AUTOMOTIVE INDUSTRY IN THE ERA OF SUSTAINABILITY AND THE FUTURE RECYCLING OF LITHIUM-ION BATTERY

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Abstract: **This paper looks forward, past the extended huge scope market entrance of electrical vehicles containing sophisticated batteries, to when the spent batteries will then be prepared for definite end-life uses. It depicts the importance of having a functioning framework for regulating, recycling, reusing and utilization of lithium-ion battery. With Electric Vehicles raising in popularity, we are looking at a potential glut of spent lithium-ion battery cells in 10-20 years. But my 2040, it is expected that half of new car sales will be electric. Recycling of lithium-ion (Li-particle) batteries is more demanding and it is expected to increase in the coming decade but only 5% of it is currently being recycled because it is more expensive to recycle than to mine for new material. Remaining 95% often find their ways into dangerous stock piles or landfills which can leak toxic chemicals into ground water or explode if not handled properly. Thus, this paper will highlight about the activities to ensure that all the hindrances to reusing are dealt with while also guarantee that affordable and manageable alternatives are achievable for end-of-life batteries.**

Keywords: **Sustainability, Automotive industry, recycling, lithium-ion.**

I. INTRODUCTION

One of the most important and fundamental technology which most people take for granted are batteries but without batteries some of the most important technology could not fundamentally exist such as mobile phones, laptops, electric scooters and even the 12V batteries that runs the regular electric cars. In 2020, battery technology is finally starting to move with 3.4 million Electric Vehicle batteries expected to be produced by 2025. But once they all become obsolete what really happens to the used battery. In this research paper, we will put Lithium-ion battery technology used in Automotive under scrutiny and analyze the importance of establishing proper guidelines to address the end-of-life batteries along with relevant economic, technical and environmental aspects of recycling and how new industries are emerging from raising wave of development to accelerate recycling of those batteries before battery recycling crisis arrives.

AN END TO FALSE PROMISE

The main limiting factors for modern batteries are the cost, size and storage capacity. Over the last decade, the so- called breakthroughs ("infinite" Battery Life Discovery) were announced many times but fell short of their promises. It is not to say that there have not been any improvements. For example, Tesla's battery cost has been cut in half and capacity increased by 60% between 2008 and 2015 (MIT technology review). It is also been reported that between 2012 and 2017 general battery cell prices fell by 70% (BNEF forecasts of lithium-ion battery).

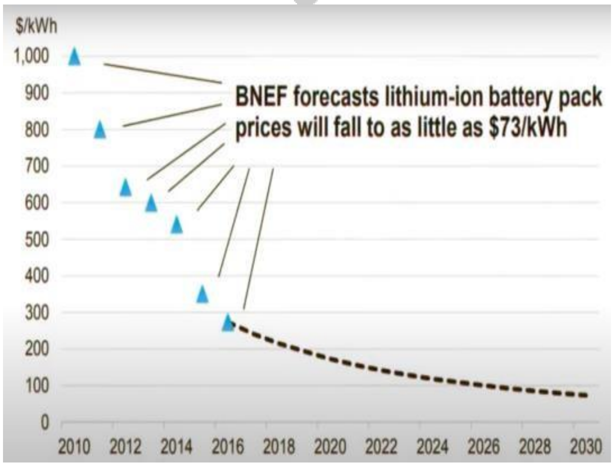

Fig. 1 Price of Lithium-ion battery over years

However, despite the progress batteries are often a limiting factor of new technology and by that sentiment they must improve.

A. Finding a solution

One issue with renewable energy is storage. Electricity can be generated by renewable sources but the productions by these sources don't coincide with the electrical demand of the population. For example, in solar the Sun sets just as the electricity demand increases when people come home from work. Better batteries will make renewables able to supply more of the electricity demand even if the source isn't live.

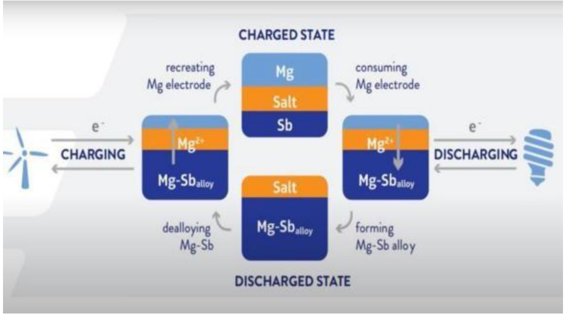

Fig. 2 Charging & discharging mechanism

Tesla is aiming to solve the same problem with a new giant battery storage facility in California and is expected to debut in the near future. The company has already solved South Australia's blackout issues by installing their battery facilities in under 90 days. The tesla battery pack was a massive success and performed well possessing the ability to supply hundred megawatts of power in just 140 milliseconds. The energy prices for on current demand response service went down 90% in the first 4 months of operation. Furthermore, the state saved 35 million dollars in that same 4 months period.

Fig. 3 Performance chart of Tesla Battery pack

B. Some encouraging News

Currently, lithium-ion batteries are the king of battery technology where lithium atoms are stored inside of graphite layers inside a cell. The lithium atoms lose and regain electrons providing the electrical output.

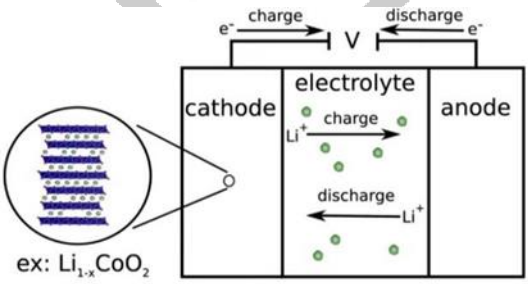

Fig. 4 Electrons movement in Lithium-ion

A SILA nanotechnology is a company based in California that is trying to create a breakthrough in lithium-ion technology. They intend to use microscopic silicon particles to store the lithium inside battery which stores 20 times more lithium than atoms of carbon.

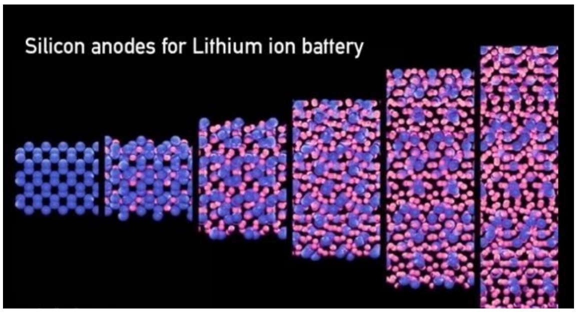

Fig. 5 Silicon anodes for lithium-ion Battery

An atom of silicon can store about 20 times more lithium than atoms of carbon. Essentially, it takes fewer atoms to store lithium so smaller volume of materials during smaller amount of energy.

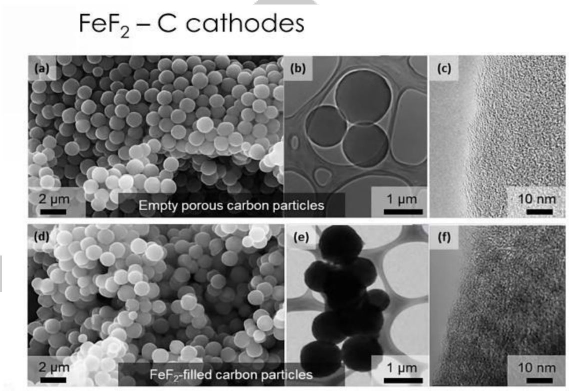

Fig. 6 Expansion problems in Battery

Expansion problems in battery arises when silicon expands and damages the battery wood leads charged. But SILA technologies has overcome this hurdle and their new battery seems to perform 40% better and charge up to nine times as fast because of the reduced thickness of anode. Research into aluminum-ion batteries have been conducted for several years now. It promises to be safer and cheaper than lithium-ion which has a tendency to explode or catch fire if damaged (Samsung galaxy note 7 debacle of 2016). Aluminum-ion batteries don't react in the same way and can still keep working even after having a hole drilled into them. The cost of the battery in contrast to lithium-ion is also much cheaper as aluminum is the 3rd most abundant element taking up to 8.1% of earth crust. Researchers claims that Aluminum-ion is promising technology but still is in the early days in terms of development and commercial viability.

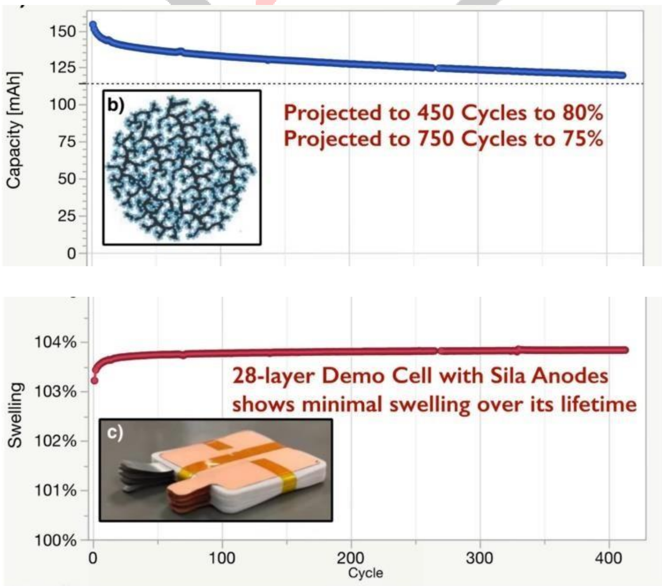

Fig. 7 Result of swelling after reducing anode thickness

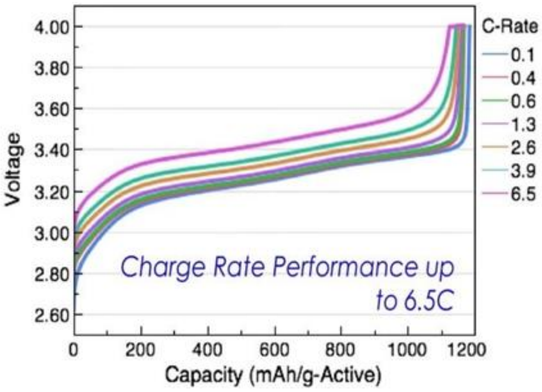

Fig. 8 charging rate after reduced anode thickness

II. RACE TOWARDS DEVELOPING A STATE-OF- ART BATTERY

There is countless number of batteries being developed such as vanadium redox, lithium air, fluoride ion and the list goes on. Previous to the last decade there were no strong financial incentives to improve battery technology, now those electric cars with better utility storage are proving to have a definite potential for a viable large-scale market, everyone is rushing to create the best tech and sell it. For example, Toyota has 233 patents and has invested 14 billion dollars into commercializing a new solar state battery for the early 2020s. Ten years ago, people didn't believe decent electric cars were possible and established car manufacturers weren't taking them seriously until 2018. A battery revolution is coming and this time it's different. But for now, lithium-ion battery reigned supreme and the demand will not stop.

Lithium-ion recycling crisis

Assume we stick to lithium-ion battery for the next decade rather than liquid, aluminum or anything else. The volume of lithium-ion battery cells being sold will surge, which will create opportunities for recyclers. It is clear that battery revolution is coming but how long do we have to start worrying about environment factors from when a new wave of electric cars and battery systems start expiring. In terms of global environmental issue, Tesla batteries degrade about 9% after travelling 270,000 kilometers or 168 thousand miles. A model X has been clocked at over 600,000 km.

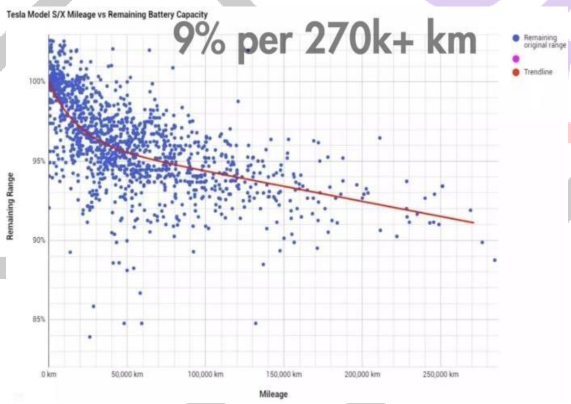

Fig. 9 Tesla Model X Battery Consumption

So, in truth, no one really knows how long these cars will last but some estimates put it about 17 years. There are secondhand uses after electric cars. These involves things like household power, commercial infrastructure and gradually fewer demanding uses until the batteries can only power something like a TV remote reliably but it has reached the end of its life and it's time for recycling. So, let's be conservative and say that we have about 20 years all up before the battery crisis arrive.

A. Problems in recycling Lithium-ion

Currently there is a joint effort from top automobile manufacturers around the globe to keep batteries out of landfill.

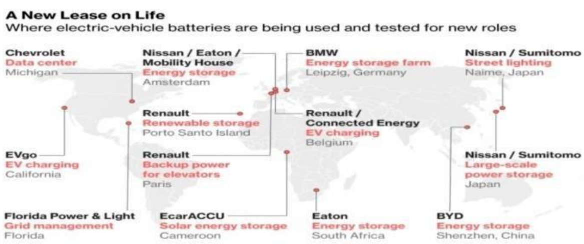

Fig. 10 Energy storage facilities of top Automobile manufacturers

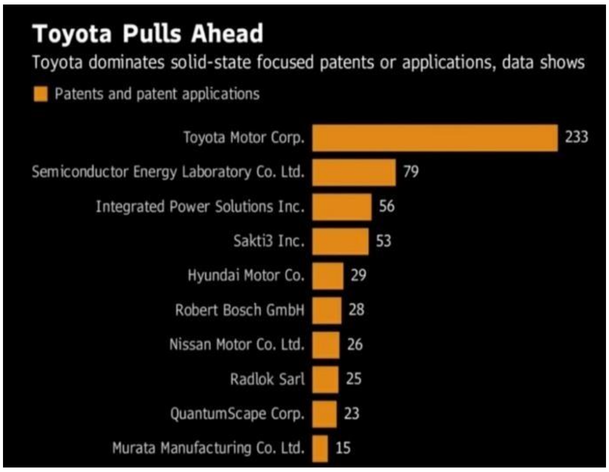

Fig. 11 Patents and patent application on Solid-state

The waste materials of batteries can be toxic. We have metal oxides, phosphates as well as aluminum, copper, graphite and organic electrolytes but there are also harmful lithium salts and various plastics. If we don't take care of recycling these components, there could be major environmental consequences.

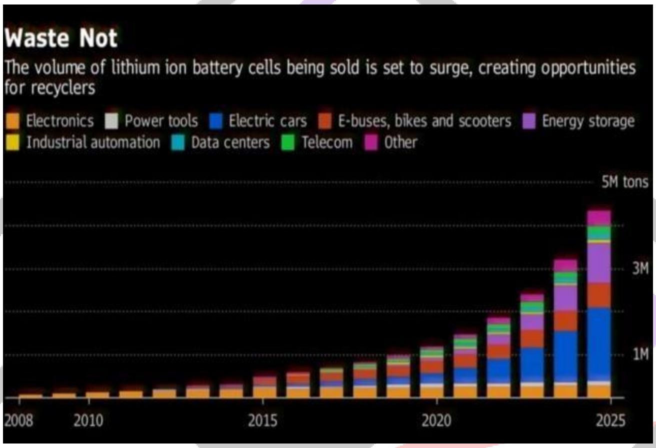

Fig. 12 Forecast on the volume of Lithium-ion sold

Today, the problem is 95% of lithium-ion are either stockpiled or end up in landfill which can cause explosions (thermal runaway) or prolonged environmental damage. Also, to avoid explosions, lithium-ion batteries must be fully drained before recycling. The main culprits are phones and laptops, right now when we throw them in the garbage; it is way too expensive to sort them from the rest of the trash, so the people need to be educated. But with electric cars and utility storage, this is much less of an issue. The recycler knows that they are dealing solely with batteries and can recycle accordingly but there still remains a problem of battery labeling. Packages of a lot of lithium-ion batteries does not describe what is inside the cell making it significantly harder for people looking at recycling but specifying roughly what is in there would be very important.

B. Recent advances and perspectives in Recycling of lithium-ion batteries

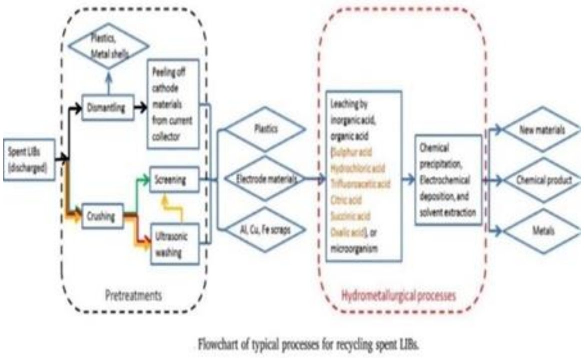

Fig. 13 Flowchart of typical processes for recycling spent LIBs

(i) Hydrometallurgical processes:

Here grinded battery material is leached in order to obtain an aqueous solution containing the battery metals (Li, Ni, Mn, Co, Cu and Al) and then purified to selectively isolate elements that are further processed in the next precipitation stage in order to obtain metals or products used to make new batteries.

(ii) Ultrasonic washing (2018):

Using high frequency sound to agitate has been proven to use less energy than crushing or heating separate parts. In the study, there have been many chemical components separation methods that you recover above 90 percent of important raw materials.

(iii) Bio-leaching:

Bio-leaching (bio-hydro-metrology) process recovers a 100% copper and lithium and 75% of the aluminum. This method used hydrochloric acids as well as citric acids present in fruits. Surprisingly, even certain types of fungi found in decaying vegetation in soil can lure bacteria that remove and separate cobalt from lithium. On the plus side, its running cost is low however the disadvantage is, it is relatively slow.

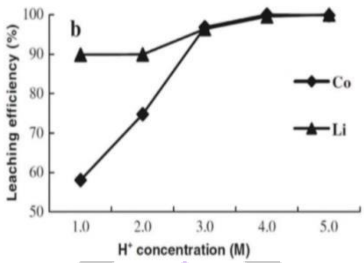

Fig. 14 Performance chart of Bio-leaching process

III. ECONOMIC AND ENVIRONMENTAL ASPECTS OF RECYCLING

When the raw materials are recovered, some elements can be used in concrete, magnets and even new batteries. The ideal recycling methodology should involve low energy consumptions but also recovers all important elements but with zero environmental pollutions. To achieve this, the batteries should also be designed with recycling in mind. Currently 99% of all lead acid batteries are recycled. This is because lead acid batteries are much older technology that stretches back to 1859 but lithium-ion on the other hand has only been in widespread use since the early 1990s. Companies like lifecycle are close to total recovery and can produce chemicals well enough for a satisfactory performance in a second-generation recycled battery. The system is a closed loop and their goal is to process up to 250,000 tons of Li batteries per year. Envirostream has recycled 240,000 kg of batteries in 2018. A company called Umicore has a fully closed loop recycling system where they can prevent 70% of CO2 emission from their recycling process. The byproducts such as refined metals like cobalt and nickel can be used to harden tools or used in grease like WD-40 and even resold to battery manufacturers. To highlight this, Umicore is one of the largest suppliers of lithium, cobalt oxide to the battery manufacturers.

A. Incentives from Governments Governments around the world are looking at different options to incentivize recycling. Australia for example, has put a ban on sending batteries to waste and landfill. In January 2019, USA has established the battery recycling R and D center as well as prizes totaling 5.5 million dollars for entrepreneurs to find innovative solutions to collecting, storing and transporting discarded lithium-ion batteries for recycling. In countries like Switzerland, there is additional tax on batteries which will go to the recyclers. The batteries will be sent to central facilities where they will be separated for recycling. China has implemented a policy with more subsidies (China Electric vehicle subsidies program to favor long range BEVs) to provide manufacturers of longer range EVs. China will subsequently pull back the subsidies on companies that are not producing as long-range batteries as their competitors.

IV. CONCLUSION: A VISION OF IDEAL FUTURE SYSTEM

Since we only have one planet and the need to share and conserve its resources benefits not only us, but also our future generations. So, recycling enables the reuse of materials that would otherwise be discarded. It promotes the ―take, make and reuse‖ circular model that will help to sustain our planet for generations to come. The current batteries are not designed with recycling in mind and the common-sense approach would be ease of recyclability and it should be a fundamental part of product design. Education for consumers is the also a key to stop disposing of them in the rubbish bin.

Mechanisms should be in place to return all batteries at the extremity of their (first or second) useful lives to the appropriate recycling facilities in a safe and legal manner.

User-friendly labeling would aid appropriate routing. Regulations would assure safe transport and handling, and discourage any sort of cross-contamination. Recycling begins with sorting of discarded batteries through a transfer station or within a integrated recycling installation. Concurrently, an independent system should be established be process and produce valuable, high- purity materials that could be reused in batteries or in another high-value product if the recovered material had become obsolete. Strict industry standards should ensure that recycled products meet the same high-quality standards as virgin materials and thereby are accepted for reuse. Accomplishment of this future vision before large numbers of automotive propulsion batteries have reached the end of their useful lives requires research and planning to continue over the next 10 years or so. It is a daunting task, but if there is a broad commitment from industry and government, it can be done.

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