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Driving the Future: Leveraging Regional Cooperation for Inclusive, Sustainable, and Resilient Electric Vehicle Battery Supply Chains

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KEY MESSAGES

- Global momentum is strong for the transition to electric vehicles (EVs), with the APEC region leading efforts to drive the future of the industry. Despite vulnerabilities in the EV supply chain due to geopolitical tensions and extreme weather, APEC economies are well-positioned to address EV battery challenges, as reaffirmed at the APEC Automotive Dialogue in May 2024.
- The transition to EVs relies on a complex ecosystem of supporting technologies and services, including critical minerals, supply chain distribution, and battery recycling. Addressing these factors is essential for creating an inclusive, sustainable, and resilient EV battery supply chain.
- APEC economies should promote research and development initiatives to reduce reliance on critical minerals and enhance battery recyclability. Technological advancements could eventually minimise dependence on specific resources, reducing the environmental impact of mineral extraction and processing.
- Building a circular and distributed supply chain will enhance climate resilience and sustainability while reducing supply chain risk. This can be achieved by fostering joint investments among APEC economies in battery recycling and mineral recovery. Increased partnerships within the EV supply chain can also help reduce tensions and create a more balanced playing field for APEC economies.
- Setting standards and regulations for EV battery production and logistics is important for ensuring sustainability and inclusivity, in line with international agreements. Establishing environmental, labour, and ethical standards will promote domestic market standardisation, regional cooperation, and integration in EV battery supply chains.

Introduction

Climate change is a global existential threat, making it a key priority to address. Eliminating greenhouse gas emissions from the transportation sector is crucial for mitigating climate change, and electric vehicles (EVs) play a key role in developing sustainable, low-emission land transport solutions.[1] However, the EV industry faces sustainability and resilience challenges, particularly concerning the EV battery supply chain.

This Policy Brief aims to analyse EV battery supply chain challenges in the APEC region, focusing on insights from the private sector and businesses. It seeks to guide policymakers by bridging the gap between the business sector's challenges and needs and the support that policymakers can provide to promote an inclusive, sustainable, and resilient EV supply chain.

To develop this Policy Brief, several interviews were conducted with private sector representatives and experts. These interviews shed light on challenges, potential solutions, and policy initiatives that can support the private and public goals towards a just and sustainable land transport decarbonisation process. A deep understanding of the private sector's challenges in the EV supply chain is crucial for formulating effective and impactful policies.

APEC economies are well-positioned to tackle these EV battery challenges and create a more sustainable, inclusive, and resilient supply chain. This can be achieved by (1) investing and cooperating in research and development, (2) developing a distributed and circular economy, and (3) setting standards and ensuring supply chain transparency.

The Road to Electrification: Risks and Opportunities

There is significant global momentum toward adopting EVs, with the APEC region particularly committed to advancing this transition. Many APEC economies have committed to ambitious targets for electrifying their domestic transportation sectors, driving a rapid increase in battery EV sales across the world over the past decade[2] (Figure 1). This surge is mirrored within APEC economies, where battery EV sales have also experienced substantial growth.

In 2023, the top five APEC economies for battery EV sales were China; the United States; Canada; Korea; and Japan. Together, these five APEC economies accounted for over 70 percent of battery EV sales worldwide (Figure 2).

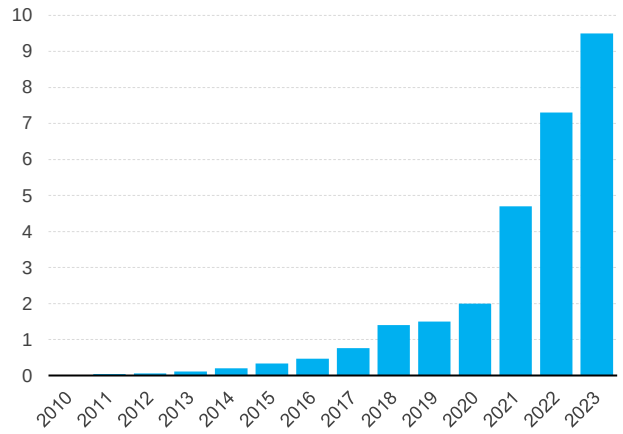

Figure 1. Global Battery EV Sales (million vehicles), 2010-2023
Source: International Energy Agency (2024)

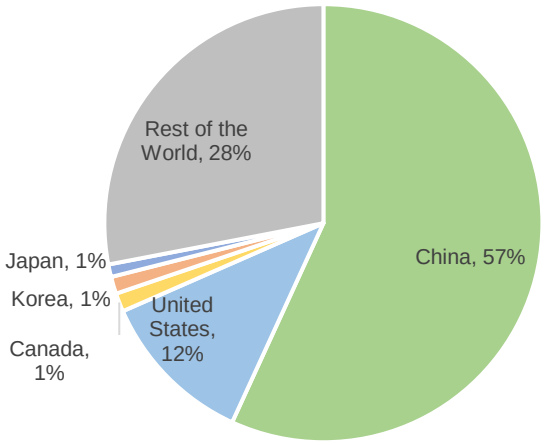

Figure 2. Battery EV Sales Share by Selected APEC Economies (%), 2023
Source: International Energy Agency (2024). APEC PSU calculations.

Despite this significant growth, challenges remain in ensuring that EV adoption effectively decarbonises the land transportation sector. For instance, EV adoption is constrained by public concerns about high costs and battery reliability. EV batteries operate optimally at ambient temperatures between 15ºC to 35ºC.[3] Temperatures beyond this range, such as those caused by winter weather or heat waves, reduce both the range and charging capacity of EV batteries. Likewise, a lack of low-cost models continues to be a major barrier to EV adoption. These concerns contribute to the challenges faced within the industry. In addition, the environmental costs associated with the mining of critical minerals, energy-intensive battery production, and transportation have been cited as significant barriers to using EVs for climate change mitigation and adaptation.

A related concern is the source of electricity for producing and recharging these energy-intensive batteries, highlighting the importance of renewable energy.[4] If the electricity comes mostly from fossil fuels, the overall reduction in carbon footprint will be limited. Increasing power generation from renewable sources is important for making EVs more environmentally friendly. Integrating renewable energy sources such as wind and solar into power grids must be prioritised to reduce overall emissions and ensure that the transition to EVs is sustainable.[5]

APEC economies are particularly well-positioned to address EV battery challenges. In May 2024, the APEC Automotive Dialogue reaffirmed the region's commitment to developing a more sustainable EV supply chain.[6] Many APEC economies play prominent roles within the global EV battery supply chain. Economies that produce significant raw materials for lithium-ion batteries include Australia; Canada; Chile; China; Indonesia; Japan; Korea; Mexico; the Philippines; Thailand; the United States; and Viet Nam.[7] Peru is currently exploring lithium mining opportunities and is already a large producer of copper and other minerals essential for EV-related technologies.[8] Malaysia is ramping up battery and semiconductor manufacturing, as well as battery recycling.[9] Russia is one of the world's largest producers of nickel, a key mineral for EV batteries.[10] Chinese Taipei produced USD 12.8 billion in automotive electronics in 2023.[11] Papua New Guinea's mining industry is its largest source of revenue.[12] These diverse contributions underscore the interconnected nature of the APEC region's involvement in advancing global EV battery technologies.

Many of these economies are also home to significant manufacturing and production capacity. Economies that have traditionally been part of automobile manufacturing hubs, such as Indonesia; Malaysia; Mexico; and Thailand, are now attracting significant investment to develop the EV battery industry. It is critical that APEC adopts reforms to ensure that these structural changes help drive decarbonisation and sustainable economic growth.

EV Battery Supply Chain: Caution, Bumps Ahead

The transition to EVs depends not just on the vehicles themselves but on a complex ecosystem of supporting technologies and services (Figure 3). Critical minerals, supply chain distribution (transportation), and battery recycling are components of the supply chain that must be addressed to form a more sustainable and resilient EV battery supply chain. Each part of the supply chain must be optimised not only to meet the rising demand for EVs but also to ensure the long-term sustainability of the EV market. The analysis of this paper will focus on three key segments of the EV battery supply chain: mineral extraction and battery production, supply chain distribution, and battery recycling, all of which play an indispensable part in ensuring sustainable outcomes.

Mineral Extraction and Battery Production

Critical minerals, such as lithium, graphite, cobalt, and nickel are indispensable for producing EVs. Indeed, EVs have more intensity and diversity in mineral inputs compared to internal combustion engine vehicles (ICEVs) (Figure 4).[13] The lithium-ion battery, in

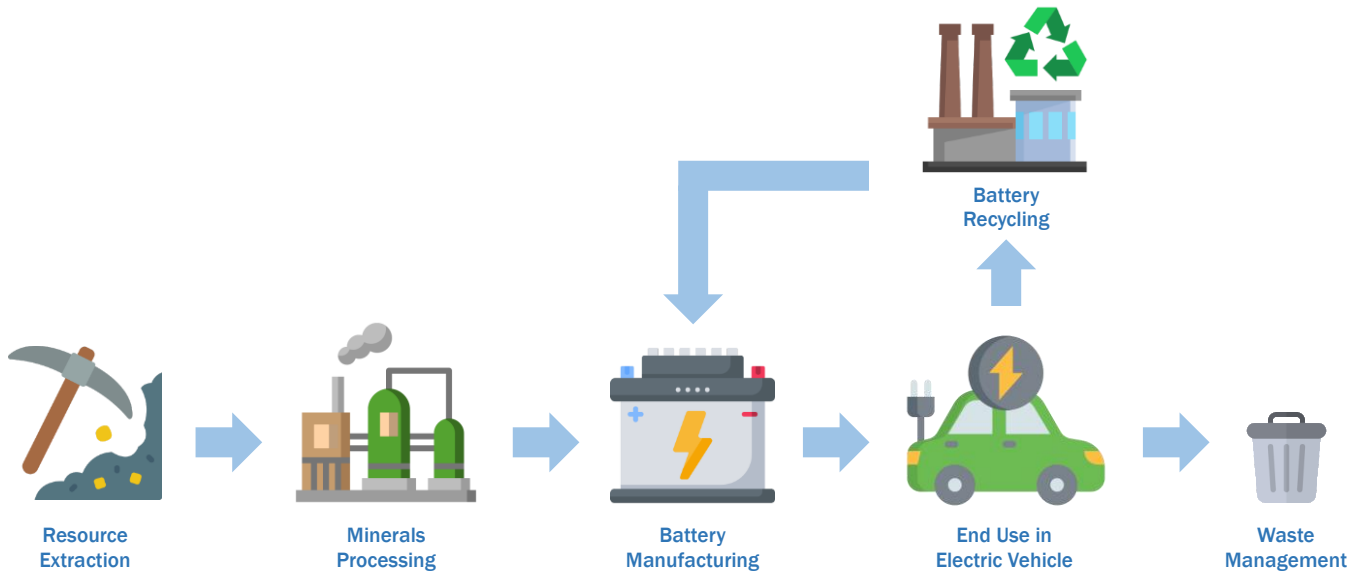

Figure 3. A Visual Representation of the EV Battery Supply Chain
Source: Authors

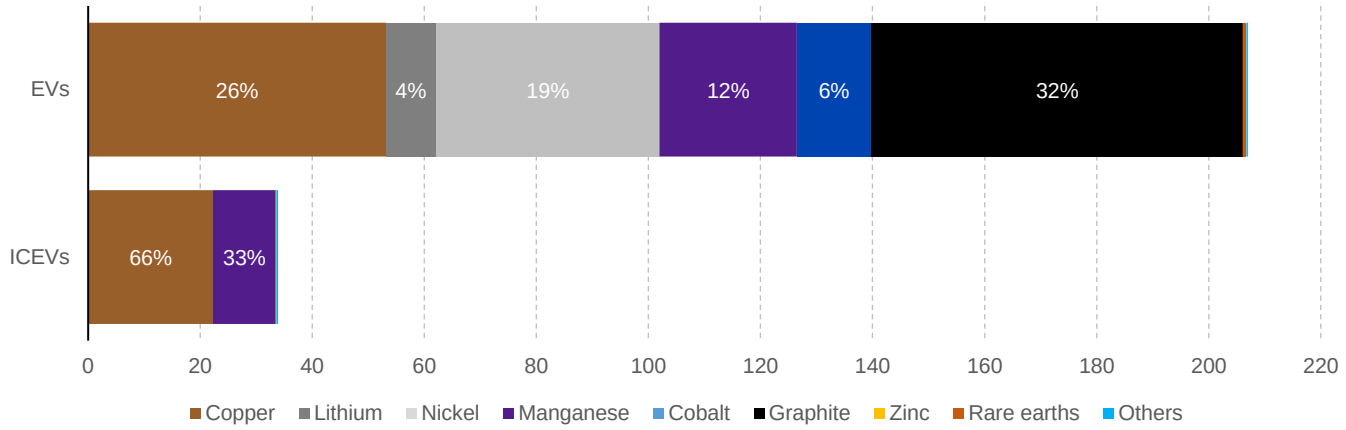

Figure 4. Minerals Used in EVs vs ICEVs (kg)
Note: Excludes steel and aluminium.
Source: International Energy Agency (2021). APEC PSU calculations.

particular, is the most commonly used EV battery, but the type of lithium-ion battery varies and is dependent on a variety of mineral and chemical compositions. These minerals are extracted, processed, and refined to create cathode and anode active materials used in batteries.[14] These components are then assembled into battery cells and modules that can be used to power EVs.

It is worth noting that many of the top producers of critical minerals used in EV battery manufacturing—such as lithium, nickel, and graphite—are APEC member economies. This highlights the strategic importance of APEC in the EV battery supply chain.

According to an OECD Trade Policy Paper, the demand for lithium will face a 42 percent increase by 2040.[15] Australia; Chile; and China are currently the top three producers of lithium, accounting for 90 percent of the global supply.[16] Graphite and nickel are the two most challenging minerals to access in the current battery supply chain. Nickel demand is expected to increase by 19 percent by 2040.[17] Indonesia; the Philippines; and Russia are the top three producers of nickel in the world, accounting for 60 percent of the global supply.[18] Meanwhile, graphite demand is expected to increase by 25 percent by 2040,[19] with China currently supplying about 77 percent of the world's graphite.[20]

On the other hand, the same policies driving EV adoption in some APEC economies are also aiming to reshape global mineral supply chains. For example, Australia's "Australian Made Battery Plan," Japan's "Green Growth Strategy," Mexico's "Lithium for Mexico," and the United States' "Inflation Reduction Act" are some policies intended to increase domestic mineral and battery supply in the APEC region.[21]

Some interviewees opined that the current mineral supply chain is complex and lacks transparency, particularly in price setting, adding uncertainty to the sector. The geography of EV inputs poses a significant challenge to the sector's sustainability and cost-effective development. The high concentration of EV battery minerals and processing capacity in certain economies could create a supply chain that is not only sensitive to geopolitical tensions but also susceptible to natural disasters or other hazards.

Some private sector leaders are also increasingly concerned about the sustainability of critical mineral extraction. The environmental costs of mining and EV battery production could undermine the potential of EVs to address climate change and environmental issues effectively. Furthermore, environmental policies and regulations could limit the development of mineral extraction and processing industries in some economies, necessitating a balanced approach to ensure supply chain sustainability while meeting the urgent need to decarbonise transportation.

A recent study highlighted that "global lithium-ion battery emissions are on track to reach a maximum of 1 $GtCO_2$-eq per year if no significant measures are taken."[22] The EV battery production process is both energy-intensive and potentially highly polluting, which could offset the benefits of electrification. Beyond mineral sourcing, the stringent purity requirements for batteries puts a strain on costs and sustainability. High purity demands of minerals like graphite make this process even more capital- and energy-intensive.

Additionally, climate change exacerbates the frequency of extreme weather events such as floods, heat waves, and blizzards, which can disrupt mining operations and transportation routes, as well as reduce EV battery performance. Mining operations often require substantial water usage, and climate-induced water shortages can impede these activities and heighten competition for water resources. For example, extracting one ton of lithium requires up to half a million gallons of water, and often occurs in regions that are already water-stressed.[23] High temperatures can also

Box 1. The Importance of Regional Cooperation in Innovation

In the mid-1990s, scientists in an APEC economy discovered lithium iron phosphate, a key compound for lithium-ion batteries.[1] This technology was later commercialised by a startup company. However, the company faced challenges due to low demand for EVs and initial hesitation from domestic automobile manufacturers to invest in an emerging technology.[2] By 2013, the startup went bankrupt and was acquired by a major international auto parts company based in another APEC economy.[3] This acquisition coincided with efforts to develop a domestic EV market in that economy, leveraging the startup's technology to make significant advancements in the global EV battery industry.[4]

This case emphasises the importance of robust support for technological research and development complemented with efforts to bring them to market. Furthermore, it highlights the benefits of regional cooperation and the sharing of ideas. As the case of lithium-ion batteries shows, innovation can happen in a market that is not yet ready to accept it, while another market may be ready and hungry for such an innovation.

When innovative technologies are disseminated widely, all economies in the APEC region gain the opportunity to drive progress and development, advancing public knowledge and benefiting the region and the world as a whole. A collaborative approach to innovation fosters mutual economic benefit and ensures that technological advancements contribute to the progress of all economies.

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affect worker health and safety as well as the efficiency of mining equipment. Furthermore, climate change can intensify habitat destruction associated with mining activities, threatening biodiversity and ecological balance.

Technological development and cooperation could provide a solution. Since the invention of the lithium-ion battery in the 1990s, the technology has advanced to reduce its reliance on critical minerals, and different batteries require different mineral compositions. Currently, there are three dominant varieties of lithium-ion batteries available: lithium nickel manganese cobalt oxide (NMC), lithium iron phosphate (LFP), and nickel cobalt aluminium oxide (NCA). Technological advancements are needed to further reduce dependence on specific critical minerals and diversify options for production. To further advance battery technology, continued innovation and regional cooperation are essential (Box 1).

Supply Chain Distribution

Navigating the complexities of global trade relations and regulatory controls is essential for the growth and sustainability of the EV battery supply chain. Recent discussions in the EV industry have focused on export and import controls, which create constraints within the supply chain. In the past, competition and trade were encouraged, but current trade controls and stringent regulations like import and export restrictions pose significant challenges, especially for smaller businesses. Experts advocate for reducing export controls to support the growth of EV development and innovation.

While the efforts to build a more localised battery supply chain in response to trade restrictions are ongoing, many experts emphasise that global trade relationships for EV batteries will remain crucial for the foreseeable future. If the superior quality materials for EVs are produced in other regions, it is important for companies to access and import these resources. While shorter transportation distances can reduce carbon emissions and vulnerabilities, relying solely on a localised supply chain may not be feasible in the long run. A balanced approach that integrates both global sourcing and localised efforts is necessary to ensure the efficiency and sustainability of the EV battery supply chain. By strategically sourcing materials from both local and international sources, companies can optimise operations, minimise environmental impact, and increase resilience against disruptions.

Unclear and frequently changing policies pose significant challenges for firms in the EV supply chain distribution. Confusing legal regulations deter business engagements and limit international trade and partnerships. The constant flux of export controls and international trade regulations, coupled with vague policy language, exacerbates these challenges. Experts also point out that new regulations are often introduced without adequate notification or guidance. APEC market economies are diverse and complex, requiring a thorough understanding to navigate entry into these markets. In the absence of clear guidance, these

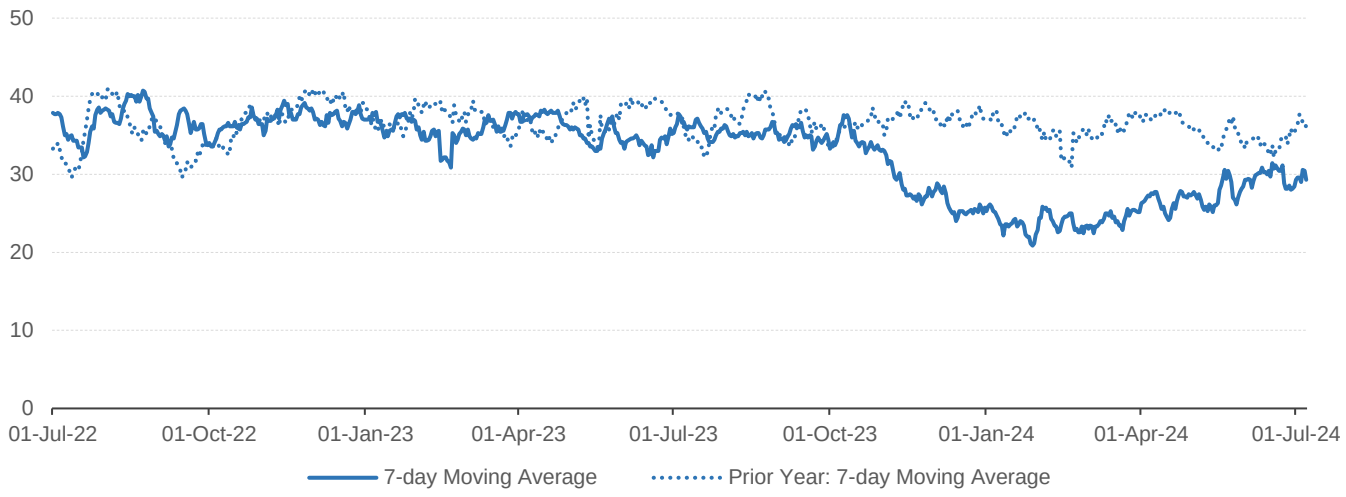

Figure 5. Panama Canal Daily Transit Calls
Source: United Nations Global Platform, International Monetary Fund Port Watch.

complexities can present significant hurdles to businesses to invest and operate.

Increased logistics and transportation costs present major challenges to the sustainable and cost-effective development of EVs. Transporting minerals over long distances is expensive, and export/import controls further inflate distribution costs within the EV supply chain. The energy-intensive nature of current transportation methods, combined with the need for infrastructure resilience against climate impacts, exacerbates these expenses. As companies strive to integrate sustainable practices, higher initial costs present a barrier to widespread adoption.

The production and transportation of EV batteries are particularly energy-intensive, often relying on energy grids powered by fossil fuels and susceptible to climate change impacts.[24] A recent study revealed that lithium-ion battery production could soon reach emissions of 1 billion tons of CO_2 per year.[25] This amount is approximately equivalent to the annual emissions of the global aviation industry.[26] The transportation of input materials makes up 5 percent of CO_2 emissions from batteries—on top of emissions from manufacturing, this can offset some of the carbon savings achieved by EVs.[27] Transitioning to renewable energy sources for battery production is crucial to minimise its carbon footprint. The entire EV battery supply chain, from mineral extraction to manufacturing and transportation, contributes to greenhouse gas emissions: streamlining and greening the supply chain by adopting energy-efficient logistics practices, optimising transportation routes, and investing in resilient infrastructure can help reduce these emissions.

Extreme weather events can damage transportation infrastructure like roads, bridges, and ports, leading to delays and increased costs. Transportation systems reliant on electricity or fuel can be disrupted by energy supply issues caused by climate change. Rising sea levels and increased flooding may necessitate changes in transportation routes, affecting delivery times and logistics efficiency. Likewise, droughts and rising temperatures can impact traffic in trade routes, such as what happened to the Panama Canal in early 2024 (Figure 5). The costs associated with rerouting, repairing damaged infrastructure, and mitigating climate impacts can further raise overall supply chain distribution expenses. By streamlining the supply chain, companies can reduce emissions and improve cost efficiency.

Battery Recycling

The lifespan and subsequent reuse or recycling of EV batteries are becoming increasingly important as global EV sales continue to surge. At the end of their life cycle, EV batteries pose disposal challenges, and improper disposal can lead to environmental contamination due to hazardous materials. As of 2024, only 5 percent of EV batteries are recycled.[28]

After being used in an EV, a battery can be repurposed for other technologies or recycled to create new batteries. EV batteries typically last 10-20 years, depending on the model and usage.[29] With global EV sales having surged in the past decade, the first wave of EV batteries will soon reach the end of their lifecycle. Developing efficient and sustainable recycling methods is essential to manage the growing battery waste and recover valuable materials.

China currently leads in EV battery recycling capacity, with the capacity to recycle 500,000 metric tons of lithium-ion battery materials per year. The United States follows, with the capacity to process 200,000 metric tons of recycled materials per year. EV batteries weigh on

average 454 kg (1,000 pounds).[30] Based on this data, China currently has the capacity to recycle approximately 1,101,321 EV batteries, and the United States has the capacity to recycle approximately 440,529 EV batteries. A report projects that battery recycling demand could rise to 14 million batteries per year by 2040.[31] Within the next ten years, there is likely to be a significant waste problem.[32] Therefore, increasing domestic and global EV battery recycling capacity is essential for maintaining EV supply and uptake, as well as addressing gaps in the upstream mineral supply for batteries.

Battery recycling is essential for decarbonising the EV battery supply chain and the broader transportation sector. Recycling batteries can reduce up to 25 percent of the carbon footprint associated with battery production.[33] However, EV batteries present significant recycling challenges, and the current demand for battery recycling remains low. For example, it is difficult to recover high levels of minerals from discarded batteries. Often, large portions of minerals are discarded along with the rest of the battery.[34] However, advances in battery technology hold promise for improving the recyclability of batteries, and new chemical compositions and battery technologies are making some batteries easier to recycle.

Figure 6. Summary of Challenges
Source: Authors.

The current demand for battery recycling is relatively low compared to future projections. This discrepancy creates investor risk, as there are not yet enough batteries available for recycling to sustain these businesses economically. Consequently, while some companies are prepared to invest in battery recycling, the insufficient volume of batteries hampers their financial viability. Industry sources estimate it could take over a decade for battery recycling facilities to become profitable.[35] To avoid a massive waste problem as the first generation of EV batteries reaches the end of their lifecycle, battery recycling must be more profitable than just throwing away the batteries (Figure 6 presents a summary of the key challenges discussed). Addressing this challenge will require both private and public financing support.

This challenge of battery recycling has been recognised by the APEC Automotive Dialogue, a forum bringing together the automotive industry's public and private sectors. In 2024, the APEC Automotive Dialogue emphasised its commitment to enhancing collaboration for designing batteries for reuse, repurposing, and recycling; and developing a circular economy model for efficient recycling of batteries and EVs.[36]

Policy Recommendations

Sustainability and resilience are intrinsically linked. Developing a green supply chain is not only good for the environment, but also enhances its overall resilience. Therefore, solutions to EV battery supply chain challenges must be oriented toward fostering a more sustainable, resilient, and inclusive industry. To achieve this, APEC economies could cooperate in research and development, build a distributed yet circular economy, set standards, and ensure visibility throughout the supply chain (Figure 7).

Cooperate on Research and Development

APEC economies should promote research and development initiatives that reduce reliance on minerals from primary sources and increase battery recyclability. This is key for reducing costs and increasing sustainability within the EV battery supply chain.

In the long term, technological advancements can eliminate dependency on specific resources, such as critical minerals, thereby reducing the environmental impact of mineral extraction and processing. Moving to more advanced forms of cathodes and battery chemical compositions can also free up the supply chain by reducing reliance on critical minerals.

Exploring other types of batteries beyond the currently dominant lithium-ion battery can mitigate reliance on critical minerals and related supply chain challenges through diversification. For example, the sodium-ion battery is an emerging technology that relies on abundant and well-distributed materials and can be used as batteries in EVs. While several companies around the world are already building sodium-ion battery manufacturing facilities, commercial use in EVs is still a few years away. Investing in this technology now can help speed up the process and reduce future critical mineral supply chain issues.

Battery recycling is another critical area for research and development. If batteries can be efficiently recycled, this will reduce the carbon footprint of EVs as well as supply chain risks. However, due to the current low demand and investment in battery recycling facilities, scaling up the battery recycling industry to meet future demand is a challenge. Additionally, as battery

composition changes and even shifts to other formats, such as sodium-ion batteries, recycling facilities will need to adapt.

Develop a Circular and Distributed Economy

Building a circular and distributed supply chain will increase climate change resilience and sustainability while reducing investor risk. This can be done by creating mechanisms for joint investments among APEC economies, with a focus on battery recycling and mineral recovery.

Investment in EV manufacturing and battery recycling will enable economies to create distributed supply chain hubs, diversifying supply chains, and lowering risks from disruptions. These hubs can attract investments in low-emission transportation, even if the economies lack the natural resources needed for EVs. By investing in battery recycling facilities across APEC economies, the region can also develop a circular economy approach to EV batteries. This will reduce reliance on critical minerals from primary sources, and transform the supply chain by including more economies, such as those with strong battery recycling capacities.

Increased partnerships within the EV supply chain can help reduce tensions and level the playing field for APEC economies. This will also mitigate market risks by distributing investment burdens and stabilising the supply chain. Additionally, the more invested economies are in each other's EV supply chain, the less likely they are to impose trade restrictions. This interdependency can be fostered through encouraging foreign investment in EV manufacturing and battery recycling. For EV manufacturing, offering tax breaks, temporary subsidies, and streamlined regulatory processes can attract foreign direct investment, while facilitating technology transfers through joint ventures can help local firms adopt advanced manufacturing processes. In battery recycling, attracting investment to build state-of-the-art recycling plants and implementing favourable policies to support these facilities can ensure a steady supply of recycled materials and adherence to environmental standards.

Set Standards and Ensure Supply Chain Visibility

Setting clear standards and regulations regarding EV battery production and logistics is essential. Environmental, labour, and ethical standards—in line with international agreements and commitments—will ensure that EV battery inputs, processing, and supply chains are sustainable and inclusive. This approach will also help motivate domestic market standardisation and promote continued regional cooperation and integration in EV battery supply chains.

Figure 7. Summary of Policy Recommendations
Source: Authors.

Setting standards is also essential in developing a circular economy for EV batteries. What can be considered as recyclable material, and therefore moved across borders for processing and resource recovery, needs to be defined and standardised.

Setting standards needs to come with supply chain transparency and visibility. This will provide EV producers and consumers the assurance that their batteries adhere to proper standards of sustainability, labour practice, and ethics.

Digitalisation will be a key ingredient for supply chain transparency and visibility.[37] Transparent disclosure of EV supply chain data, from mineral processing and pricing to recycled batteries, will help support trade and sustainability goals. This information can support policy cooperation and harmonisation, especially in emerging areas like battery recycling. Transparency will also enable global pricing mechanisms that price in the costs of carbon emissions, pollution, and other externalities.

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