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Exploring the Trade of Raw Materials for Electric Vehicles Batteries

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Abstract

This article examines the complex and evolving nature of the trade of raw materials for electric vehicle (EV) batteries, highlighting the need for sustainable and ethical practices in the extraction, processing, and trade of these materials. The study draws on industry reports and interviews with experts to identify challenges and concerns associated with the trade, including environmental impacts, human rights abuses, and lack of competition. The research also identifies opportunities for innovation in recycling technologies, new battery chemistries, and ethical sourcing practices. The findings suggest that companies and governments must invest in new technologies, responsible sourcing initiatives, and transparent supply chain models to ensure that the growth of the EV industry is sustainable, responsible, and beneficial for all stakeholders. The implications of these findings for the future of the EV industry are discussed.

Keywords: electric vehicles, batteries, raw materials, trade, sustainability, ethics, recycling technologies, human rights, competition, responsible sourcing, supply chain.

1. Introduction

The introduction will provide a brief overview of the importance of raw materials for electric vehicle batteries and the research question. It will also discuss the significance of the study and the need for further research.

1.1. General statement

The growing popularity of electric vehicles has brought significant changes to the automotive industry. One of the key components that enable electric vehicles to operate is the battery. Electric vehicle batteries are complex systems that require a variety of raw materials to function efficiently. The availability and sustainability of these materials are crucial for the performance and sustainability of electric vehicles.

Raw materials such as lithium, cobalt, nickel, manganese, and graphite are commonly used in electric vehicle batteries. Lithium is a critical component in the production of electric vehicle batteries, and it is mainly sourced from countries such as Chile, Argentina, and Australia. Cobalt is another essential material used in the production of electric vehicle batteries, and it is primarily sourced from the Democratic Republic of Congo. Nickel is also an important material used in the production of electric vehicle batteries, and it is mainly sourced from countries such as Indonesia, the Philippines, and Russia. Manganese is another material used in the production of electric vehicle batteries, and it is primarily sourced from South Africa. Finally, graphite is also used in the production of electric vehicle batteries, and it is mainly sourced from China.

The trade of these rare earth metals has significant sustainability issues that need to be addressed. For example, the mining of these materials often involves environmental degradation, human rights violations, and child labor. Additionally, the extraction and transportation of these materials require significant amounts of energy and contribute to greenhouse gas emissions. Therefore, it is essential to ensure that the trade of these materials is conducted sustainably and ethically to avoid negative impacts on the environment and society.

1.2. Research question

The research question that this study aims to address is "Exploring the Trade of Raw Materials for Electric Vehicles Batteries". The trade of rare earth metals used in electric vehicle batteries has become an increasingly important topic due to the growing demand for electric vehicles and the need for sustainable transportation solutions. However, the trade of these materials is not without its sustainability issues.

This study is significant because it highlights the need for further research to better understand the global trade of these raw materials, the sustainability issues surrounding their extraction and transportation, strategies for promoting sustainable trade of raw materials, and prospects. By exploring these issues, we can gain a better understanding of the impact of rare earth metal trade on the environment and society, and identify ways to mitigate negative impacts and promote sustainable trade.

The findings of this study can inform policymakers, industry stakeholders, and consumers about the sustainability issues surrounding the trade of rare earth metals used in electric vehicle batteries. It can also contribute to the development of sustainable trade policies and practices, and support the transition towards a more sustainable and equitable future. Overall, this study is an important step towards promoting sustainable trade of raw materials and achieving a more sustainable and equitable global economy.

2. Literature Review

2.1. The introduction of the literature review

The trade of raw materials for electric vehicle batteries is a topic of increasing importance as the demand for electric vehicles continues to grow. Raw materials such as lithium and cobalt are essential components of electric vehicle batteries, and the sustainability and ethical sourcing of these materials are critical considerations for the industry.

The existing literature on the topic of raw materials for electric vehicle batteries covers a range of themes, including the environmental impact of raw material extraction and processing, the potential for monopolies and lack of competition in the market, the need for sustainable and circular economies, and the ethical issues associated with the trade of these materials.

Many studies (Flexer, Baspineiro, & Galli, 2018; Fallah & Fitzpatrick, 2022) have focused on the environmental impact of raw material extraction and processing, highlighting the need for more sustainable and responsible practices. Others (Zhao, B., Shi, Y. & Dong, X. D., 2014) have examined the potential for monopolies and the need for greater competition in the market, as well as the emergence of new supply chain models (Rajaeifar, M. A., Ghadimi, P., Raugei, M., Wu, Y., & Heidrich, O., 2022) that promote transparency and sustainability.

There is also a growing body of research (Almeida, Sousa, & Coutinho-Rodrigues, 2019; Harper, Sommerville, Kendrick, et al., 2019; Neumann, Petranikova, Meeus, et al., 2022) focused on the development of new battery

chemistries and recycling technologies, as well as the increasing demand for recycled materials in battery production (Martins, L. S., Guimaraes, L. F., et al., 2021). Additionally, there is a growing awareness of the ethical issues associated with the trade of raw materials (Gałaś & Gałaś, 2016; Mancini, Eslava, Traverso, & Mathieux, 2021; Cheyns et al., 2014), particularly around the use of child labor and other human rights abuses.

Overall, the literature on the topic of raw materials for electric vehicle batteries highlights the complexity and importance of this issue, and the need for greater collaboration, innovation, and responsible practices to ensure the sustainability and ethical sourcing of these critical materials.

2.2. Environmental and social impact of raw materials trade

The key raw materials used in electric vehicle batteries include lithium, cobalt, nickel, and manganese. These materials are primarily sourced from countries such as China, Australia, Chile, the Democratic Republic of Congo (DRC), and Indonesia. However, the extraction and trade of these materials are associated with a range of environmental and social issues.

In the DRC, for example, the extraction of cobalt has been linked to child labor and other human rights abuses (Brown, C., Daniels, A., Boyd, D. S., Sowter, A., Foody, G., & Kara, S., 2020). Additionally, the production of lithium and cobalt can have significant environmental impacts (Schmidt, Buchert, & Schebek, 2016), including water pollution and deforestation. The transportation of raw materials and finished batteries also contributes to carbon emissions and other environmental impacts (Elbel, Bose O'Reilly, & Hrzic, 2023).

The trade of raw materials for electric vehicle batteries also has economic and geopolitical implications (Charlier & Guillou, 2014). As demand for these materials grows, there is a potential for resource conflicts and the concentration of market power in a few countries or companies. This could lead to higher prices and supply chain disruptions, as well as geopolitical tensions.

The social impact of the trade of raw materials for electric vehicle batteries is also significant. The extraction of these materials can have a negative impact on local communities, including displacement and loss of livelihoods (Bauchowitz, S., 2014). There is also a risk of human rights abuses in the supply chain, particularly in countries with weaker labor laws and regulations (Sethi, S.P., Lowry, D.B., Veral, E.A. et al., 2011).

Overall, the trade of raw materials for electric vehicle batteries has significant environmental, social, economic, and geopolitical implications. To address these issues, there is a need for greater transparency and accountability in the supply chain, as well as the development of more sustainable and responsible practices for the extraction, processing, and trade of these critical materials.

2.3. Assessing literature

While there is a significant body of literature on the topic of raw materials for electric vehicle batteries, there are still gaps in our understanding of the environmental and social impacts of raw materials sourcing, as well as the need for more sustainable sourcing practices.

For example, there is a need for more comprehensive data on the environmental impacts of raw material extraction and processing, particularly in countries with weaker environmental regulations. There is also a need for more research on the social impacts of the trade of raw materials, including the impact on local communities and workers, as well as the potential for human rights abuses in the supply chain.

In addition, while there is growing awareness of the need for sustainable and responsible sourcing practices, there is a need for more research on the effectiveness of these practices and their potential to promote sustainability and ethical sourcing in the electric vehicle battery industry.

The research question addressed in this study is of critical importance, as the demand for electric vehicles continues to grow and the trade of raw materials becomes increasingly globalized and consolidated. By addressing the gaps in the literature and promoting more sustainable and responsible practices in the industry, we can help to ensure that the growth of the electric vehicle industry is sustainable, responsible, and beneficial for all stakeholders.

3. Key Areas of Research

3.1. Overview of these raw materials and their sources

Electric vehicle batteries rely heavily on a few key raw materials, including lithium, cobalt, nickel, manganese, and graphite. Lithium is the most commonly used material in electric vehicle batteries, followed by cobalt and nickel. Manganese and graphite are also used but in smaller quantities.

These raw materials are mainly sourced from countries such as Chile, Argentina, Australia, the Democratic Republic of Congo, Indonesia, the Philippines, Russia, and South Africa (Egan, 2023). For example, Chile is the world's largest producer of lithium, while the Democratic Republic of Congo is the largest producer of cobalt. Australia and Indonesia are also significant producers of nickel.

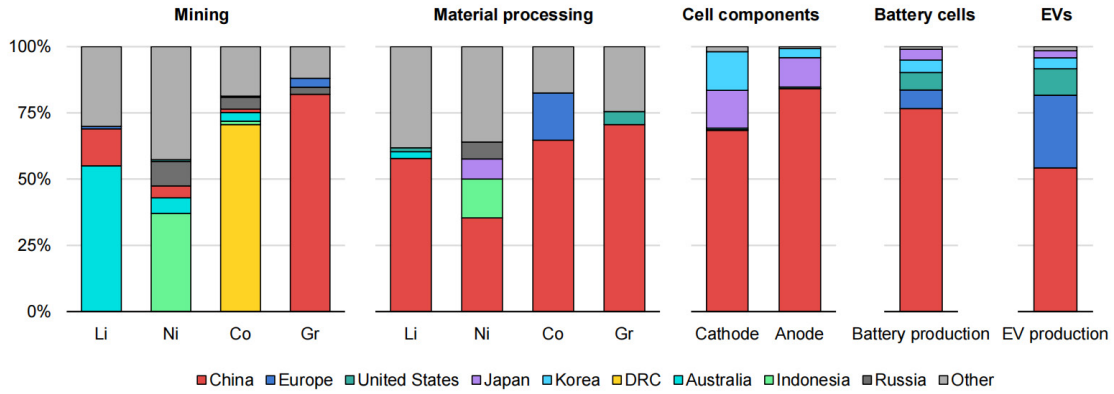

Figure 1. Geographical Distribution of the Global EV Supply Chain
Source: International Energy Agency (IEA)

The supply chains for these raw materials are complex and involve multiple stages, including mining, processing, and transportation. The mining and processing of these materials can have significant environmental impacts, such as soil erosion, water pollution, and deforestation (Robert et al., 2022). Additionally, there are concerns about human rights abuses associated with the mining and processing of some of these materials, particularly in the Democratic Republic of Congo, where child labor and forced labor have been reported in cobalt mines.

Given the significant environmental and social impacts associated with the extraction and processing of these raw materials, it is essential to ensure that the supply chains for these materials are sustainable and ethical. This involves promoting responsible mining practices, reducing waste and pollution, and ensuring that workers are treated fairly and have access to safe working conditions. As the demand for electric vehicles continues to grow, it is crucial to address these issues to ensure that the transition to sustainable mobility is truly sustainable and equitable.

3.2. The global trade of these raw materials: major markets and players

This area will analyze the global trade of raw materials for electric vehicle batteries, identify the major markets and players in the trade, and discuss the trends and patterns in the trade.

3.2.1. Major markets and players

The global trade of raw materials for electric vehicle batteries has become increasingly important in recent years due to the growing demand for electric vehicles and the need for sustainable transportation solutions. Major markets for these materials include China, the United States, Europe, and Japan, with each country playing a pivotal role in the production and consumption of these materials.

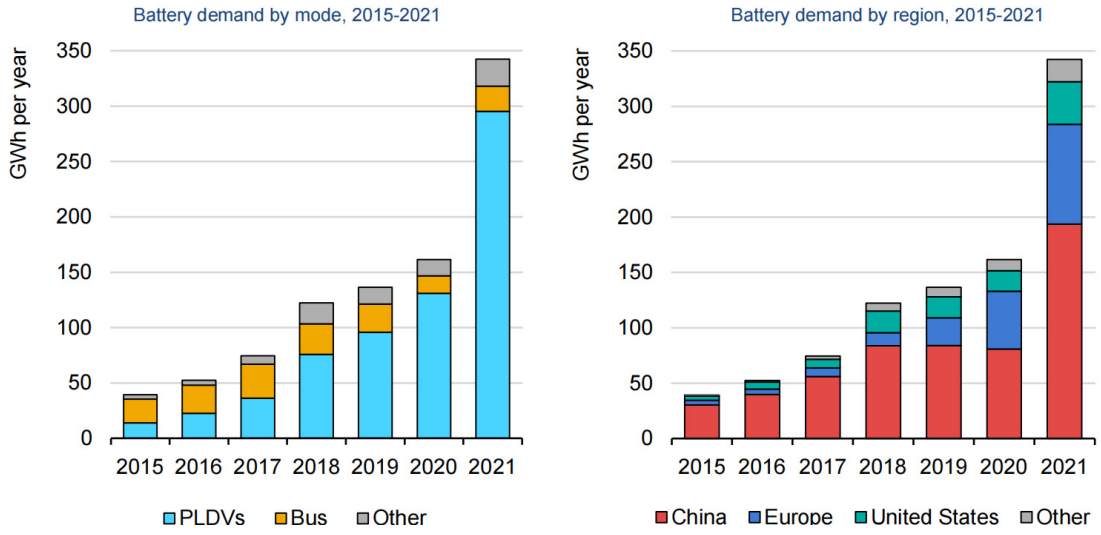

Figure 2. Global Battery Demand by mode and region
Source: International Energy Agency (IEA), 2023

China is the world's largest producer of electric vehicles (Schmidt, 2021) and is also the largest consumer of raw materials used in electric vehicle batteries. The country is a major player in the global trade of lithium, cobalt, and nickel, with significant reserves of these materials within its borders. China also dominates the production of graphite, which is used in the anodes of lithium-ion batteries (Bloomberg News, 2023).

The United States is another significant market for raw materials used in electric vehicle batteries, particularly for lithium and cobalt (NS Energy Staff Writer, 2021). The country has significant reserves of lithium, but most of its cobalt is imported from the Democratic Republic of Congo, where there are concerns about human rights abuses associated with its mining and processing.

Europe is also a major player in the global trade of raw materials for electric vehicle batteries (Colonna et al., 2023). The European Union has set ambitious targets for the adoption of electric vehicles, and the region is investing in the development of a domestic supply chain for raw materials used in electric vehicle batteries. The EU is particularly interested in developing a sustainable and ethical supply chain for these materials, with a focus on reducing the environmental and social impacts of their extraction and transportation.

Japan is another significant market for raw materials used in electric vehicle batteries, particularly for lithium and cobalt. The country has limited reserves of these materials within its borders and relies heavily on imports to meet its demand. Japan is also investing in the development of a domestic supply chain for these materials and is exploring alternative sources of raw materials, such as deep-sea mining.

3.2.2. The trends and patterns in the trade

One of the main trends in the trade of raw materials for electric vehicle batteries is the increased demand for lithium, which has led to rising prices and competition for supply. Another trend is concerns about cobalt, which has been associated with environmental and human rights concerns. As a result, there is a growing interest in developing alternative materials and technologies that reduce the reliance on these raw materials. Overall, the global trade of raw materials for electric vehicle batteries is complex and involves multiple players and stages, and there is a need for further research to better understand the sustainability issues surrounding their extraction and transportation.

Trend 1: Increased Demand for Lithium. The increased demand for electric vehicles has led to a surge in demand for lithium, as it is a key component of lithium-ion batteries, which are commonly used in electric vehicles. This increased demand has led to rising prices and competition for supply, particularly in countries such as China, the United States, Europe, and Japan, which are major markets for these materials. As a result, there is growing interest in

developing alternative materials and technologies that reduce the reliance on lithium and other rare earth metals.

According to a report by BloombergNEF (McCrone, 2018), the demand for lithium is expected to increase by more than 40 times by 2030, driven by the growth of the electric vehicle market.

The International Energy Agency (International Energy Agency, 2023) estimates that the number of electric vehicles on the road could increase from 3 million in 2017 to 125 million by 2030, which would require a significant increase in the production of lithium-ion batteries.

The price of lithium has increased significantly in recent years, with the average price of lithium carbonate increasing from around $6,000 per tonne in 2015 to over $17,000 per tonne in 2021, according to the United States Geological Survey (U.S. Geological Survey, 2022).

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	W	W	W	W	W
Imports for consumption	3,330	3,420	2,620	2,460	2,500
Exports	1,960	1,660	1,660	1,170	1,900
Consumption, estimated[1]	3,000	3,000	2,000	2,000	2,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[2]	15,000	17,000	12,700	8,000	17,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>50	>50	>25	>50	>25

Figure 3. Domestic Production and Use of Lithium in the US
Source: U.S. Geological Survey, 2022

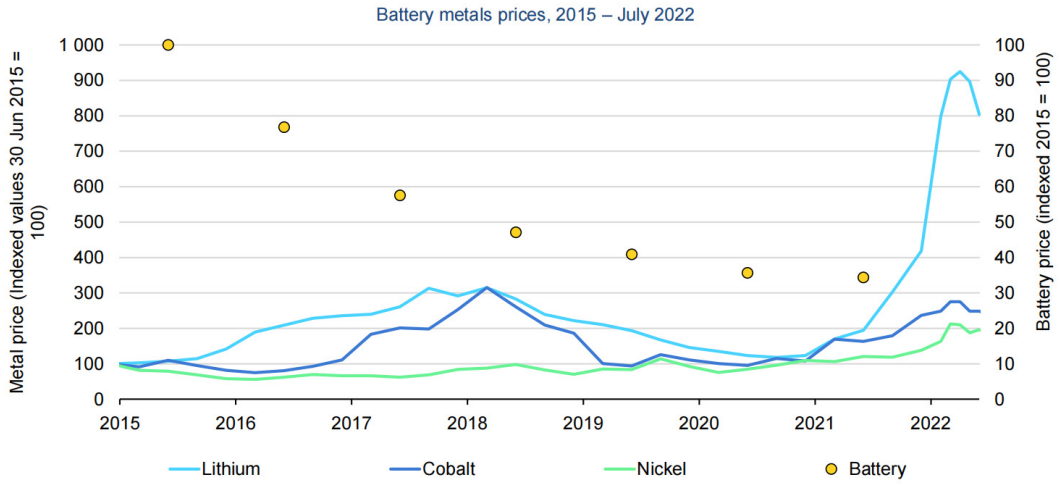

Figure 4. Battery Metals Prices, 2015 – July 2022
Source: International Energy Agency (IEA), 2023

According to a report by World Economic Forum (Shine, 2022), dividing lithium production by the amount needed per battery shows that enough lithium was mined in 2021 to make just under 11.4 million EV batteries. Using the same kind of calculation shows that global reserves are sufficient to produce just under 2.5 billion batteries. The IEA's Net Zero by 2050 roadmap says the world will need 2 billion battery electric, plug-in hybrid, and fuel-cell electric light-duty vehicles on the road by that date to hit net zero. However, not all of the world's lithium can go into EV batteries. The metal is also used in batteries for a host of other items, such as laptops and mobile phones, as well as to make planes, trains, and bikes.

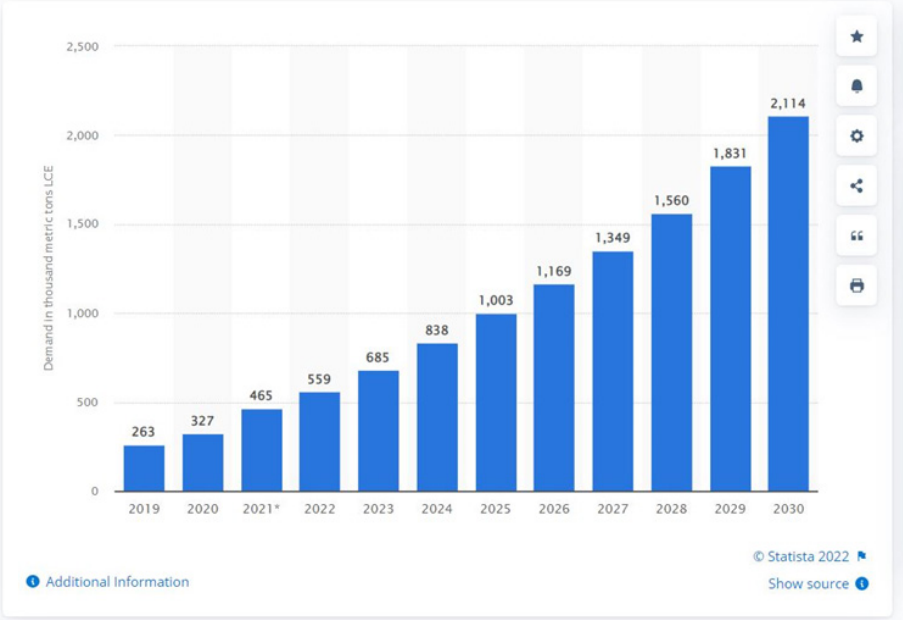

Figure 5. Projection of Worldwide Lithium Demand from 2019 to 2030
Source: International Energy Agency (IEA), 2023

Major automakers such as Tesla, Volkswagen, and General Motors have announced plans to significantly increase their production of electric vehicles in the coming years, which will further drive the demand for lithium and other rare earth metals used in electric vehicle batteries.

Overall, these data highlight the significant increase in demand for lithium due to the growth of the electric vehicle market, which has led to rising prices and competition for supply.

Trend 2: Concerns about Cobalt. Cobalt is a key component of lithium-ion batteries, which are used to power electric vehicles and other electronic devices. However, the mining and production of cobalt have been associated with environmental and human rights concerns, particularly in the Democratic Republic of Congo (DRC), which is the world's largest producer of cobalt (Campbell, 2020).

In the DRC, cobalt is often mined by hand by workers who are paid very low wages and work in dangerous conditions. Many of these workers are children, and they are often forced to work long hours in mines that are not safe. In addition, the mining of cobalt has been linked to environmental damage, including deforestation, soil erosion, and water pollution.

There have also been concerns about the supply of cobalt. The DRC currently produces about 60% of the world's cobalt, and there are fears that the supply could be disrupted by political instability or conflict in the region. In addition, the demand for cobalt is expected to increase significantly in the coming years as the production of electric vehicles and other electronic devices continues to grow.

As a result of these concerns, there has been a push to reduce the amount of cobalt used in batteries or to find alternative sources of the mineral. Some companies are working to develop new battery technologies that use less cobalt or that use other materials instead. Others are exploring the possibility of recycling cobalt from old batteries to reduce the need for new mining. There is also a growing interest in developing ethical and sustainable supply chains for cobalt and other minerals used in electronics. According to a report by McKinsey & Company (Breiter et al., 2023), with about four times lower virgin materials, recycled materials reduce the carbon footprint.

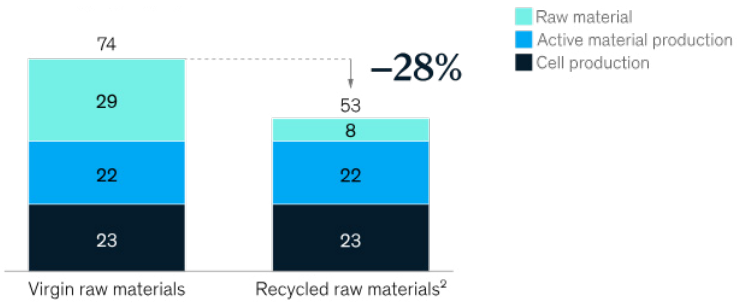

Figure 6. Total CO2e Battery Cell Production Emissions from a Nickel-based Lithium-ion Battery with Virgin Versus Recycled Materials
Source: McKi nsey & Company

Trend 3: Development of Domestic Supply Chains. The development of domestic supply chains for raw materials used in electric vehicle batteries is becoming increasingly important as the demand for electric vehicles continues to grow. Many countries, particularly in Europe, have been investing in the development of these supply chains to reduce their reliance on imports and to ensure a more sustainable and ethical supply chain.

For example, the European Union has launched a program called the European Battery Alliance (European Battery Alliance, 2022), which aims to develop a competitive and sustainable battery industry in Europe. This includes investing in the development of domestic mining and processing of raw materials such as lithium, cobalt, and nickel. The European Commission (European Commission, 2023) has also proposed a new regulation (European Critical Raw Materials Act) that would require companies to demonstrate that their supply chains for raw materials are environmentally and socially sustainable.

Several countries in Europe are also investing in the development of domestic mining industries. Portugal (World Wildlife Fund, 2019), for example, intends to create a lithium and battery manufacturing industry in the border areas between Portugal and Spain, to meet the growing demand for batteries for electric vehicles. Portugal is currently the main lithium producer in the European Union and has the largest known reserves in the continent, occupying the 8th position worldwide.

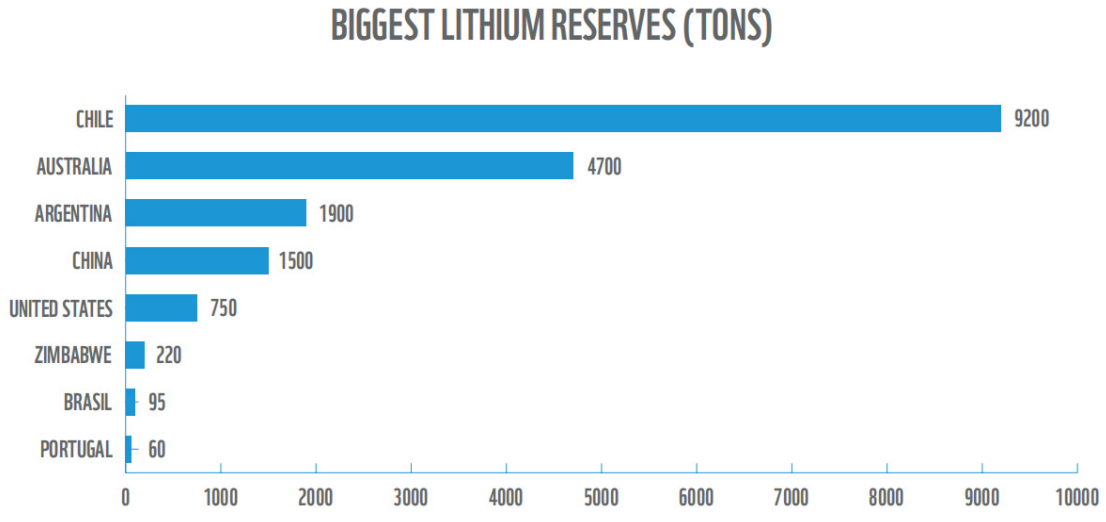

Figure 7. Biggest Lithium Reserves (Tons)
Source: U.S. Geological Survey

In addition, Germany is investing in the development of a domestic supply chain for raw materials used in electric vehicle batteries (International Energy Agency, 2021). The country invested EUR 1 billion (USD 1.2 billion) in funding through 2022 was allocated by the Federal Ministry for Economic Affairs and Climate Action to establish the country as a global leader in battery cell production. For example, BASF (Germany) is building a major cathode material precursor plant in Finland and already has a long-term nickel supply agreement with Norilsk Nickel.

Other countries outside of Europe are also investing in the development of domestic supply chains. For example, Australia is investing in the development of a domestic lithium mining industry, and China is investing in the development of a domestic rare earth mining industry.

Overall, the development of domestic supply chains for raw materials used in electric vehicle batteries is becoming increasingly important as the demand for electric vehicles continues to grow. While there are challenges to developing these supply chains, such as the high cost of developing new mines and processing facilities, the potential benefits in terms of job creation, economic growth, and a more sustainable and ethical supply chain are significant.

Trend 4: Consolidation of the Market. The market for raw materials used in electric vehicle batteries is becoming increasingly consolidated, with a few key players dominating the market. This consolidation has been driven by several factors, including the high cost of developing new mines and processing facilities, the complexity of the supply chain, and the significant capital investments required to enter the market.

One key player in the market is China, which is the world's largest producer of rare earth metals, including the metals used in electric vehicle batteries. China currently produces about 80% of the world's rare earth metals and has been accused of using its dominance in the market to manipulate prices and restrict exports (CSIS, 2021).

Another key player in the market is the Democratic Republic of Congo, which is the world's largest producer of cobalt. The DRC currently produces about 60% of the world's cobalt, and there are concerns about the environmental and human rights impacts of cobalt mining in the country (Murray, 2022).

The consolidation of the market has led to concerns about the potential for monopolies and the need for greater competition in the market. Some experts have called for greater investment in the development of domestic supply chains for these raw materials, as well as greater investment in research and development of alternative materials and technologies that could reduce the reliance on these raw materials.

There are also concerns about the potential for geopolitical tensions and conflicts over access to these raw materials. For example, there have been concerns about the potential for conflict between China and the United States over access to rare earth metals, which are used in a wide range of electronic devices, including electric vehicles.

Overall, the consolidation of the market for raw materials used in electric vehicle batteries is a complex issue that requires careful consideration of the potential risks and benefits. While there are concerns about the potential for monopolies and geopolitical tensions, there are also opportunities for greater investment in the development of domestic supply chains and alternative materials and technologies.

Trend 5: Innovative Recycling Solutions. As the use of electric vehicles continues to grow, there is a need for

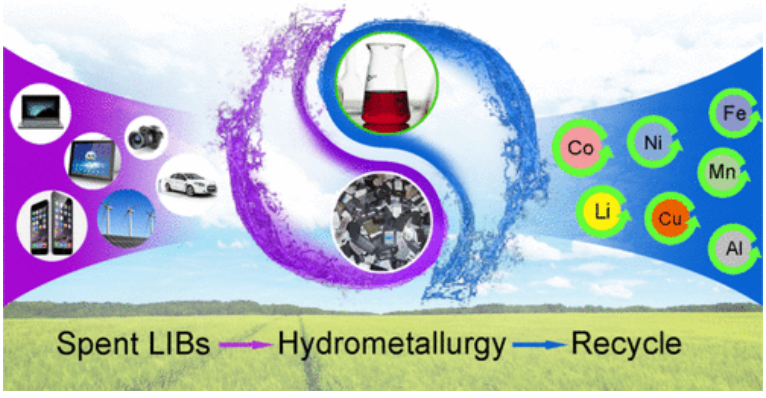

Figure 8. Hydrometallurgical Recycling

Source: Yao, Y., Zhu, M., Zhao, Z., Tong, B., Fan, Y., & Hua, Z. (2018).Hydrometallurgical Processes for Recycling Spent Lithium-Ion Batteries: A Critical Review. ACS Sustainable Chemistry & Engineering, 6(11), 13611-13627. https://doi.org/10.1021/acssuschemeng.8b03545

innovative recycling solutions for batteries once they reach the end of their lifespan. This is because electric vehicle batteries contain a range of valuable raw materials, including lithium, cobalt, and nickel, which can be recycled and repurposed for use in new batteries or other applications.

One innovative recycling solution is known as hydrometallurgical recycling (Yao et al., 2018), which involves dissolving the raw materials in the battery in a liquid solution and then separating the different metals. This process can be used to recover up to 95% of the raw materials in the battery, making it a highly efficient and sustainable recycling solution.

Another innovative recycling solution is known as pyrometallurgical recycling (Zhou et al., 2021), which involves heating the battery to high temperatures to separate the different metals. While this process is less efficient than hydrometallurgical recycling, it can still recover a significant amount of the raw materials in the battery.

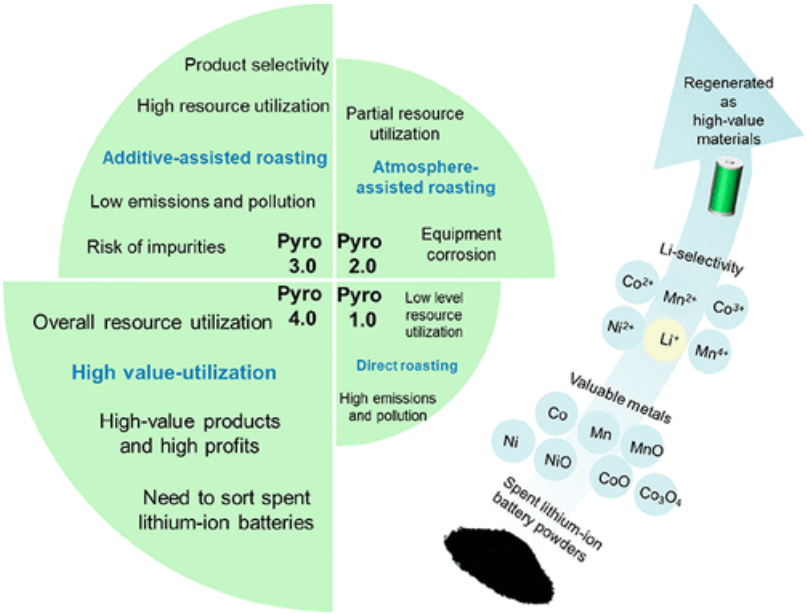

Figure 9. Pyrometallurgical Recycling

Source: Zhou, M., Li, B., Li, J., & Xu, Z. (2021). Pyrometallurgical Technology in the Recycling of a Spent Lithium Ion Battery: Evolution and the Challenge. ACS EST Engg., 1(10), 1369-1382. https://doi.org/10.1021/acsestengg.1c00067

In addition to these recycling solutions, there are also efforts underway to repurpose the raw materials in electric vehicle batteries for use in other applications. For example, lithium can be used in the production of ceramics and glass, while cobalt can be used in the production of jet engine parts.

Overall, the development of innovative recycling solutions for electric vehicle batteries is an important step toward creating a more sustainable and circular economy. By recovering and repurposing the raw materials in these batteries, we can reduce our reliance on virgin materials and minimize the environmental impact of the electric vehicle industry.

3.3. The sustainability issues related to the extraction and trade of these materials

This area will analyze the environmental and social impacts of the extraction and trade of raw materials for electric vehicle batteries, identify the key sustainability issues related to the trade, and discuss the initiatives and policies aimed at promoting sustainable trade.

3.3.1. Environmental impacts

The extraction and processing of raw materials for electric vehicle batteries can have significant environmental impacts. For example, the production of lithium, which is a key component of lithium-ion batteries, often involves the use of large amounts of water and chemicals, which can lead to water pollution and soil erosion. In addition, the mining of lithium can require the clearing of large areas of land, which can lead to deforestation and the destruction of natural habitats.

According to a report by the International Energy Agency (International Energy Agency, 2023), the production of lithium-ion batteries for electric vehicles is expected to increase significantly in the coming years, with demand for lithium expected to increase by a factor of 40 by 2040. This growth in demand could lead to significant environmental impacts, particularly in regions where lithium is mined and processed.

The production of electric vehicle batteries also requires large amounts of energy, which can contribute to climate change. According to a study by McKinsey & Company (Linder et al., 2023), producing the large lithium-ion batteries used to power EVs is the biggest source of embedded emissions for both electric cars and trucks, accounting for about 40 to 60 percent of total production emissions. This is because the production of electric vehicle batteries requires the mining and processing of raw materials, as well as the manufacturing and transportation of the batteries themselves.

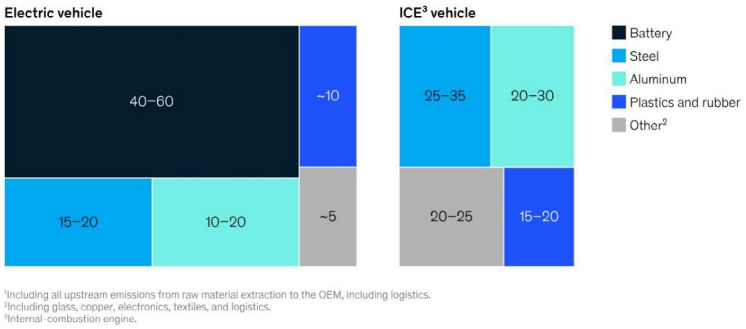

Figure 10. Typical Upstream Battery-electric-vehicle emissions
Source: McKinsey & Company

In addition to the environmental impacts of battery production, there are also concerns about the environmental impacts of battery disposal. While efforts are underway to develop innovative recycling solutions for electric vehicle batteries, many batteries still end up in landfills, where they can release toxic chemicals and heavy metals into the environment.

Overall, the environmental impacts of the production and disposal of electric vehicle batteries are complex and multifaceted. While the growth of the electric vehicle industry has the potential to reduce greenhouse gas emissions and improve air quality, it is important to carefully consider the environmental impacts of the entire lifecycle of electric vehicle batteries, from extraction and processing to disposal and recycling.

3.3.2. Human rights abuses

The extraction of raw materials for electric vehicle batteries has been associated with human rights abuses, particularly in countries where labor laws are weak and worker protections are limited. This includes issues such as child labor, forced labor, and unsafe working conditions.

One key example of this is the mining of cobalt, which is a key component of lithium-ion batteries. According to a report by Amnesty International (Amnesty International, 2016), over half of the world's cobalt comes from the Democratic Republic of Congo, where child labor is common in the mining industry. The report found that children as young as seven were working in mines, often in hazardous conditions, and were exposed to high levels of cobalt dust, which can cause respiratory problems and other health issues.

Figure 11. Children sorting cobalt ore in the neighborhood of Kasulo
Source: Amnesty International and Afrewatch

In addition to child labor, there have also been reports of forced labor and unsafe working conditions in the cobalt mining industry. According to a report by the International Labour Organization (International Labour Organization, 2017), many cobalt miners work in informal and unregulated mines, where they are not provided with adequate safety equipment or training. This can lead to accidents and injuries, as well as long-term health problems such as lung disease and cancer.

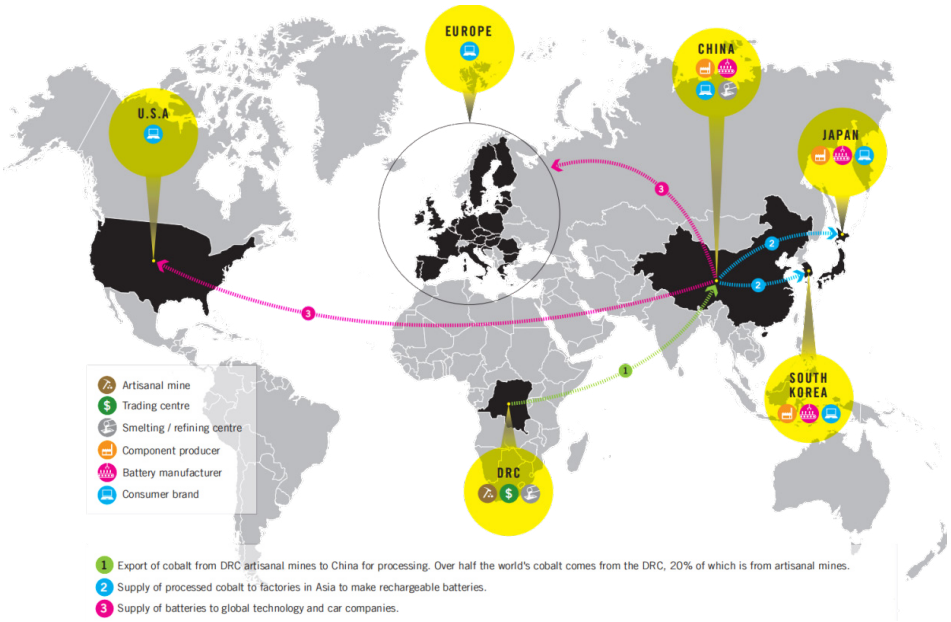

Figure 12. Movement of cobalt from artisanal mines in the DRC to the global market
Source: Amnesty International and Afrewatch

The issue of human rights abuses in the cobalt mining industry has been widely publicized in recent years, leading to increased scrutiny of the supply chains for electric vehicle batteries. Many companies have committed to improving the transparency and traceability of their supply chains, and efforts are underway to develop more sustainable and ethical supply chains for raw materials used in electric vehicle batteries.

However, the issue of human rights abuses in the mining industry is complex and multifaceted, and there are no easy solutions. Companies and governments need to work together to address these issues and to ensure that the production of electric vehicle batteries does not come at the expense of human rights and worker protections.

3.3.3. Supply chain transparency

The supply chains for raw materials used in electric vehicle batteries can be complex and opaque, making it difficult to ensure that the trade is sustainable and ethical. There is a need for greater transparency and traceability in the supply chain to ensure that environmental and social standards are being met.

One key challenge in achieving greater transparency in the supply chain for electric vehicle batteries is the complexity of the industry. The production of electric vehicle batteries involves multiple stages, from the mining and processing of raw materials to the manufacturing and distribution of the batteries themselves. This can involve a large number of different players, including mining companies, battery manufacturers, and transportation companies, making it difficult to track the movement of raw materials and ensure that environmental and social standards are being met.

Figure 13. Flow chart of the cobalt supply chain
Source: Amnesty International and Afrewatch

To address this challenge, there have been efforts (Rajaeifar et al., 2022) to develop more transparent and traceable supply chains for electric vehicle batteries. One example of this is the Responsible Minerals Initiative, which is a multi-stakeholder initiative that works to promote the responsible sourcing of minerals, including those used in electric vehicle batteries. The initiative has developed a set of due diligence guidelines for companies to follow, which includes steps such as identifying risks in the supply chain, engaging with suppliers to address these risks, and monitoring and reporting on progress.

In addition to industry-led initiatives, there have also been efforts by governments and non-governmental organizations to promote greater transparency in the supply chain for electric vehicle batteries. For example, the European Union (Colonna, E., Dekimpe, V., Duffau, E., Calvetti, R., & Bertsch, M., 2023) has developed regulations requiring companies to conduct due diligence on their supply chains to ensure that they are not contributing to human rights abuses or environmental degradation. Similarly, non-governmental organizations such as Amnesty International (Amnesty International, 2016) have called on companies to be more transparent about their supply chains and to take steps to address human rights abuses and environmental concerns.

Overall, the issue of supply chain transparency in the electric vehicle battery industry is complex and multifaceted, and there is no easy solution. However, efforts are underway to promote greater transparency and traceability in the supply chain, which can help to ensure that environmental and social standards are being met and that the trade is more sustainable and ethical.

3.3.4. Resource depletion

The extraction of raw materials for electric vehicle batteries can contribute to the depletion of natural resources, particularly if demand continues to grow at current rates. This can lead to environmental degradation and social conflicts over access to resources.

One key example of this is the mining of lithium, which is a key component of lithium-ion batteries. Accord-

ing to a report by the International Energy Agency (International Energy Agency, 2023), the production of lithium is expected to increase significantly in the coming years, driven by the growth of the electric vehicle market. This growth in demand could lead to significant environmental impacts, particularly in regions where lithium is mined and processed.

In addition to lithium, other raw materials used in electric vehicle batteries, such as cobalt and nickel, are also subject to resource depletion concerns. According to a report by the European Commission (Alves Dias et al., 2022), the demand for cobalt is expected to increase significantly in the coming years, driven by the growth of the electric vehicle market. This growth in demand could lead to environmental degradation and social conflicts over access to resources in regions where cobalt is mined.

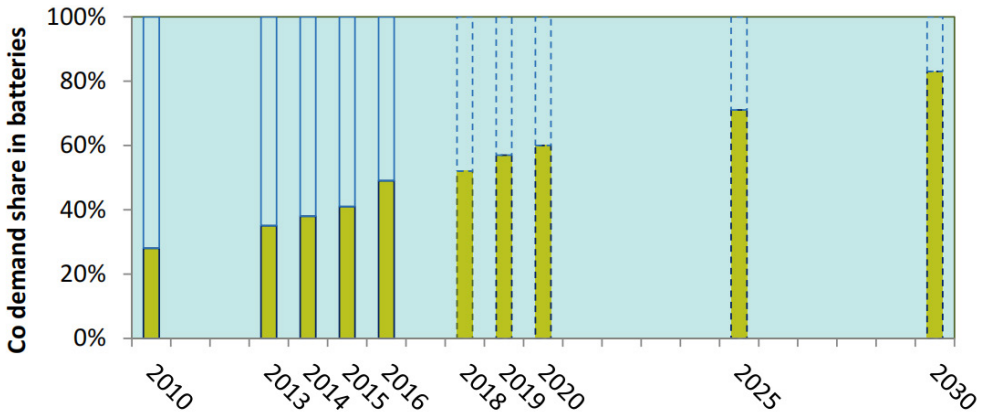

Figure 14. Cobalt Demand Share in Rechargeable Batteries
Source: the European Commission

The issue of resource depletion is complex and multifaceted, and there are no easy solutions. However, there are efforts underway to promote more sustainable and responsible mining practices and to encourage the development of alternative materials and technologies that can reduce the demand for these resources.

Overall, the issue of resource depletion in the electric vehicle battery industry is an important one, and companies and governments need to work together to address these concerns and promote more sustainable and responsible practices. This can help to ensure that the growth of the electric vehicle market does not come at the expense of the environment or social well-being.

3.4. Strategies for promoting sustainable trade of raw materials

This area will identify the strategies for promoting sustainable trade of raw materials for electric vehicle batteries, discuss the effectiveness of these strategies, and analyze the challenges and limitations of implementing these strategies.

3.4.1. Certification schemes

Several certification schemes aim to promote sustainable practices in the mining and processing of raw materials used in electric vehicle batteries. These schemes set environmental and social standards that companies must meet to receive certification.

One example of a certification scheme is the Responsible Minerals Initiative (RMI), which is a joint initiative of companies and NGOs working to promote responsible mineral sourcing. The RMI has developed a set of standards for responsible sourcing of minerals, including those used in electric vehicle batteries, and provides a certification process for companies that meet these standards. The RMI's standards cover a range of issues, including labor rights, environmental impacts, and community engagement.

Another example of a certification scheme is the Initiative for Responsible Mining Assurance (IRMA), which is a multi-stakeholder initiative that aims to promote responsible mining practices. The IRMA has developed a set of standards for responsible mining, including those related to the mining of minerals used in electric vehicle batteries, and provides a certification process for companies that meet these standards. The IRMA's standards cover a range of issues, including human rights, labor rights, environmental impacts, and community engagement.

Overall, certification schemes can play an important role in promoting more sustainable and responsible practices in the mining and processing of raw materials used in electric vehicle batteries. By setting clear standards and providing a certification process, these schemes can help to ensure that companies are meeting environmental and social standards, and can provide consumers with greater confidence in the sustainability and ethicality of the products they purchase.

3.4.2. Responsible sourcing initiatives

Responsible sourcing initiatives are becoming increasingly common in the electric vehicle battery industry, as companies and governments seek to promote sustainable and ethical trade in raw materials. These initiatives seek to ensure that environmental and social standards are being met throughout the supply chain.

One example of a responsible sourcing initiative is the European Union's Raw Materials Alliance, which was launched in 2021. The Raw Materials Alliance aims to promote sustainable and responsible sourcing of raw materials, including those used in electric vehicle batteries, by bringing together companies, governments, and civil society organizations to work towards common goals. The initiative seeks to promote sustainable and ethical trade by improving transparency, promoting responsible sourcing practices, and promoting the development of domestic supply chains.

Another example of a responsible sourcing initiative is the Global Battery Alliance, which was launched in 2017 by the World Economic Forum. The Global Battery Alliance aims to promote sustainable and responsible trade in batteries, including those used in electric vehicles, by bringing together companies, governments, and civil society organizations to work towards common goals. The initiative seeks to promote sustainable and ethical trade by improving transparency, promoting responsible sourcing practices, and promoting the development of circular economies.

In addition to these initiatives, many companies in the electric vehicle battery industry have launched their responsible sourcing initiatives. For example, Tesla has committed to using only responsibly sourced materials in its batteries and has developed a due diligence process to ensure that its suppliers are meeting environmental and social standards. Other companies, such as BMW and Volkswagen, have also launched responsible sourcing initiatives aimed at promoting sustainable and ethical trade in raw materials.

Overall, responsible sourcing initiatives are an important tool for promoting sustainable and ethical trade in raw materials used in electric vehicle batteries. By bringing together companies, governments, and civil society organizations to work towards common goals, these initiatives can help to ensure that environmental and social standards are being met throughout the supply chain, and can promote the development of more sustainable and responsible practices.

3.4.3. Recycling and circular economy

Recycling and circular economy solutions are becoming increasingly important in the electric vehicle battery industry, as companies and governments seek to reduce their environmental impact and promote more sustainable practices. This includes initiatives aimed at increasing the recycling rate of batteries and repurposing the raw materials used in these batteries.

One example of a recycling initiative is the Closed Loop Fund, which is a public-private partnership that aims to invest in recycling infrastructure in the United States. The Closed Loop Fund has invested in several projects aimed at increasing the recycling rate of batteries, including a project to recycle lithium-ion batteries from electric vehicles.

Another example of a recycling initiative is the ReLieVe project, which is a European Union-funded project aimed at developing new recycling technologies for electric vehicle batteries. The project aims to increase the recycling rate of batteries to more than 95% and to develop new technologies for repurposing the raw materials used in these batteries.

In addition to recycling, there are also initiatives aimed at promoting the circular economy by repurposing the

raw materials used in electric vehicle batteries. For example, the Finnish company Fortum has developed a process for recovering cobalt (Fortum, 2023) and other metals from lithium-ion batteries, which can then be repurposed for use in new batteries or other applications.

Overall, recycling and circular economy solutions important tools for promoting more sustainable and responsible practices in the electric vehicle battery industry. By increasing the recycling rate of batteries and repurposing the raw materials used in these batteries, companies and governments can reduce their environmental impact, conserve natural resources, and promote a more sustainable and circular economy.

3.5. Future prospects

This area will analyze the innovations and trends shaping the trade of raw materials for electric vehicle batteries, discuss the potential impact of these innovations and trends on the trade, and identify the areas for future research.

3.5.1. Development of new battery chemistries

There is a growing interest in developing new battery chemistries that can reduce reliance on scarce or problematic raw materials. These new battery chemistries have the potential to reduce the environmental impact of electric vehicle batteries, as well as reduce the cost and improve the performance of these batteries.

3.5.2. Increased demand for recycled materials

As the market for electric vehicles grows, the demand for recycled materials to be used in battery production is also increasing. This is creating new opportunities for companies that specialize in battery recycling and driving innovation in recycling technologies. Companies are investing in new recycling processes and technologies to increase the efficiency and scale of battery recycling, as well as improve the quality of the recycled materials. This increased demand for recycled materials is also driving down the cost of recycled materials, making them more competitive with virgin materials.

3.5.3. The emergence of new supply chain models

The supply chains for raw materials used in electric vehicle batteries are becoming increasingly complex, with new models emerging that seek to promote transparency and sustainability. One example is the use of blockchain technology to create transparent supply chains, which can provide a secure and transparent record of the movement of raw materials from extraction to production. This can help to promote ethical and sustainable practices by enabling companies to trace the origin of raw materials and ensure that they are sourced responsibly. Other models include certification schemes and responsible sourcing initiatives, which aim to promote sustainable and ethical trade in raw materials.

3.5.4. The growing importance of ethical sourcing

There is a growing awareness of the ethical issues associated with the trade of raw materials for electric vehicle batteries, particularly around the use of child labor and other human rights abuses. This is driving innovation in ethical sourcing practices, with companies investing in responsible sourcing initiatives and certification schemes to promote sustainable and ethical trade in raw materials. Companies are also working to increase transparency in their supply chains and trace the origin of raw materials to ensure that they are sourced responsibly. This growing importance of ethical sourcing is creating new opportunities for companies that can demonstrate ethical sourcing credentials, and is promoting more responsible and sustainable practices in the electric vehicle battery industry.

4. Conclusion

In conclusion, the research highlights the complex and evolving nature of the trade of raw materials for electric

vehicle batteries. As the demand for electric vehicles grows, there is an increasing need for sustainable and ethical practices in the extraction, processing, and trade of raw materials. This is driving innovation in recycling technologies, new battery chemistries, and ethical sourcing practices, and creating new opportunities for companies that can demonstrate sustainability and ethical credentials.

However, there are also challenges and concerns associated with the trade of raw materials for electric vehicle batteries, including environmental impacts, human rights abuses, and the potential for monopolies and lack of competition. To address these challenges, future research should focus on developing new technologies and solutions that promote sustainability and ethical practices, as well as exploring new supply chain models and policy frameworks that can support more responsible and sustainable trade in raw materials.

Overall, the findings have important implications for the trade of raw materials for electric vehicle batteries, and highlight the need for greater collaboration and innovation to promote sustainability and ethical practices in this important and rapidly growing industry. By investing in new technologies, responsible sourcing initiatives, and transparent supply chain models, companies and governments can help to ensure that the growth of the electric vehicle industry is sustainable, responsible, and beneficial for all stakeholders.

References

[1] ALMEIDA A, SOUSA N, COUTINHO-RODRIGUES J. (2019). Quest for sustainability: life-cycle emissions assessment of electric vehicles considering newer Li-Ion batteries[J]. Sustainability, 11(8):2366. DOI:10.3390/su11082366.

[2] ALVES DIAS P, BLAGOEVA D, PAVEL C, ARVANITIDIS N. (2022). Cobalt: demand-supply balances in the transition to electric mobility[EB/OL]. European Commission. [2022-12-23]. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1145.

[3] AMNESTY INTERNATIONAL. (2016). This is what we die for: human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt[EB/OL]. [2016-01-19]. https://www.amnesty.org/en/documents/afr62/3183/2016/en/.

[4] BAUCHOWITZ S. (2014). A race to the middle: governance in the extractive industries and the rise of China[D]. New York: Columbia University. https://www.proquest.com/dissertations-theses/race-middle-governance-extractive-industries-rise/docview/1782840533/se-2.

[5] BLOOMBERG NEWS. (2023). China could control a third of the world's lithium by 2025[EB/OL]. Bloomberg. [2023-03-13]. https://www.bloomberg.com/news/articles/2023-03-13/china-could-control-a-third-of-the-world-s-lithium-by-2025.

[6] BREITER A, LINDER M, SCHULDT T, SICCADO G, VEKIĆ N. (2023). Battery recycling takes the driver's seat[EB/OL]. McKinsey & Company. [2023-03-13]. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-recycling-takes-the-drivers-seat.

[7] BROWN C, DANIELS A, BOYD D S, SOWTER A, FOODY G, KARA S. (2020). Investigating the potential of radar interferometry for monitoring rural artisanal cobalt mines in the Democratic Republic of the Congo[J]. Sustainability, 12(23):9834. DOI:10.3390/su12239834.

[8] CAMPBELL J. (2020). Why cobalt mining in the DRC needs urgent attention[EB/OL]. Council on Foreign Relations. [2020-10-19]. https://www.cfr.org/blog/why-cobalt-mining-drc-needs-urgent-attention.

[9] CHARLIER C, GUILLOU S. (2014). Distortion effects of export quota policy: an analysis of the China-raw materials dispute[J]. China Economic Review, 31:320-338. DOI:10.1016/j.chieco.2014.10.004.

[10] CHEYNS K, et al. (2014). Pathways of human exposure to cobalt in Katanga, a mining area of the D.R. Con-

go[J]. Science of the Total Environment, 490:313-321. DOI:10.1016/j.scitotenv.2014.05.014.

[11] COLONNA E, DEKIMPE V, DUFFAU E, CALVETTI R, BERTSCH M. (2023). Lithium: Europe joins the "white gold" rush[EB/OL]. France 24. [2023-02-10]. https://www.france24.com/en/tv-shows/down-to-earth/20230210-lithium-europe-joins-the-white-gold-rush.

[12] CSIS. (2021). Does China pose a threat to global rare earth supply chains?[EB/OL]. ChinaPower Project. [2021-05-12]. https://chinapower.csis.org/china-rare-earths/.

[13] EGAN T. (2023). Where do electric vehicle batteries come from?[EB/OL]. EnergyX. [2023-03-10]. https://energyx.com/blog/where-do-electric-vehicle-ev-batteries-come-from/.

[14] ELBEL J, BOSE O'REILLY S, HRZIC R. (2023). A European Union corporate due diligence act for whom? considerations about the impact of a European Union due diligence act on artisanal and small-scale cobalt miners in the Democratic Republic of Congo[J]. Resources Policy, 81:103241. DOI:10.1016/j.resourpol.2022.103241.

[15] EUROPEAN BATTERY ALLIANCE. (2023). International Energy Agency[EB/OL]. [2023-12-12]. https://www.iea.org/policies/15093-european-battery-alliance.

[16] EUROPEAN COMMISSION. (2023). Critical raw materials: ensuring secure and sustainable supply chains for EU's green and digital future[EB/OL]. [2023-03-16]. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661.

[17] FALLAH N, FITZPATRICK C. (2022). How will retired electric vehicle batteries perform in grid-based second-life applications? a comparative techno-economic evaluation of used batteries in different scenarios[J]. Journal of Cleaner Production, 361:132281. DOI:10.1016/j.jclepro.2022.132281.

[18] FLEXER V, BASPINEIRO C F, GALLI C I. (2018). Lithium recovery from brines: a vital raw material for green energies with a potential environmental impact in its mining and processing[J]. Science of the Total Environment, 639:1188-1204. DOI:10.1016/j.scitotenv.2018.05.223.

[19] FORTUM. (2023). Fortum battery recycling opens Europe's largest closed-loop hydrometallurgical battery recycling facility in Finland[EB/OL]. [2023-04-27]. https://www.fortum.com/media/2023/04/fortum-battery-recycling-opens-europes-largest-closed-loop-hydrometallurgical-battery-recycling-facility-finland.

[20] GAŁAŚ S, GAŁAŚ A. (2016). The qualification process of mining projects in environmental impact assessment: criteria and thresholds[J]. Resources Policy, 49:204-212. DOI:10.1016/j.resourpol.2016.06.003.

[21] HARPER G, SOMMERVILLE R, KENDRICK E, et al. (2019). Recycling lithium-ion batteries from electric vehicles[J]. Nature, 575:75-86. DOI:10.1038/s41586-019-1682-5.

[22] INTERNATIONAL ENERGY AGENCY. (2021). Global supply chains of electric vehicle batteries: outlook 2030[EB/OL]. [n.d.]. https://iea.blob.core.windows.net/assets/961cfc6c-6a8c-42bb-a3ef-57f3657b7aca/GlobalSupplyChainsofEVBatteries.pdf.

[23] INTERNATIONAL ENERGY AGENCY. (2023). Global EV outlook 2023[EB/OL]. [n.d.]. https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries.

[24] INTERNATIONAL LABOUR ORGANIZATION. (2017). Individual case (CAS) - discussion: 2017. 106th ILC session[EB/OL]. [n.d.]. https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:13100:0::NO::P13100_COMMENT_ID:3331022.

[25] LINDER M, NAUCLÉR T, NEKOVAR S, PFEIFFER A, VEKIĆ N. (2023). The race to decarbonize electric-vehicle batteries[EB/OL]. McKinsey & Company. [2023-02-23]. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-race-to-decarbonize-electric-vehicle-batteries.

[26] MANCINI L, ESLAVA N A, TRAVERSO M, MATHIEUX F. (2021). Assessing impacts of responsible sourcing initiatives for cobalt: insights from a case study[J]. Resources Policy, 71:102015. DOI:10.1016/j.resourpol.2021.102015.

[27] MARTINS L S, GUIMARAES L F, et al. (2021). Electric car battery: an overview on global demand, recycling and future approaches towards sustainability[J]. Journal of Environmental Management, 295:113091. DOI:10.1016/j.jenvman.2021.113091.

[28] MCCRONE A. (2018). The force is with clean energy: 10 predictions for 2018[EB/OL]. BloombergNEF. [2018-01-16].
https://about.bnef.com/blog/clean-energy-10-predictions-2018/.

[29] MURRAY A. (2022). Cobalt mining: the dark side of the renewable energy transition[EB/OL]. Earth.Org. [2022-09-27].
https://earth.org/cobalt-mining/.

[30] NEUMANN J, PETRANIKOVA M, MEEUS M, et al. (2022). Recycling of lithium-ion batteries-current state of the art, circular economy, and next generation recycling[J]. Advanced Energy Materials, 12(17). DOI:10.1002/aenm.202102917.

[31] NS ENERGY STAFF WRITER. (2021). Profiling the six largest cobalt reserves in the world by country[EB/OL]. NS Energy. [2021-06-07].
https://www.nsenergybusiness.com/features/largest-cobalt-reserves-country/.

[32] RAJAEIFAR M A, GHADIMI P, RAUGEI M, WU Y, HEIDRICH O. (2022). Challenges and recent developments in supply and value chains of electric vehicle batteries: a sustainability perspective[J]. Resources, Conservation and Recycling, 180:106144. DOI:10.1016/j.resconrec.2021.106144.

[33] ROBERT C, RAVEY A, PEREY R, HISSEL D. (2022). Environmental impacts of batteries for transportation application according to different life cycle steps[C]. 2022 IEEE Vehicle Power and Propulsion Conference (VPPC), 1-6. DOI:10.1109/VPPC55846.2022.10003370.

[34] SCHMIDT H. (2021). How are electric vehicle batteries made?[EB/OL]. The New York Times. [2021-11-20].
https://www.nytimes.com/interactive/2021/11/20/world/electric-vehicle-battery.html.

[35] SCHMIDT T, BUCHERT M, SCHEBEK L. (2016). Investigation of the primary production routes of nickel and cobalt products used for Li-ion batteries[J]. Resources, Conservation and Recycling, 112:107-122. DOI:10.1016/j.resconrec.2016.04.017.

[36] SETHI S P, LOWRY D B, VERAL E A, et al. (2011). Freeport-McMoRan Copper & Gold, Inc.: an innovative voluntary code of conduct to protect human rights, create employment opportunities, and economic development of the indigenous people[J]. Journal of Business Ethics, 103:1-30. DOI:10.1007/s10551-011-0847-4.

[37] SHINE I. (2022). The world needs 2 billion electric vehicles to get to net zero. but is there enough lithium to make all the batteries?[EB/OL]. World Economic Forum. [2022-07-20].
https://www.weforum.org/agenda/2022/07/electric-vehicles-world-enough-lithium-resources/.

[38] U.S. GEOLOGICAL SURVEY. (2022). Lithium[M]. Mineral Commodity Summaries, 2022:70-71.
https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-lithium.pdf.

[39] WORLD WILDLIFE FUND. (2022). Lithium and the transition to a low-carbon economy: a sustainable opportunity[EB/OL]. [n.d.].
https://wwfeu.awsassets.panda.org/downloads/litio_ing.pdf.

[40] YAO Y, ZHU M, ZHAO Z, TONG B, FAN Y, HUA Z. (2018). Hydrometallurgical processes for recycling spent lithium-ion batteries: a critical review[J]. ACS Sustainable Chemistry & Engineering, 6(11):13611-13627. DOI:10.1021/acssuschemeng.8b03545.

[41] ZHAO B, SHI Y, DONG X D. (2014). Pricing and revenue maximization for battery charging services in PHEV markets[J]. IEEE Transactions on Vehicular Technology, 63(4):1987-1993. DOI:10.1109/TVT.2013.2288354.

[42] ZHOU M, LI B, LI J, XU Z. (2021). Pyrometallurgical technology in the recycling of a spent lithium ion battery: evolution and the challenge[J]. ACS EST Engg, 1(10):1369-1382. DOI:10.1021/acsestengg.1c00067.