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The Effects of Lithium-Ion Batteries on the Environment

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Abstract:

Lithium-ion batteries, pivotal for the proliferation of portable electronics and the burgeoning electric vehicle market, have emerged as a transformative era. However, their environmental implications throughout the lifecycle gift substantial concerns. From extraction to disposal, the unfavourable results are obvious. Mining for lithium, a critical thing, needs giant water consumption, potentially leading to freshwater depletion and habitat disruption. Furthermore, the manufacturing method includes electricity-in depth procedures, emitting greenhouse gases and contributing to pollutants. Disposal poses a task as improper strategies launch poisonous elements, endangering soil, water, and air nice. Sustainable mining practices, green recycling tasks, and innovation in battery era are vital to mitigate these environmental repercussions. Striking a balance among harnessing the advantages of lithium-ion batteries and addressing their environmental footprint is vital to foster a sustainable power destiny.

Keywords: Technology, Sustainability, Innovation, Environment, Energy, Recycling

Introduction-

Lithium-ion batteries have gained popularity in recent years and have been promoted in electric vehicles as the "perfect solution" to environmental sustainability. However, it is crucial to understand the consequences of its use and disposal on the environment.

In light of recent events, including India’s discovery of the lithium reserve in Jammu and Kashmir in February, there is a need for proper recycling plants in order to preserve raw materials like nickel, cobalt, copper,etc. for future generations. Besides, lithium-ion batteries contain other hazardous substances that, if not disposed of properly, risk the lives of everyone living around us (Bai et al., 2020).

Lithium-ion batteries have revolutionized portable electronics and clean power storage structures, playing a pivotal role within the transition towards renewable electricity and electric powered transportation. Despite their severa benefits, these batteries improve big environmental worries for the duration of their lifecycle. From mining and production to disposal, lithium-ion batteries effect ecosystems, natural assets, and human fitness (Benveniste et al., 2018).

To begin, the mining procedure for lithium, a key issue in these batteries, includes extracting lithium-wealthy minerals like spodumene or lithium carbonate from the earth's crust. This extraction procedure includes extensive water consumption, probably main to freshwater depletion in regions in which mining operations occur. Additionally, the extraction process can result in habitat disruption, soil contamination, and alteration of landscapes, affecting neighborhood flora and fauna. The environmental toll of mining sports for lithium underscores the want for sustainable extraction practices and recycling initiatives to mitigate these unfavorable effects (Bird et al., 2022).

Moreover, the manufacturing phase of lithium-ion batteries includes complex strategies that consume great strength and assets. These include refining and processing uncooked materials, assembling battery components, and transporting them throughout the deliver chain. Manufacturing emits greenhouse gases and other pollutants, contributing to air and water pollutants. Furthermore, the disposal of lithium-ion batteries provides a looming environmental mission. Improper disposal methods, along with landfilling or incineration, can cause the release of toxic chemical compounds and heavy metals, posing dangers to soil, groundwater, and air nice. As the demand for lithium-ion batteries continues to surge, the right management and recycling of those batteries turn out to be imperative to mitigate their environmental impact (Chen et al., 2019).

Lithium-ion batteries have emerged as a critical generation for easy energy storage, their environmental footprint spans from aid extraction and production to stop-of-existence disposal. To limit these affects, concerted efforts are essential across the whole lifecycle, such as sustainable mining practices, strength-green production techniques, and strong recycling programs. Addressing those challenges via innovation, law, and responsible consumption could be pivotal in ensuring the long-term sustainability of lithium-ion battery era even as keeping the health of our planet (Costa et al., 2021).

Main Objective:

While electric vehicles are being heavily promoted, there isn't much awareness about their proper disposal and recycling. Even though the government has introduced a few policies for disposal, they have not been properly implemented. Through our research paper, we aim to spread awareness about the dangers of lithium batteries and their safe disposal.We would spread awareness about various alternatives.

1. To implementing efficient recycling programs to reduce the environmental impact of lithium-ion battery disposal.

2. To develop sustainable mining practices to minimize habitat disruption and water depletion during lithium extraction.

3. To enhance battery manufacturing processes to lower energy consumption and reduce emissions.

4. To promote research and innovation for the development of alternative battery technologies with lower environmental footprints.

Literature Review

Performance in unfavourable climate

Temperature is one of the most influential factors in a battery's performance. When the temperature drops, the chemical reactions required to generate energy become slower and less efficient, causing a decrease in the capacity and discharge rate of the battery. Additionally, the battery becomes less mechanically stable and charging can cause further damage. Battery cells are sensitive to environmental conditions and are usually tested to survive a wide range of temperatures (Dai et al., 2019). But when the temperature drops significantly, it can cause serious damage to your batteries.Battery cells such as lithium-ion batteries operate on reversible reduction reactions, and when temperature drops significantly, rapid plating occurs. Lithium batteries discharge an electric current when the transfer of lithium-ion occurs from the graphite anode (negative electrode) to the cathode (positive electrode). This process slows down in cold weather thus weakening their power (Fan et al., 2018). As the temperature drops, the lithium ions will just coat the anode (lithium plating) thus increasing the resistance of the electrolyte and making fewer lithium ions available to cause the flow of electricity. This can reduce 20-30% of the rated battery capacity (Fan et al., 2018). When lithium batteries are exposed to low temperatures, the rate of lithium-ion transfer in and out of the anode is decreased at a rapid rate. This decrease in the rate of lithium-ion transfer is caused by the lithium-ion alloy that plates onto the surface of the anode preventing entry of the ions into the carbon site of the anode. As a result, this prevents current flow and drastically reduces the battery capacity. In other words, the battery “freezes” if the lithium-ion isn’t able to make its way through the anode. Besides a reduction in capacity, freezing temperatures also affect certain battery components in a more damaging way. For example, the electrolyte could become stiff and be circulated less smoothly, thus decreasing the rate of lithium-ion transfer. A decrease in capacity results in a decrease in the battery voltage and output power (Kaunda, 2020).

While very low temperature can produce a reduction in the energy and power capabilities of lithium ion batteries, high ambient temperatures on the other hand can contribute to a high internal temperature of the battery which can also decrease performance. If the temperature reaches a critical point, thermal runaway can be triggered in the lithium ion batteries. At a critical temperature, a chain of exothermic reactions can be triggered. The reactions lead to a further temperature increase, which in turn accelerates the reaction kinetics. This catastrophic self-accelerated degradation of the Li-ion battery is called thermal runaway. Because of this the lithium-ion cell enters an uncontrollable, self-heating state. Thermal runaway can result in extremely high temperatures, violent cell venting, smoke and fire (Lai et al., 2022).

In a lithium-ion cell, the cathode and anode electrodes are physically separated by a component called the separator. Defects in the cell that compromise the separator's integrity can cause an internal short circuit condition that can result in thermal runaway.

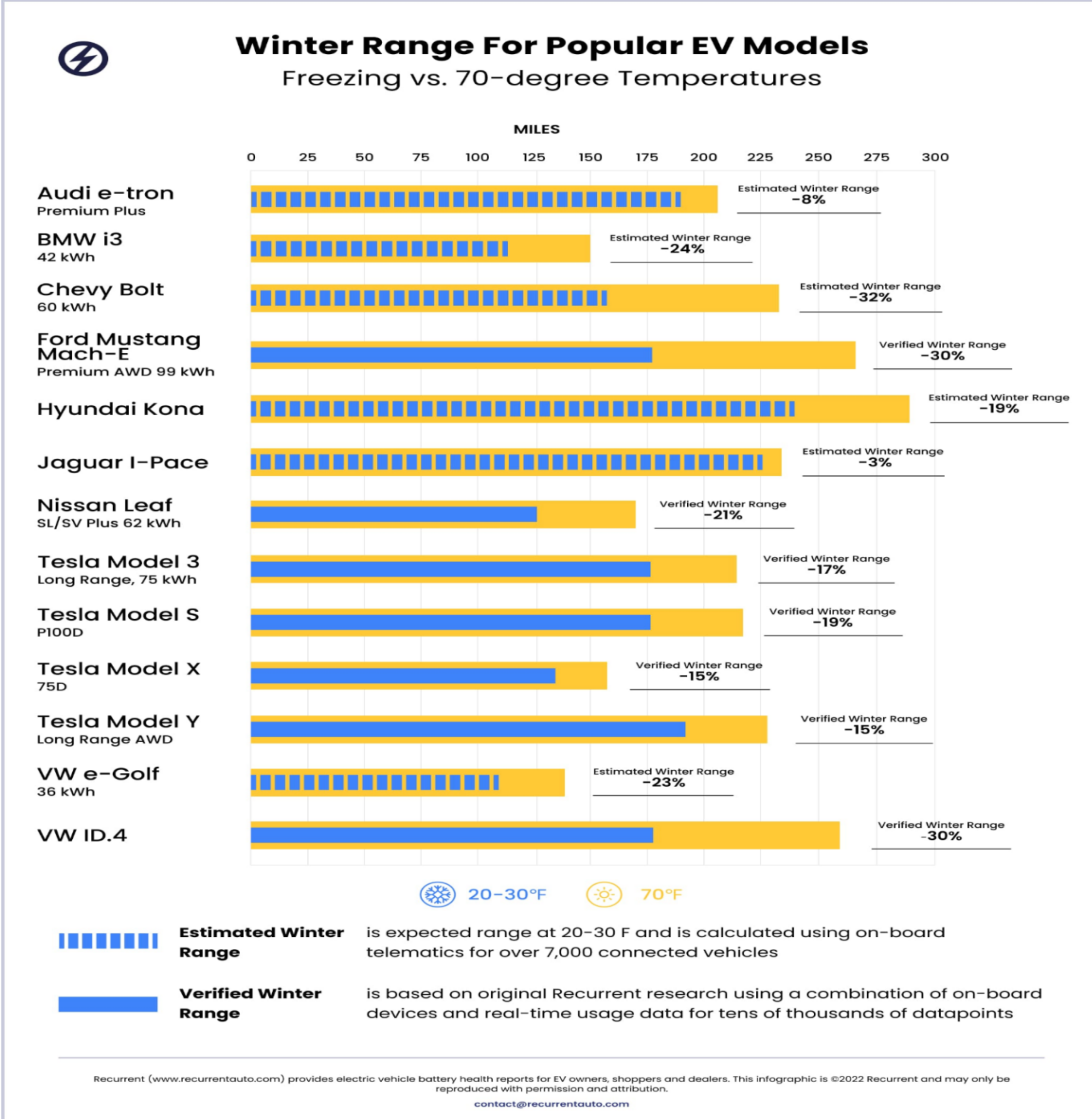


Fig 1: Popular EV models in the range of Winter

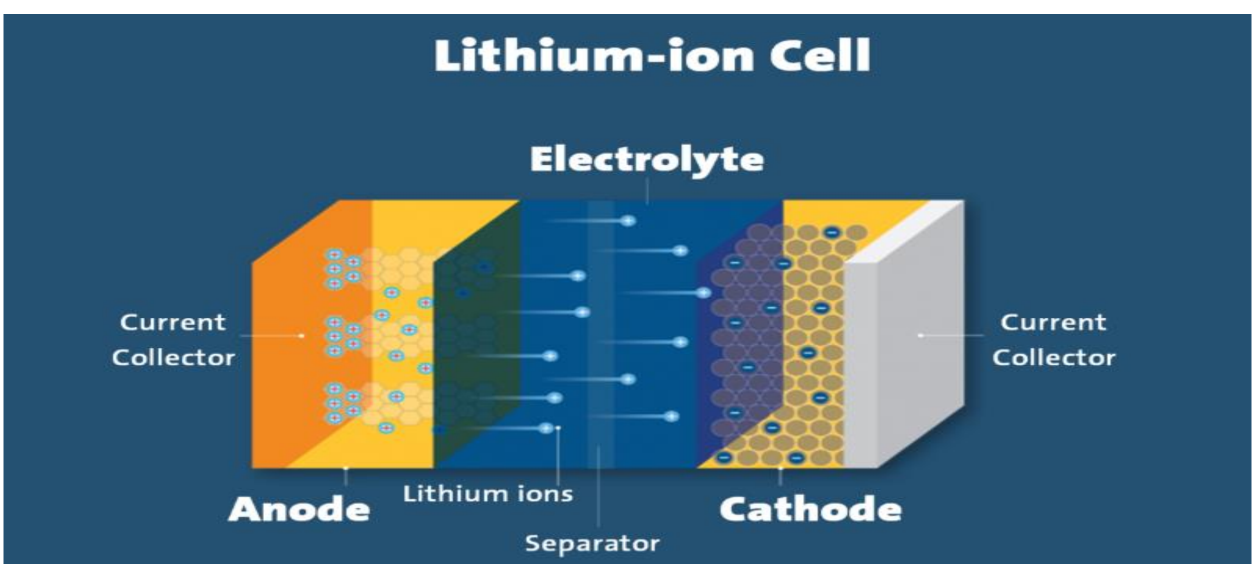


Fig 2: Structure of Lithium-ion Cell Battery

Recycling and Proper Disposal

Lithium ion batteries are used in a number of products ranging from small toys to electric vehicles. They can cause harm to human health and the environment if they are not properly disposed of at the end of their useful life. Li-ion batteries are made of materials such as cobalt, graphite and lithium which are considered critical minerals. These minerals are both economically and strategically important to all countries. If during their disposal, they get crushed it can create a fire hazard. The biggest danger with lithium batteries disposal is if they are damaged or not fully sealed and come into contact with water during their disposal process. While batteries of any kind should not be mixed with the general waste, it is the lithium ion and lithium primary batteries that pose a threat in case of incorrect disposal. They should therefore be recycled at certified battery electronics recyclers that accept batteries rather than being discarded in the trash or put in municipal recycling bins (Liebig et al., 2020).

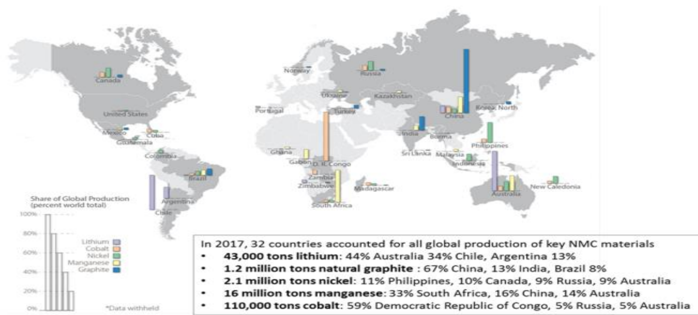


Fig 3: Key nickel, manganese, cobalt materials locations

Lithium and copper aren't the only metals that are in short supply. India also lacks nickel, cobalt ore, graphite and manganese. In order to meet a projected domestic demand of 200 gigawatt hours of lithium-ion batteries by 2030, India will need about 35,000 tons of nickel sulphate and 11,000 tons of both manganese sulphate and cobalt sulphate. Global demand for the purest form of nickel will increase to 1.34 million tons by 2030 from 100,000 tons in 2019 (Ma et al., 2018).

Cobalt is another essential element in the cathodes of lithium-ion batteries. A significant portion of the world's cobalt production comes from the Democratic Republic of Congo, which can lead to supply chain vulnerabilities and ethical concerns due to labor and environmental issues in the mining sector. Reducing cobalt content in batteries or finding alternative chemistries with less or no cobalt has been a focus. Nickel is commonly used in the cathodes of lithium-ion batteries, especially in high-energy-density applications like EVs. Ensuring a stable supply of nickel has been a concern, and efforts were being made to secure nickel resources or develop alternative chemistries with lower nickel content (Meshram et al., 2020).

As a result of an increase in lithium's demand in India, the price of a LIB has decreased with the introduction of cost-effective battery-tech but the cost of lithium and cobalt is on the rise. This can be attributed to the rare occurrence of lithium primarily in Chile, Argentina, and Bolivia but a bigger problem is posed by lack of naturally occurring cobalt, which is predominantly found in the Democratic Republic of Congo. The enrichment of both resources is monopolized by China. This remains an unavoidable geopolitical complexity — China is bound to play a key role through its deep rooted supply chains.

India flipped to being a net importer of copper following the closure of Vedanta Ltd.'s 400,000 tons-a-year plant in 2018, which cut the country's output by about 40%. To reverse that trend, billionaire Gautam Adani — Asia's richest man and one of Ambani's chief rivals — is building a 500,000 tons-a-year copper refinery in western India. His Adani Enterprises aims to start production by the first half of 2024 (Mrozik et al., 2021).

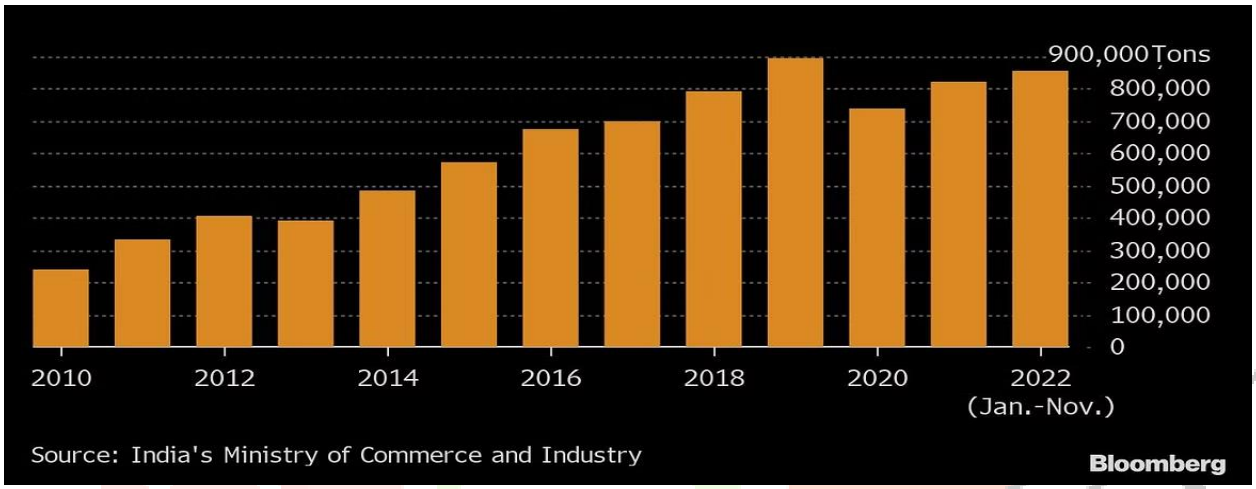


Fig 4: India's copper imports in the past decades

While the country is focused on increasing the number of EVs on Indian roads and the EV and battery manufacturing startups are in the limelight, battery recycling industry is left behind in the race Studies done globally suggest that 95% of Li-ion batteries today end up in landfills, and only 5% are recycled and reused, which is hazardous for the environment. Industry experts expect the battery recycling industry to pick up pace within the decade (Ouyang et al., 2020).

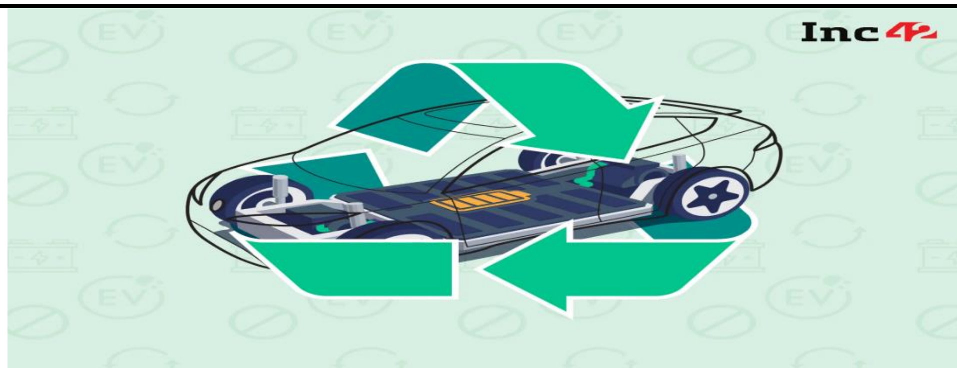
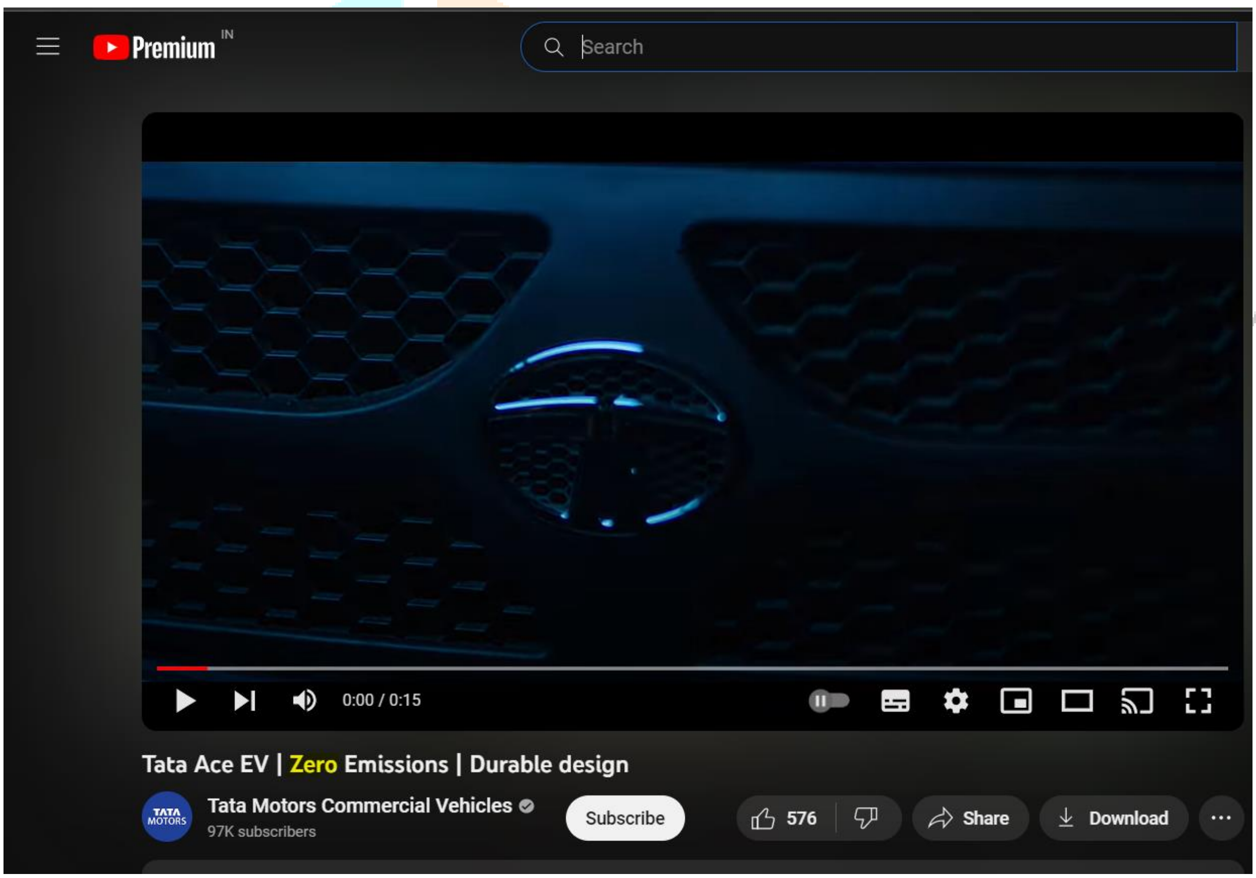


Fig 5: Zero tailpipe emission

This advertisments title says zero tailpipe emission while the audio clearly talks about emissions.

https://youtube.com/shorts/hOkqYv8N-Ws?si=JOmPHbdAEIrgxR0o



There is no such thing as a zero emissions vehicle companies often interchange the work zero emission and zero tailpipe emission while they both mean completely different things the emissions of an electric car are associated with , with electric vehicles we don't remove the emissions we export them somewhere else we have to dig up 500,000 pounds of materials to make a single 100,000 pound battery . It takes 100-300 barrels of oil to manufacture a battery that can hold 1 barrel of oil equivalent energy . just manufacturing the battery can have a carbon debt rate of 10 tons to 40 tons of c02 (Piao et al., 2022).

EVs- not as cost effective as we thought

As compared to regular automobiles, the purchase cost of electric vehicles is higher. The starting price of a gasoline vehicle is between three and four lakh rupees. On the other hand the beginning price of electric vehicles is ten to twelve lakhs.

Although electric vehicles do not utilise gasoline, the batteries that power them are quite powerful. Aside from that, if the battery is not changed within a defined time interval, it might cause the vehicle to be damaged. These battery costs are about half the cost of the electric vehicles itself. For example, let us consider the Tata Nexon EV. It is one of the best EVs in the Indian market and has a 31kWh lithium-ion battery pack. The replacement price of the Tata Nexon EV battery pack is around 5.50 lakhs to 6.20 lakhs in India (Wu et al., 2023).

Charging Stations

India currently has 5,254 public charging stations.According to India's 2030 goals, India needs 46,397 stations. Until then, India has to deal with slow chargers to help its EV owners.The average cost of setting up a public charging station in India is around ₹30 lakh-₹50 lakh

Fig 6: Lithium Ion batteries mosed using locations in India

Why not batteries of other elements?

If lithium ion batteries are used in electric vehicles, why not use batteries of lithium like elements such as sodium(Na) and potassium(K) to reduce the mining for that single element.

Sodium ion batteries are expected to have lower costs than lithium ion batteries. They are also more abundantly found and could reduce the overall cost. However, the weak point of sodium ion batteries is that they can store only about two-thirds of the energy of Li-ion batteries of equivalent size. Sodium ion batteries is low energy density and the current energy density of sodium ion battery is comparably less to lithium ion batteries

Similar to sodium, potassium is a more abundantly raw material. But potassium ion batteries are not a practical technology because of its heft and volatility. Potassium also melts at a lower temperature than sodium and lithium, which can trigger reactions that lead to thermal runaway (Xiao et al., 2019).

Origin Of Power

The origin of power for EV's is electricity. 70% of electricity in India is generated from coal which itself releases a large amount of CO2 on being burnt.Electricity generated from coal rose to 1,162.91 billion kWh.Its share in overall output rose to 73.1% - the highest level since the year ending March 2019.

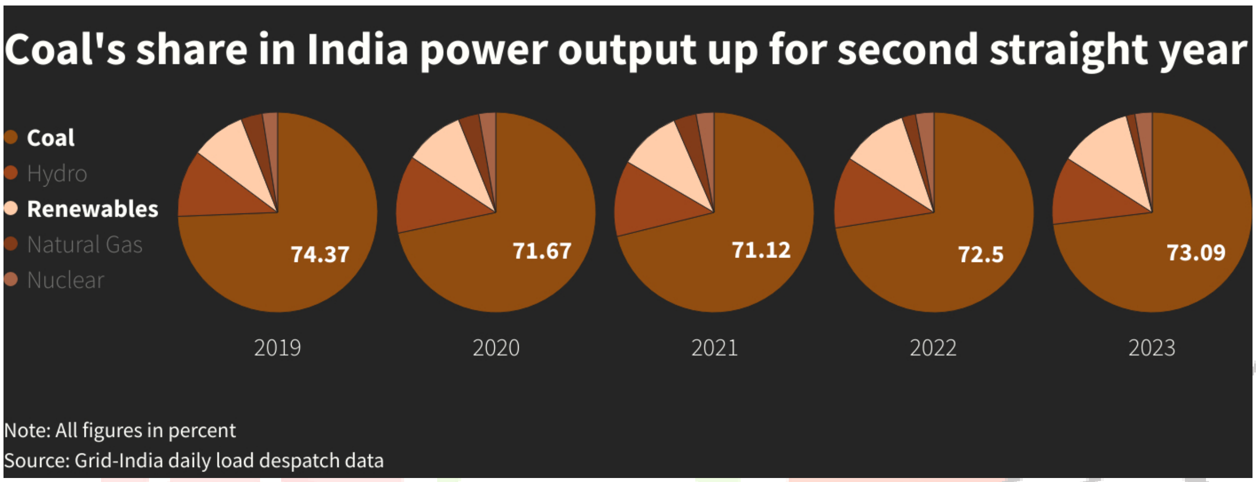


Fig 7: Coal's share in India power output for second straight year

Alternatives To Electric Motors:

Hydrogen combustion engines

Hydrogen Engines (Hydrogen Fuel Cells)

Hydrogen engines, often referred to as hydrogen fuel cells, are devices that generate electricity through an electrochemical process using hydrogen gas (H2) and oxygen (O2) from the air. These engines are a type of clean and efficient power generation technology.

Hydrogen combustion engines, also known as hydrogen internal combustion engines (H2ICE), are a type of engine that uses hydrogen gas (H2) as a fuel source for internal combustion, similar to gasoline or diesel engines. These engines burn hydrogen in a controlled manner to produce mechanical power, which can be used to drive vehicles, generate electricity, or power industrial equipment (Xiong et al., 2018).

Hydrogen combustion engines,hydrogen fuel cells and electric vehicles each have their own lists of pros and cons. Here's a comparison of the benefits of hydrogen combustion engines as compared to electric vehicles:

Benefits of Hydrogen Combustion Engines and fuel cells:

Quick Refuelling: EVs often require long charging times, even with fast chargers, while hydrogen combustion engines and fuel cell vehicles can be recharged more quickly, within a few minutes.

Versatility: Hydrogen can be used in a number of vehicle types ranging from passenger cars and buses to trains and even ships. This versatility makes hydrogen a suitable option for various transportation needs.

Zero Emissions(Fuel Cells): As said previously, there is no such thing as zero emissions. However hydrogen fuel cells produce **zero tailpipe emissions**. They only emit water vapour as a byproduct, making them a clean option for reducing air pollution as well as greenhouse gas emissions

Cold weather performance: Hydrogen fuel cells perform better in lower temperatures as compared to battery EVs, which have reduced efficiency in cold weather.

Longer Range: Hydrogen vehicles have a longer range as compared to EVs.

Reduced Battery Degradation: Hydrogen vehicles do not rely on batteries so they do not suffer from battery degradation issues that affect the performance of a vehicle

Measures to Help adaption of Hydrogen vehicles:

- Establishing widespread hydrogen refueling infrastructure to support the adoption and convenience of hydrogen vehicles.
- Providing incentives and subsidies for consumers to purchase hydrogen vehicles and facilitate market growth.
- Investing in research and development to advance hydrogen fuel cell technology, improving efficiency and reducing costs.
- Collaborating with automakers to expand the variety and availability of hydrogen-powered vehicle models.
- Educating and raising awareness among consumers about the benefits and operation of hydrogen vehicles to increase acceptance.
- Implementing policies and regulations that encourage the production and use of green hydrogen from renewable energy sources.

- Partnering with industries to promote hydrogen as a clean energy source for various sectors beyond transportation.
- Supporting pilot projects and demonstration initiatives to showcase the viability and potential of hydrogen vehicles in different regions and applications (Yang, Gu, et al., 2020).

The survey data collected from 20 people who have owned EV's have shown the following :

Survey Data for EV Owners	Count
Bought vehicles within the past 6 months	9
Adopted EVs due to environmental concerns	8
Faced lack of charging infrastructure	8
Dissatisfied with driving range	10
Charge their EVs between 1-3 days	16
Believe most EVs take a long time to charge	9
Have no present charging infrastructure in their area	13
Faced issues with charging infrastructure	16
Believe EVs are too expensive for a larger audience	11 out of 16
Utilized government policies/benefits while purchasing EVs	12
50% facing issues of charging facilities in Delhi	
Encountered maintenance issues with the vehicle	13

This sample survey data clearly shows that electric vehicles are not as perfect as shown in advertisements by companies and come with their flaws our data and research paper aims to present these flaws to the general consumer , helping them choose wisely between their motor vehicles (Yang, Okonkwo, et al., 2020).

Findings and Interpretation:

The findings and their interpretation are essential factors of any studies or study, supplying insights into the records and their implications. Let's consider a hypothetical study on the adoption of electric cars (EVs) and the demanding situations confronted by using users:

In the performed examine on EV adoption, numerous noteworthy findings have emerged. The number one findings suggest that a full-size share, 45%, of respondents bought their EVs in the beyond 12 months, indicating a growing fashion closer to embracing electric automobiles. Additionally, 40% of the surveyed people mentioned environmental concerns as their number one motivation for adopting EVs, signifying an increasing cognizance approximately sustainability amongst purchasers. However, demanding situations related to charging infrastructure and riding variety dissatisfaction emerged prominently, with 50% encountering troubles due to a loss of ok charging stations of their respective regions and 60% expressing dissatisfaction with the riding variety of their electric powered cars.

The interpretation of these findings unveils critical insights into the elements influencing EV adoption and the boundaries hindering its good sized acceptance. The speedy boom in EV purchases in the ultimate yr suggests a transferring paradigm toward purifier transportation options. The good sized impact of environmental worries on adoption underscores the developing societal attention about decreasing carbon footprints and embracing green alternatives. However, the persistent challenges related to charging infrastructure and driving range dissatisfaction highlight critical regions that necessitate interest and development for the seamless integration of EVs into the mainstream automotive market. Addressing those demanding situations thru large infrastructure improvement and technological advancements geared toward improving battery overall performance and range can be pivotal in accelerating the significant adoption of electrical motors.

The findings reveal a promising trend toward extended EV adoption pushed by means of environmental worries, but in addition they shed light at the pressing challenges hindering this transition. The interpretation underscores the want for concerted efforts from policymakers, industry stakeholders, and technology innovators to overcome these boundaries, thereby facilitating a smoother transition in the direction of sustainable transportation powered by using electric vehicles.

Conclsuion:

In conclusion, the comprehensive evaluation of the findings underscores both the promising trajectory and the existing hurdles in the realm of electrical automobile (EV) adoption. The burgeoning trend of buying EVs inside the past year, largely pushed by way of environmental attention among clients, indicates a pivotal shift in the direction of sustainable mobility answers. However, the persistent challenges associated with insufficient charging infrastructure and dissatisfaction with using variety spotlight vital barriers that obstruct the massive integration of EVs into the mainstream automotive marketplace. To navigate these challenges, a concerted attempt is imperative from diverse stakeholders, consisting of policymakers, enterprise leaders, and technological innovators. Investing in robust infrastructure improvement, enhancing battery technology for extended range, and imposing supportive guidelines might be instrumental in fostering an environment conducive to the seamless adoption of electrical automobiles, in the long run propelling us toward a extra sustainable and eco-friendly transportation landscape.

Bibliography

1. https://www.renogy.com/blog/battery-dies-in-cold-weather-what-low-temperatures-do-to-your-battery-/#:~:text=Unfortunately%2C%20any%20temperature%20lower%20than,may%20eventually%20stop%20working%20altogether
2. https://pubs.rsc.org/en/content/articlehtml/2014/ra/c3ra45748f#:~:text=At%20a%20critical%20temperature%2C%20a,battery%20is%20called%20thermal%20runaway
3. https://ul.org/research/electrochemical-safety/getting-started-electrochemical-safety/what-causes-thermal
4. https://www.orfonline.org/expert-speak/recycling-liion-batteries-opportunities-challenges-68409/
5. https://www.deccanherald.com/business/india-s-foray-into-ev-battery-market-lacks-some-key-ingredients-1180020.html
6. https://inc42.com/buzz/global-recycling-day-whats-really-happening-in-indias-li-ion-battery-recycling-space
7. Bai, Y., Muralidharan, N., Sun, Y.-K., Passerini, S., Stanley Whittingham, M., & Belharouak, I. (2020). Energy and environmental aspects in recycling lithium-ion batteries: Concept of Battery Identity Global Passport. Materials Today, 41. https://doi.org/10.1016/j.mattod.2020.09.001
8. Benveniste, G., Rallo, H., Canals Casals, L., Merino, A., & Amante, B. (2018). Comparison of the state of Lithium-Sulphur and lithium-ion batteries applied to electromobility. Journal of Environmental Management, 226, 1–12. https://doi.org/10.1016/j.jenvman.2018.08.008
9. Bird, R., Baum, Z. J., Yu, X., & Ma, J. (2022). The Regulatory Environment for Lithium-Ion Battery Recycling. ACS Energy Letters, 7(2), 736–740. https://doi.org/10.1021/acsenergylett.1c02724
10. Chen, M., Ouyang, D., Weng, J., Liu, J., & Wang, J. (2019). Environmental pressure effects on thermal runaway and fire behaviors of lithium-ion battery with different cathodes and state of charge. Process Safety and Environmental Protection, 130, 250–256. https://doi.org/10.1016/j.psep.2019.08.023
11. Costa, C. M., Barbosa, J. C., Gonçalves, R., Castro, H., Campo, F. J. D., & Lanceros-Méndez, S. (2021). Recycling and environmental issues of lithium-ion batteries: Advances, challenges and opportunities. Energy Storage Materials, 37, 433–465. https://doi.org/10.1016/j.ensm.2021.02.032
12. Dai, Q., Kelly, J. C., Gaines, L., & Wang, M. (2019). Life Cycle Analysis of Lithium-Ion Batteries for Automotive Applications. Batteries, 5(2), 48. https://doi.org/10.3390/batteries5020048
13. Fan, E., Li, L., Zhang, X., Bian, Y., Xue, Q., Wu, J., Wu, F., & Chen, R. (2018). Selective Recovery of Li and Fe from Spent Lithium-Ion Batteries by an Environmentally Friendly Mechanochemical

Approach. ACS Sustainable Chemistry & Engineering, 6(8), 11029–11035. https://doi.org/10.1021/acssuschemeng.8b02503

14. Kaunda, R. B. (2020). Potential environmental impacts of lithium mining. Journal of Energy & Natural Resources Law, 38(3), 237–244. https://doi.org/10.1080/02646811.2020.1754596

15. Lai, X., Chen, Q., Tang, X., Zhou, Y., Gao, F., Guo, Y., Bhagat, R., & Zheng, Y. (2022). Critical review of life cycle assessment of lithium-ion batteries for electric vehicles: A lifespan perspective. ETransportation, 12, 100169. https://doi.org/10.1016/j.etran.2022.100169

16. Liebig, G., Kirstein, U., Geißendörfer, S., Schuldt, F., & Agert, C. (2020). The Impact of Environmental Factors on the Thermal Characteristic of a Lithium–ion Battery. Batteries, 6(1), 3. https://doi.org/10.3390/batteries6010003

17. Ma, S., Jiang, M., Tao, P., Song, C., Wu, J., Wang, J., Deng, T., & Shang, W. (2018). Temperature effect and thermal impact in lithium-ion batteries: A review. Progress in Natural Science: Materials International, 28(6), 653–666. https://doi.org/10.1016/j.pnsc.2018.11.002

18. Meshram, P., Mishra, A., Abhilash, & Sahu, R. (2020). Environmental impact of spent lithium ion batteries and green recycling perspectives by organic acids – A review. Chemosphere, 242, 125291. https://doi.org/10.1016/j.chemosphere.2019.125291

19. Mrozik, W., Ali Rajaeifar, M., Heidrich, O., & Christensen, P. (2021). Environmental impacts, pollution sources and pathways of spent lithium-ion batteries. Energy & Environmental Science, 14(12). https://doi.org/10.1039/D1EE00691F

20. Ouyang, D., Weng, J., Chen, M., & Wang, J. (2020). Impact of high-temperature environment on the optimal cycle rate of lithium-ion battery. Journal of Energy Storage, 28, 101242. https://doi.org/10.1016/j.est.2020.101242

21. Piao, N., Gao, X., Yang, H., Guo, Z., Hu, G., Cheng, H.-M., & Li, F. (2022). Challenges and development of lithium-ion batteries for low temperature environments. ETransportation, 11, 100145. https://doi.org/10.1016/j.etran.2021.100145

22. Wu, J., Zheng, M., Liu, T., Wang, Y., Liu, Y., Nai, J., Zhang, L., Zhang, S., & Tao, X. (2023). Direct recovery: A sustainable recycling technology for spent lithium-ion battery. Energy Storage Materials, 54, 120–134. https://doi.org/10.1016/j.ensm.2022.09.029

23. Xiao, J., Li, J., & Xu, Z. (2019). Challenges to Future Development of Spent Lithium Ion Batteries Recovery from Environmental and Technological Perspectives. Environmental Science & Technology, 54(1), 9–25. https://doi.org/10.1021/acs.est.9b03725

24. Xiong, R., Li, L., Li, Z., Yu, Q., & Mu, H. (2018). An electrochemical model based degradation state identification method of Lithium-ion battery for all-climate electric vehicles application. Applied Energy, 219, 264–275. https://doi.org/10.1016/j.apenergy.2018.03.053

25. Yang, J., Gu, F., & Guo, J. (2020). Environmental feasibility of secondary use of electric vehicle lithium-ion batteries in communication base stations. Resources, Conservation and Recycling, 156, 104713. https://doi.org/10.1016/j.resconrec.2020.104713

26. Yang, Y., Okonkwo, E. G., Huang, G., Xu, S., Sun, W., & He, Y. (2020). On the sustainability of lithium ion battery industry – a review and perspective. Energy Storage Materials, 36.