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This document will discuss and expose the hazards of the lithium-ion battery industry and the possible long-term affects the industry has on the environment. There will also be a comparison made on the petroleum industry and lithium-ion battery industry to see which one is causing the most environmental damage.

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LITHIUM CAR BATTERY INDUSTRY

"Is this Industry Really Environmentally Friendly?

Submitted by:
Shannon K. Bencs
CP&E #804
4 February 2020

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Foreword

Electric vehicles have been getting a lot of publicity lately, especially, when it comes to the federal and state governments offering support via subsidies, consumer friendly regulations, and even tax breaks/incentives. Are electric cars improving and making way for cleaner air and truly reducing carbon dioxide emissions? Currently, there is an increased pressure on the government to convert traditional energy sources to "green" energy sources and step away from the offerings that the petroleum industry offers, such as, fuel, natural gas, crude oil, and by-products. As you will see, by evidence I provide, there is no significant change in carbon dioxide emissions when switching from gas powered vehicles to electric vehicles. The industry is just shifting the time, in the manufacturing process, in which the largest quantity of emissions enters the atmosphere. Instead of the significant amount of emissions being exposed to the environment while daily driving your electric vehicle, large quantities are emitted during production of the lithium-ion (Li-ion) batteries (at the manufacturing plant), which are required for the electric vehicles. This part of the Li-ion batteries lifecycle has been hidden from consumers and politicians, therefore, most of the public is unaware that electric vehicles are no better for the environment than gas vehicles are that emit carbon dioxide.

This document will discuss and expose the hazards of the lithium-ion battery industry and the possible long-term affects the industry has on the environment. There will also be a comparison made on the petroleum industry and lithium-ion battery industry to see which one is causing the most environmental damage.

The primary focus will be on:

- Chronological list of the history of the Lithium-ion Battery industry
- Major Players in the Lithium-Ion Battery and Petroleum Industry
- Current and future Lithium-ion Battery concerns and recycling capabilities
- Comparison of carbon dioxide emissions between electric and gas-powered vehicles
- Where the Lithium-ion Industry is headed
- Possible outcomes if the Lithium-ion Battery Industry continues to grow

Introduction

Electric vehicles, specifically, lithium batteries are more damaging and toxic to the environment than gas emitting vehicles over a long-term time span. Lithium batteries are actually more damaging to the environment, especially, if the battery cells are broken, releasing harmful toxins and emissions. Also, disposing of Li-ion battery produces more hazardous material waste and ultimately, they are not a good reliable, long-term solution for “green” renewable energy, as promoted to be to the public. The waste generated by the batteries, once discarded, and the bare existence of li-ion recycling plants prove there is no long-term infrastructure and sustainment for proper disposal of li-ion batteries, Once electric vehicles are mass produced, sold, and electric vehicles are accepted and widely used on the roads, there will also be issues with safe disposal and recycling of lithium batteries as the technology isn’t there to support a safe, fast, efficient and affordable way to recycle the batteries. Thus, the batteries become hazardous waste and they will have a greater and devastating impact on the environment. There is also a hazard of Li-ion batteries, if disposed of in landfills, to inadvertently heat up and causing “thermal runaway,” which is a raging, uncontrollable fire as a result. “Thermal runaway” can also occur during the Li-ion battery production if requirements are not met in the factory to keep the battery at proper temperatures to prevent this chemical reaction to occur.

Also, Studies show that mining lithium out of the salt flats, in Bolivia, requires approximately 500,000 gallons of water per ton of lithium. Production also creates more emissions, during time of manufacturing of the batteries themselves than emissions released from gas or diesel vehicles during their life of use. From what I found, the factories themselves create emissions by the type of production that is required for Li-ion batteries. For example, the TESLA gigfactories were mainly produced for the production of batteries (supply) stays in rhythm with the amount of batteries needed for the electric vehicles they are producing for the year or their target goal, otherwise, there would be a massive battery shortage and the electric vehicles couldn't be completed and ultimately shipped. Currently, TESLA is creating more electric vehicles than batteries they can physically produce, there is a bottleneck in production. For every 100 kWh li-ion car battery (Tesla's largest battery produced), it creates approximately 17.5 tons of carbon dioxide. For every gallon of gasoline, that is burned, it creates 8,887 grams of CO_2. A gas-powered vehicle typically emits an average of 4.6 tons of CO_2 per year. So, there's an understanding that the production of 1 – 100 kWh battery is equivalent to 3.8 years of emissions from a gas-powered vehicle. A 100-kWh battery is used in TESLA's electric vehicles, specifically, the Model S and the Model X. So, each TESLA Gigafactory creates emissions, but of course, the larger the battery that is produced in the factory the more emissions that are produced during production and then multiply that number by the number of batteries that are produced by the factory. That final number, 17.5 tons of CO2 times the final production number of batteries the factory produces, outweighs the benefits that electric vehicles ultimately brings to the table. For example, if 100 – 100 kWh batteries are produced by TESLA, in a given time, those batteries will produce approximately 1,750 tons of CO2 emissions. So, the final number of actual emissions being produced depends on the size of battery being made and the number of batteries being produced by the factory. This is just one example, one factory and one company, and does not account for the numerous Li-ion factories that exist and that various different companies that own them in the industry. The numbers turn out to be astronomical.

Also, another issue that is detrimental to the environment is that actual mining of the resource (lithium) itself. It’s very cheap to mine and manufacturer lithium, but it scars the land and drains local areas of their water sources. Also, after the lithium batteries have been used in an electric vehicle(s), there is a need to properly dispose of the hazardous waste. During the disposal process, which is very costly, there is a risk of a battery fire which can produce high heat, gases, toxins and smoke. If lithium batteries are produced and become more commonplace in the world, there is a potential to release more toxins and gases then the environment can handle, and we do not have the resources to support proper disposal and recycling efforts to keep up with the market producing these batteries. I also believe citizens are at risk of being engulfed in a fire, which may result in serious injury or death, if electric vehicles are in catastrophic car accident(s), due to the Li-ion batteries that are onboard and sit underneath the passengers, in the undercarriage.

<u>History of Lithium Mining and Lithium Battery Production</u>

20th Century – Lithium is utilized for medical purposes. The demand for lithium rose, due to World War II and the Cold War, to be used in nuclear weapons

21st Century – Lithium ion battery usage increases and Australia, Chile, and Portugal become the largest source for the resource/metal

1817 – Discovery of Lithium

1818 – Chemist Christian Gmelin, of German decent, finds that lithium salts display a red color flame

1855 – Lithium is segregated as a "free metal" by Thomas Brande

1855 – Robert Bunsen, German Chemist, and Augustus Mattiessen segregate big quantities of lithium by electrolysis of lithium chloride

1870's – Carl Lange, from Denmark, and American William Alexander Hammond utilize lithium as a treatment for mania

1912 – American Gilbert N. Lewis starts exploiting and discovering different uses for lithium batteries

1923 – "Metallgesellschaft, "a German industrial conglomerate, is the first to produce commercial quantities of lithium metal

1930-1936 – Grigg commercializes a "lithiated" drink called "Bib-Label Lithiated Lemon-Line Soda." The drink helped to subdue mood swings and the drink came to be known as 7up.

1942 – The Lithium Corporation of America is established in the United States, utilized by the government for the production of Lithium-7, for the Manhattan Project, to complete the hydrogen bomb

1948 – John Cade, an Australian psychiatrist, uses lithium to treat mental disorders

1953 – The U.S. Atomic Energy Commission (AEC) utilizes large quantities of lithium hydroxide for use in thermonuclear weapons

1954 – A nuclear test in completed at "Castle Bravo, "lithium deuteride is used, which produces a yield of 15 megatons (1,000 times the impact of the Hiroshima Bomb)

1966 – First lithium clinic is opened in North America

1967 – Lithium Carbonate is used a dug

1970 – Lithium is recognized as an official treatment of manic illness in the United States

1973 – Adam Heller, an Israeli American engineer, develops the idea to use lithium thionyl chloride in batteries

1975 – Annual world consumption of lithium is 4090 tons

1975-1980 – Michael Armand, a French Chemist, introduces the idea of a battery utilizing lithium ions moving back and forth between positive and negative ions

1980 – Rachid Yazami, a French Moroccan scientist, who invented the graphite anode (negative pole) in lithium-ion batteries, shows “reversible electrochemical intercalation of lithium in graphite.”

1991 – Sony produces and announces the lithium-ion battery to the public

1990’s – John B. Goodenough develops a lithium-ion cathode created by lithium iron and phosphate

1990’s – Sony begins manufacturing lithium cobalt oxide (LiCoO2) batteries, which are highly flammable and routinely catch fire

1991 – Sony gets an international patent on a lithium-cobalt-oxide cathode

2010 – The United States Geological Survey identifies Bolivia and Chile as the resources for Lithium and estimates the world lithium reserves to be at 9.9x109 kg (economically extractable) and lithium resources at 2.55x1010 kg (potentially economic)

2011 – Sources of lithium, based on a study by University of Michigan and Ford Motor Company, are estimated to support lithium demand globally until 2100–

2016 – The International Civil Aviation Organization bans transport of lithium ion batteries on cargo and passenger airlines due to lithium battery fires on commercial aircrafts

2016 – Annual demand, globally, of metallic lithium is 37,800 tons

2018 – The United States Geological Survey re-estimates the levels of the lithium reserves to be at 16 million tons

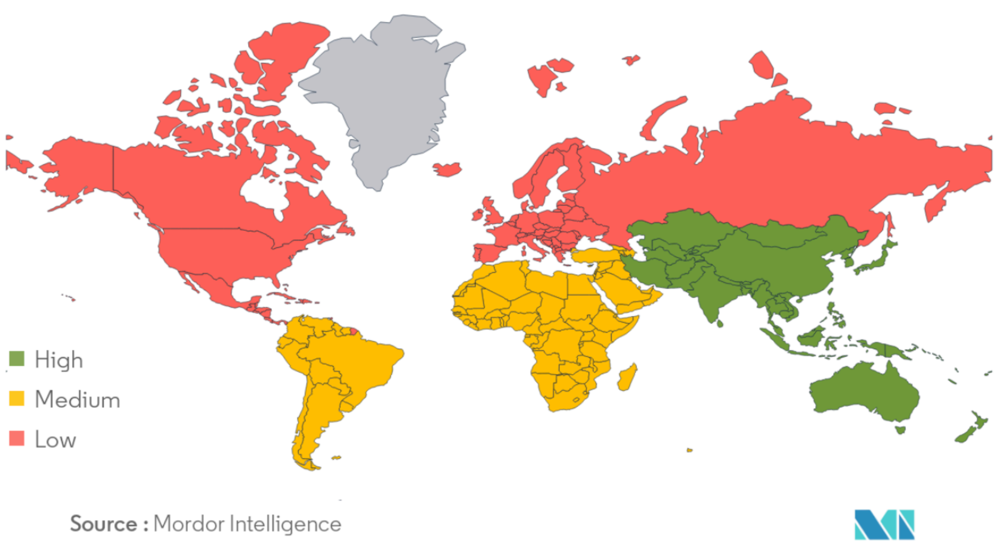
2018 – Researchers from Yale (U.S.) and Donghua University (China) find a new way to develop lithium metal electrodes, the main components in batteries

Players in the Lithium Battery Industry

The top companies competing for market share in the lithium-ion battery market include Panasonic Corporation, Tesla, Inc, Samsung SDI, Contemporary Amperex Technology Co, Ltd (CATL) and LG Chem Ltd. The lithium ion (Li-ion) battery demand is predicted to multiply by 10 times between 2008 and 2030. In 2015, there were approximately 91 factories throughout the world that manufacturer Li-ion batteries and that too is expected to increase. The largest Li-ion producers are in China/Asia and Australia, as seen in Figure 1.

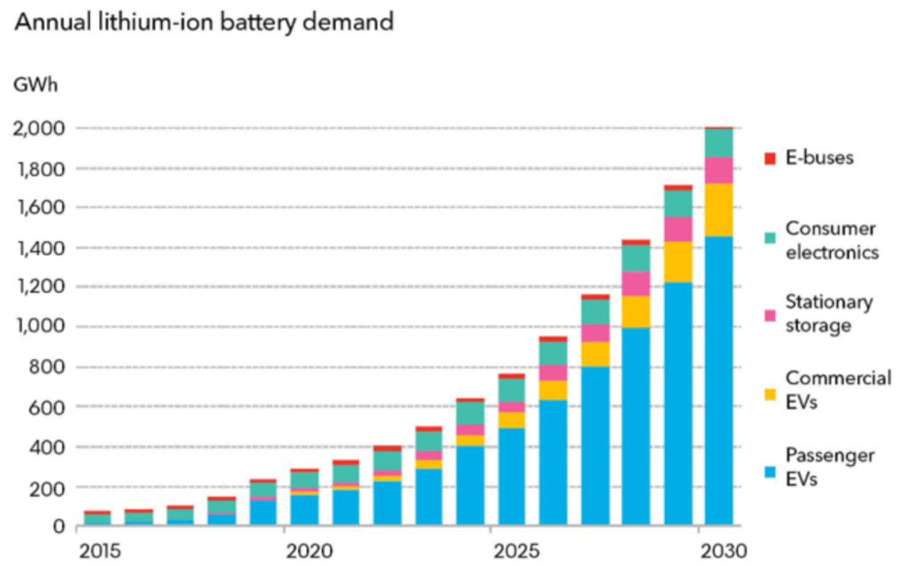
Figure 1:

Lithium-ion Battery Manufacturing Locations in 2020:



The electric car market is driving Li-ion battery production. In 2018, the electric car market represented about 2% market share, in the Li-ion battery market, and that is expected to rise to approximately 25-35% by 2030. This doesn't even account for other products in the Li-ion markets, including, consumer electronics which is growing exponentially. LG Chem is currently the number one Li-ion producer and has contracts with Volkswagen, General Motors, Ford, Renault-Nissan, Hyundai, Kia, and other big manufacturers. In order to expand market share, manufacturers like LG Chem are expanding to increase manufacturing capacity by building a second factory, and in this case, in the United States. The LG Chem plant is expected to increase capacity from 110 Gwh, by 2020, to 170 Gwh, by 2024. To give a visual, 1 Gwh is equivalent to approximately 110 million LED light bulbs producing 9 WATTs of energy. That's not the end either, LG Chem will continue to expand its manufacturing capabilities until it can support the expected increase in demand until 2030, as seen in Figure 2. LG Chem currently has a market cap of $23.51T and that will continue to increase, but as they are increasing revenue and increasing supply of Li-ion, what is the negative impact on the environment of doing so. This is just one company, which has a huge impact on the environment, there are several other Li-ion producers that will continue to increase their production capacity until demand is met (Figure 3) and currently there is not an infrastructure in place to support proper recycling and disposal of these batteries. Recycling and disposal concerns will be covered in the next section.

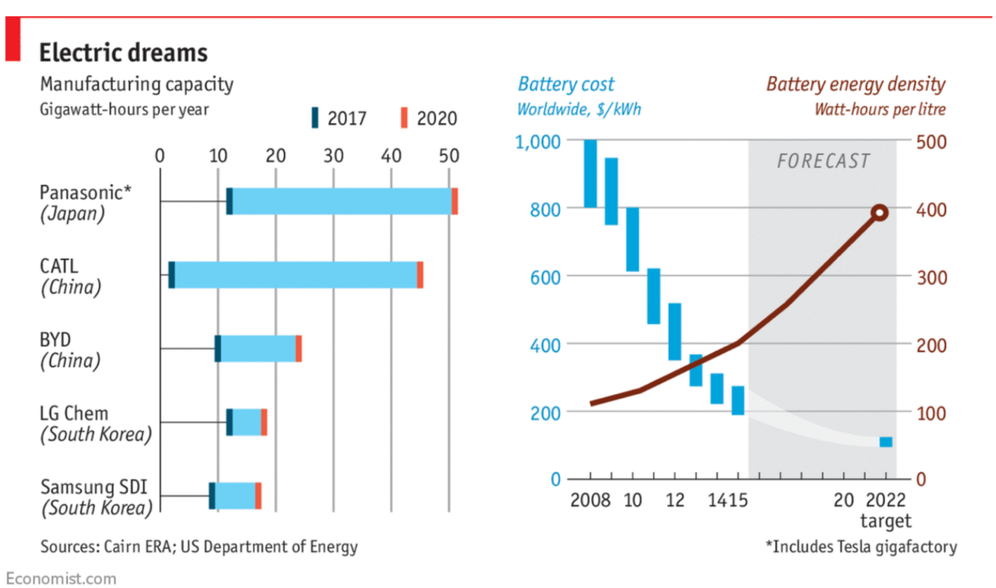
Figure 2:



Source: Bloomberg NEF 2019 Electric Vehicle Outlook

Figure 3:

Manufacturing Capacity by Leading Li-ion Producers



Tesla, the 5th largest Li-ion producer, completed its "Gigafactory," located in Shanghai, China in 2018 (Figure 4) and has others in various locations around the world. Tesla is their own sole supplier of Li-ion batteries for electric vehicles and energy storage, as discussed previously. Therefore, these factories are highly concentrated with Li-ion and have many safety concerns, that include, batteries overheating (thermally unstable at temps above 130 degrees Celsius (265 degrees Fahrenheit) causing thermal runaway, battery punctures (releasing toxic gases), short circuits, overcharge, internal cell failure, and uncontrollable fires.

Tesla is setting a target production rate of 500,000 cars a year, therefore, the number of Li-ion batteries it needs to support to be installed in vehicles is an astronomical number. Not only does TESLA produce Li-ion batteries, in their 5.3 million sq. ft., but their factory is partially powered by renewable energy sources, such as solar panels. As discussed previously, TESLA's 100 kWh battery generates approximately 1,750 tons of CO2 during production, so if TESLA's target is to produce 500,000 cars a year and need 1 – 100 kWh battery per car, then 1 factory is generating over 875 million tons of CO2 emissions per year. This is equivalent to 190,217,391 years (of 4.6 tons of CO2 emissions being released per year) from a single gas-powered vehicle.

Figure 4:

Tesla's Gigafactory located in Shanghai, China (5.3 million sq. ft.)

Current Lithium Battery Environmental Concerns and Recycling Capability

Li-ion batteries are in cell phones, electronics, electric vehicles, and are found in multiple items people use on a daily basis. Li-ion batteries have been gaining speed, with innovation and technology, because they are small, compact, rechargeable and the battery charge lasts for an extended amount of time on one charge. However, Li-ion batteries may be more damaging to the environment, more than we want to believe.

Research shows that for every gram, when an Internal Combustion Engine is operating, it emits an equivalent to a gram of carbon dioxide emitted from a power station stack. Thus, the reason people want to move away from CO2 emitting energy sources and switch to electric vehicles with lower emissions. Electric cars are marketed to emphasize that they are "zero emission vehicles," which is not the whole and complete truth. Although electric vehicles do not have emissions coming directly out of their tailpipe, the carbon dioxide emissions are being expelled from a different part of the lifecycle (of the supply chain), from the lithium-ion battery factories. The emissions released at the Li-ion battery manufacturers factories have the same effect of once released into the atmosphere. This does not even include the emissions from other factories and industries that create emissions, including the car manufacturer, part manufacturers and tire manufacturers. I do not have data directly tracking the emissions from the lithium-ion battery factories, but as a good comparison I will utilize data that has been collected form emissions or “greenhouse gas emissions” coming out of power plants/ stations (This data is pulled from the UK environmental reporting data). Also, there are data comparisons with other sources of energy, coal, gas, natural-gas, and clean energy, to include, nuclear, wind and hydroelectric power, to show the difference of emission levels from each energy type. Also, take note that methane can be up to 25 times in strength (one 100-year cycle), so carbon dioxide is a weaker greenhouse gas overall, but still can be devastating to the environment. As you see in Figure 5, emissions range from coal being the most significant, at 1101gCO2 emitted per Kwh, and then the next is natural gas, and lastly clean energy, which is at approximately 15 gCO2 emitted per Kwh. As seen in the chart, renewable energy sources still produce emissions, and they are not “zero emissions” (Figure 5). Studies have been able to provide that there is 1 gCO2/km emitted for every Kwh (battery capacity) of battery used, with an expected battery life of 250,000km.

Figure 5:

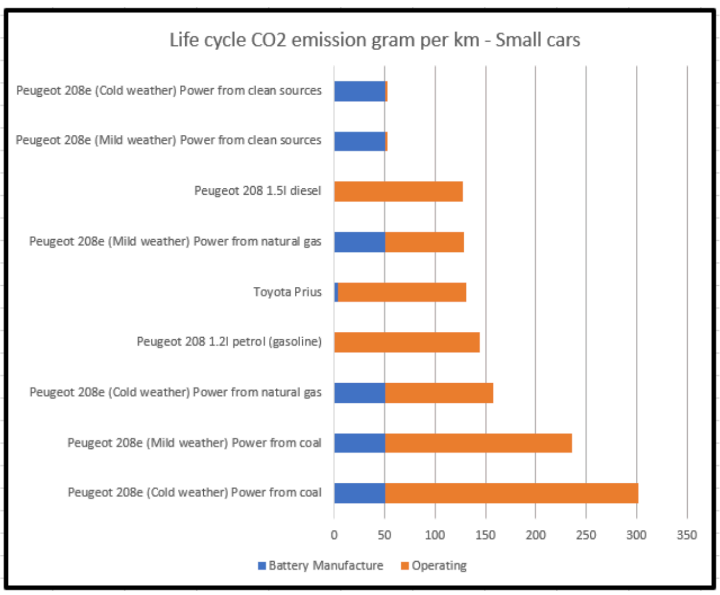
Emissions from Different Fuel Sources

	Natural gas - combined cycle	Natural gas - Thermal	Coal	Clean energy
Direct emissions from fuel	204	204	322	
Indirect emissions well to tank	27	27	52	
Methane leakage	2%	2%	2.18g/Kwh	
GHG CO2 equivalent from methane leakage	42	42	55	
Sub-total gCO2/Kwh of fuel content	273	273	374	
Power station efficiency	58%	40%	34%	
Emissions per Kwh generated	470	682	1101	15
Transmission and distribution losses	8.5%	8.5%	8.5%	8.5%
Emissions per Kwh at destination	510	740	1195	16
Charging efficiency	90%	90%	90%	90%
Emissions per Kwh at battery	567	822	1327	18

Source: https://www.gov.uk/government/organisations/environment-agency

Figure 6:

Emissions comparison with Electric, Hybrid and Gas-Powered Vehicles (Small Cars)



Source: www.seekingalpha.com

In Figure 6, we see that there is definitely an energy savings in electric vehicles, and they prove to generate less emissions, during the operation of the vehicle, but they are not “zero emission” vehicles. This data concludes that although electric vehicles are successfully reducing CO2/ greenhouse emissions, we cannot assume the car batteries in the electric vehicles are being charged with “clean energy” or power. Electric vehicles that are re-charged using “combined-cycle natural gas power” are the most efficient, which should be added to the total emission output of electric vehicles. If the power stations are switched to “thermal stations” the electric vehicles are not as efficient and will emit more greenhouse gases, data shows. Surprisingly, electric vehicles that are charged utilizing “coal-fired power stations” for recharging electric vehicles, they end up producing more emissions as a result, more than Internal Combustion Engine (ICE) vehicles. Rather than going out and buying an electric vehicle, a person can be just as energy efficient and reduce their “carbon footprint” simply by reducing the size of the internal combustion engine (ICE) vehicle they drive. By essentially switching to a small/compact ICE vehicle, a person can significantly reduce greenhouse gas emissions. So, when you add the emissions generated during the manufacture of the li-ion battery, the emissions generated from the power stations and the emissions emitted during the period where the electric vehicle is operating, the total emissions of electric vehicles total is very comparable to emissions generated by gas powered vehicles.

Currently Li-ion batteries are stacking up to be a big problem, currently there is no robust recycling infrastructure that exists for Li-ion car batteries. The industry is just starting to realize they need to design Li-ion batteries with recycling in mind and in their processes. The safest method for recycling is to use automated robots to disassemble the batteries and take resources from the old and recycle them back into the new batteries. As an example, in 2017, over 1 million electric vehicles were sold in the market. Along with those cars sold, it is perceived that they may result in over 250,000 tons of battery waste, once discarded. Of course, recycling is preferred, but if these batteries end up in landfills there is a risk of hazardous material contaminating the earth and there is also a risk of "thermal runaway" at the landfills. As a reminder, "thermal runaway" is a chemical reaction that is started when the batteries themselves heat up, therefore, there is a danger of these batteries burning controllably and exploding.

Recycling is the way to go, but it's not profitable and has no cost advantages, since there is a need to utilize robots and technology to properly disassemble the batteries. Since these recycling methods are not profitable, companies are not incentivized to make Li-ion car battery recycling into a business. There is a need for the industry to solve many problems, such as, designing a standard battery that has easy assembly, resolve risks that are imposed onto humans (if robots are not available for disassembly), and find ways to reuse sources like Cobalt to reduce the overall cost of the battery costs. Currently, all Li-ion batteries are different, and they are extremely difficult to disassemble and pose many risks to humans, like toxic gases, toxic metals, “thermal runaway,” and many more dangers. These problems add to the reason why Li-ion car batteries are extremely expensive to recycle, thus, there is a large probability that these batteries will end up in landfills. Also, the general public does not receive proper training on how to handle hazardous materials and how to properly dispose of them, therefore, by pure ignorance, when these batteries hit the end of their lifetime, they will most likely be mishandled and improperly disposed of.

To assist the effort on recycling, The Department of Energy has launched a “prize for lithium battery recycling.” An effort to speed up the process in order to find a way to properly dispose of Li-ion batteries and find the best concepts needed to lead the industry. The goal, put forth by the Department of Energy, is to find a method in which can recycle up to 90% of all lithium type batteries. Also, the department is putting $15 million towards the lithium battery recycling center, which is being ran by national laboratories. Counteracting the efforts, in 2018, the Trump Administration sponsored and jump-started a strategy, in the United States, to boost local production of “35 critical minerals used in manufacturing, batteries and electronics, including, lithium, uranium and cobalt, to reduce reliance on foreign suppliers," according to the Reuters report titled "U.S. Energy Department to Develop Lithium Recycling Research Center." So, in essence, while the United States in trying to combat lithium battery recycling efforts, which are less than satisfactory to support recycling capacity for the market, the government is promoting manufacturing of even more lithium batteries and other harmful minerals to be utilized in various products. The problems associated with recycling lithium batteries need to be corrected before the United States is incentivized to manufacturer even more batteries, because the current infrastructure is not able to support recycling and disposal efforts that are safe for humans and the environment.

Where is the Lithium Battery Industry Headed?

According to Tesla, unless production and capacity ramps up for Li-ion car batteries, a battery shortage is anticipated to occur in 2020. Present day, Audi is reporting battery shortages. Audi had a target, in 2020, to produce 4100 electric vehicles, but due to the battery supply short falls, they will be 1600 units short this year. Automakers across the industry are experiencing the same bottlenecks in production. It is projected that by 2024, the Li-ion battery industry will be worth more than $60B. While that is great for global market, this is not good for the environment and for human welfare. Cobalt is another key ingredient for Li-ion batteries and can be recycled, as discussed earlier. Cobalt is mined in the Democratic Republic of Congo (DRC) and the country is responsible for supplying the industry with over 65% of the resource. There has been numerous reports that the mining industry, located in the DRC, has many hazards to its people, to include, forced labor, child labor, abuses to human rights and provides an extremely dangerous working environment. Also, due to the extremely high demand of the resource, which is thought to reach 160,000 tons by 2023 and 430,000 tons in the next decade, a cobalt shortage will occur, prices will begin to spike and having this type of "green energy" may become very costly. Lithium does not seem to face any shortages now or in the foreseeable future, however, continued mining of the salt flats in Brazil will continue to scar the earth and impact the environment. However, to keep up with the demand of Li-ion batteries there must be a continuous resource to mine, for both cobalt and lithium. Something to keep in mind, until the battery-life runs out on these Li-ion batteries (which last for numerous years) recycling will not gain traction as there is not much demand for it now, but once these batteries start to reach the end of their lifetimes the market may be hit with more than they can handle when it's time to recycle and dispose of these batteries, if we don't get ahead of the game now.

Will the Lithium Battery Industry be Detrimental to the Environment?

Among the toxins in Li-ion batteries are hydrogen fluoride (HR), phosphoryl fluoride (POF3), lithium hexafluorophosphate (LIPF6) and carbon dioxide. In a situation of thermal runaway, a cell failure becomes unstable and starts to heat up, a chain reaction than occurs and a cell at a time starts to disintegrate. The chain reaction continues to spread throughout the cells of the battery, as long as they are connected, thus, the reason they put dividers in batteries in order to mitigate chain reactions in this sort of event. Also, there are gases that are released in thermal runaway, to include, carbon dioxide, phosphoryl fluoride (a colorless gas), and hydrogen fluoride (also colorless and can cause blindness). If the Li-ion battery heats up to the point of ignition it can burn uncontrollably because the electrolytes release gases, that are flammable, and the cathodes produce oxygen which maintain the fire. The fire is very difficult to extinguish because it is technically a Class B (flammable liquids) fire and reacts aggressively to air and water. Therefore, if the batteries contain hazardous materials, such as these, of course they will be detrimental to the environment eventually, if not now. The hazardous materials, the greenhouse emissions, the battery fires, and disposal are all elements that can have negative effects on the environment if not regulated.

Conclusion

In Conclusion, it is very important to understand the different factors taking place during mining of a resource (Lithium), production and manufacturing and the lifecycle of the product (in this case Li-ion car batteries) before a determination is made on what constitutes "green energy." The media and politicians have played a big role in pushing the benefits of Li-ion batteries and electric vehicles, but the disadvantages of the energy source have not been very well publicized. As shown by my research, I have found that Li-ion batteries are not very "green" and we must be very careful when moving forward with this technology as there might not be a strong infrastructure in place to prevent further destruction by mining lithium, proper disposal of the batteries and/or recycling if we continue to manufacturer these types of products in mass production. Also, there needs to be more safety requirements for li-ion batteries as they present a high risk of fires and explosions in an electric vehicle car accident. It is very important to educate the public, the government, and possibly even force the Environmental Protection Agency (EPA) to implement further controls on Li-ion batteries so batteries are not detrimental to the environment and pose other harms to Americans and further generations.

References

Katwala, A. (2018, August 3). The spiraling environmental cost of our lithium battery addiction. Retrieved February 4, 2020, from https://www.wired.co.uk/article/lithium-batteries-environment-impact

Rapier, R. (2020, January 20). Environmental Implications Of Lead-Acid And Lithium-Ion Batteries. Retrieved from https://www.forbes.com/sites/rrapier/2020/01/19/environmental-implications-of-lead-acid-and-lithium-ion-batteries/#1e7125687bf5

https://www.euronews.com/2019/03/21/electric-car-batteries-damaging-to-environment-amnesty-international. (n.d.).

Eckart, J. (n.d.). Batteries can be part of the fight against climate change - if we do these five things. Retrieved from https://www.weforum.org/agenda/2017/11/battery-batteries-electric-cars-carbon-sustainable-power-energy/

https://www.theguardian.com/vital-signs/2015/jun/10/tesla-batteries-environment-lithium-elon-musk-powerwall. (n.d.).

https://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/17435/Will-Your-Electric-Car-Save-the-World-or-Wreck-It.aspx. (n.d.).

(n.d.). Retrieved from https://www.industryweek.com/technology-and-iiot/article/22026518/lithium-batteries-dirty-secret-manufacturing-them-leaves-massive-carbon-footprint

Gardiner, J. (2017, August 10). The rise of electric cars could leave us with a big battery waste problem. Retrieved from https://www.theguardian.com/sustainable-business/2017/aug/10/electric-cars-big-battery-waste-problem-lithium-recycling

https://www.nature.com/articles/s41598-017-09784-z. (n.d.).

Retrieved from https://cleantechnica.com/2018/09/13/cobalt-the-toxic-hazard-in-lithium-batteries-that-puts-profit-before-people-the-planet/

http://jes.ecsdl.org/content/164/1/A5019.full. (n.d.).

https://timelines.issarice.com/wiki/Timeline_of_lithium. (n.d.).

https://www.mordorintelligence.com/industry-reports/lithium-ion-Battery-market. (n.d.).

Jaberwock. (2019, December 11). The Great Electric Car Zero Emissions Boondoggle. Retrieved from https://seekingalpha.com/article/4311761-great-electric-car-zero-emissions-boondoggle

https://www.ektinteractive.com/history-of-oil/. (n.d.).

Calma, J. (2019, November 6). The electric vehicle industry needs to figure out its battery problem. Retrieved from https://www.theverge.com/2019/11/6/20951807/electric-vehicles-battery-recycling

https://www.reuters.com/article/us-usa-energy-lithium/us-energy-department-to-develop-lithium-recycling-research-center-idUSKCN1PB1V0. (n.d.).

Gheorghiu, I. (2019, January 15). Global lithium-ion battery market expected to exceed $60B by 2024: report. Retrieved from https://www.utilitydive.com/news/global-lithium-ion-battery-market-expected-to-exceed-60b-by-2024-report/546108/

Cohen, A. (2020, March 25). Manufacturers Are Struggling To Supply Electric Vehicles With Batteries. Retrieved from https://www.forbes.com/sites/arielcohen/2020/03/25/manufacturers-are-struggling-to-supply-electric-vehicles-with-batteries/#5e09b78f1ff3