Bray, who is having production problems? So it's kind of a wait and see, honestly.No transparency. It's not even a public company. Most of these little guys aren't. So it's hard to understand. Not even just the technology, but who are the shareholders? What are their incentives? How I mean, what are they trying to do? What's the business model? They want to license their technology? Do they just want to get bought by somebody and be done with it? It's hard to know.

So my last question, if you were to recommend someone that someone's looking to invest in lithium, what instrument would you recommend? Would you recommend it?

yeah, sure. First of all, I think that look, it's a it's a this is it's a timing game, okay. If you're talking about equity investment for these lithium names, I can tell you right now, with pricing, having crashed. Again, I'm not an investment advisor, I'm not making any recommendations, but Now's not the time, now's the time to be looking and doing your due diligence, right? I think you know, what you want to do is is, you know, you want to subscribe to, for example, like benchmark has an email that comes out every week, or s&p Platts has a weekly email that they put out, and they have their own kind of view on pricing, and you just want to get, get as many of those in your inbox as possible. And all of all that is designed to do is just give you a feel for

the market and give you an idea of the general trend of pricing. Okay, unless you are literally buying or selling the material, you're never going to know what the exact price is. Okay, so don't even don't even worry about that. And, you know, on the investment side, what I look for is our large scalable assets. I don't necessarily care if it's hard rock versus Brian, but large scalable assets in reliable geopolitical jurisdictions. Have a management team that has done this before. Not a company that, you know, they're gold explorers, and they just wanted to get into lithium. I mean, and you know what that is oftentimes the hardest piece of the puzzle, because up until, you know, recently, because lithium was such a small market, there isn't a lot of experience out there. So really finding those individuals that can Shepherd these assets forward. And also ones because they're large in scale and grade. Can weather low pricing, pretty rare out there to find that.

Email template sent

Mr, Ms or Mrs.

I'm a last semester student at Geneva Business School. I'm in the process of writing my thesis on lithium and its role on the current energy transition and would love to interview you (preferably by the end of this week) to get insights from a professional like yourself. Specifically I was hoping to get comments on:

- The short and long term future of lithium
- The sustainability side of lithium extraction and processing
- The impact of the energy transition on society

This online interview won't last more than 20 minutes and it can be done through whatever video conferencing platform you desire (Google Meets, Zoom, Skype, etc) I am currently in Madrid, Spain (UTC/ GMT+2), but I can adapt to whichever time zone you are located in. These are some of the questions I will be asking during the interview and I promise that the rest will fall within the outline mentioned above:

- Aside from electric vehicles batteries what other relevant sectors do you think lithium will go to?
- Are current lithium batteries really sustainable?
- What impact do you think the current energy transition might have on the world economy?

The due date of my thesis is December 18. If you wish to be sent a copy of it I would be more than happy to do so. The goal of our interview is: to gain insights on lithium from an industry expert.

Thank you for considering my request. I hope to hear your response by the end of the week.

*Please note that in order for me to use the information gathered during our interview you need to sign the following consent form once the interview is over:
<https://form.jotform.com/202883258096060>

Questionnaire

How did you get into Lithium?

How many years do you think it will take to see a boom in the demand for lithium?

What do you think is the biggest challenge Lithium extraction and processing is facing?

Aside from electric vehicles batteries what other main sectors do you think lithium will go to?

Do you think that another battery technology that does not contain lithium can replace it?

Do you see lithium as a possible replacement for fossil fuels?(mention decarbonization)

What impact do you think this current energy transition might have on the world economy?

Are current lithium batteries really sustainable?close

Would you recommend someone to invest in lithium whether in stocks, ETFs, or commodity markets?

Contact database

-Teagan Egan: Energy-X- sent

Position: CEO

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Found contact on:

<https://www.forbes.com/sites/marekkubik/2019/09/24/this-breakthrough-lithium-extraction-technology-could-accelerate-the-sustainable-energy-transition/#3e9379dc75fc>

-Terence Bell: Strategic Metal Investment LTD. -Sent

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<https://www.thoughtco.com/lithium-production-2340123#:~:text=Most%20lithium%20is%20commercially%20produced,though%20perhaps%20not%20until%202022.>

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<https://www.investopedia.com/investing/why-lithium-stocks-are-plunging-amid-electric-car-boom/>

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<https://www.greenbiz.com/article/tech-breakthrough-could-revolutionize-lithium-extraction>

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<https://www.spglobal.com/en/research-insights/articles/lithium-supply-is-set-to-triple-by-2025-will-it-be-enough>

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<https://www.spglobal.com/en/research-insights/articles/lithium-supply-is-set-to-triple-by-2025-will-it-be-enough>

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-David Nield: Freelancer

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<https://www.sciencealert.com/new-sodium-ion-battery-performs-as-well-as-some-commercial-lithium-ion-models>

-André Agrela Gonçalves: Future Eco Surf- Sent

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<https://youmatter.world/en/hydrogen-electric-cars-sustainability-28156/>

-Tibi Puiu:

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Found contact on:

<https://www.lindau-nobel.org/blog-the-future-is-bright-for-lithium-ion-batteries/>

-Patrick Hertzke: McKinsey Center for Future Mobility's global
vehicle-electrification work- Done

Position: Partner

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Found contact on:

<https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales#>

-Ellen Chang:

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Found contact on:

<https://money.usnews.com/investing/stock-market-news/slideshows/ways-to-invest-in-lithium?slide=3>

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<https://www.pv-magazine-latam.com/2020/01/21/chile-sigue-buscando-productores-de-litio/>

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-E3Metals Corp

Location: Canada

Website Contact: <https://www.e3metalscorp.com/contact>

-Sociedad Química y Minera

Location: Chile

Website Contact: <https://www.sqm.com/contacto/>

-Green Center Canada

Location: Canada

Website Contact: <https://www.greencentrecanada.com/contact-us/>

Consent Form Teague Egan

Thursday, October 22, 2020



CONSENT TO PARTICIPATE IN RESEARCH

I agree to participate in the research project entitled "Lithium and it's role in the new energy transition" undertaken by the researcher named below:

Eduardo Salazar

By signing below, I acknowledge that:

- I have agreed to participate in this study.
- I have been informed of and understand the purpose of this study.
- I understand that I can withdraw from the study at any time without prejudice.
- I understand how the data collected will be used, and that any confidential information will be seen only by the researchers and will not be revealed to anyone else.
- Details relating to anonymity and confidentiality have been explained and I understand these.
- I have had the opportunity to ask any questions. With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

Signature

A handwritten signature in black ink, appearing to read "Teague Egan".

Date

Thursday, October 22, 2020

Consent Form Daniela Sanchez

Consent Form Chris Berry

Thursday, November 5, 2020



CONSENT TO PARTICIPATE IN RESEARCH

I agree to participate in the research project entitled "Lithium and it's role in the new energy transition" undertaken by the researcher named below:

Eduardo Salazar

By signing below, I acknowledge that:

- I have agreed to participate in this study.
- I have been informed of and understand the purpose of this study.
- I understand that I can withdraw from the study at any time without prejudice.
- I understand how the data collected will be used, and that any confidential information will be seen only by the researchers and will not be revealed to anyone else.
- Details relating to anonymity and confidentiality have been explained and I understand these.
- I have had the opportunity to ask any questions. With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

Signature

CAB

Date

Thursday, November 5, 2020