DRIVING GROWTH IN SOUTH CAROLINA'S BATTERY AND EV SUPPLY CHAIN

C2ES CENTER FOR CLIMATE AND ENERGY SOLUTIONS

by

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With a strong foundation of legacy automotive companies, a skilled workforce experienced in advanced manufacturing, and a network of world class research and technical educational institutions, South Carolina is a natural location for both new and existing companies to expand and establish electric vehicle (EV) and battery operations. In the last decade, the state has seen historic levels of investment across the EV and battery manufacturing subsectors, due in part to South Carolina's strong advantages. The state's central position along the growing "battery belt"—which runs from Michigan to the Southeast—of battery and EV manufacturing projects positions it well logistically and strategically for further investment. Through this growth sector, the state has an opportunity to continue leading as a producer of vehicles while capitalizing on opportunities across the battery supply chain—from battery recycling and material production to cell manufacturing and final assembly. This brief provides insights from a roundtable hosted in Columbia, South Carolina, in November 2024 that explored how South Carolina can build on its strong manufacturing base through the opportunities offered by the battery and EV supply chain.

INTRODUCTION

REGIONAL ROUNDTABLES

The United States and the world are transitioning to a low-carbon economy. Communities across the country have an opportunity to leverage their existing advantages to lead the transition while supporting good-paying jobs, attracting investment, and improving the local quality of life. While the low-carbon economy offers new opportunities for many communities, capitalizing on them will require proactively developing new strategies to attract investment.

As the private sector leans in, enabling federal and state policies have proven crucial to supporting community efforts to attract investment and grow a secure and resilient, domestic advanced energy manufacturing base. Community stakeholders are often the best-positioned experts to identify the opportunities they want to pursue, the challenges they will need to navigate, and which supports are most impactful. Local perspectives can offer unique and invaluable nuance and grounding to federal climate policy conversations.

The Center for Climate and Energy Solutions' (C2ES) regional roundtable program elevates the perspectives of community stakeholders to inform state and federal policy debates and identify concrete next steps to bring home the economic opportunity of investing in the low-carbon transition. Through interactive group discussions, educational programming, and informative sessions—supplemented with research and analysis—C2ES's regional roundtable program brings together leaders of business, government, and communities to explore these opportunities and develop collaborative policy solutions.

Our November 2024 roundtable held in Columbia, South Carolina, brought over 40 participants together. They represented companies, industry groups, state and local government, economic development professionals, nonprofits, academic experts, and others for a discussion touching on how to strengthen crucial components of the electric vehicle and battery supply chain to ensure the long-term vitality of the industry in the state. Discussion topics included: (1) strategies to increase investment security in crucial inputs into the battery supply chain; (2) planning considerations to create a circular economy for battery materials in the state; and (3) workforce preparedness support for the coming growth in advanced energy manufacturing.

FRAMING THE DISCUSSION IN SOUTH CAROLINA

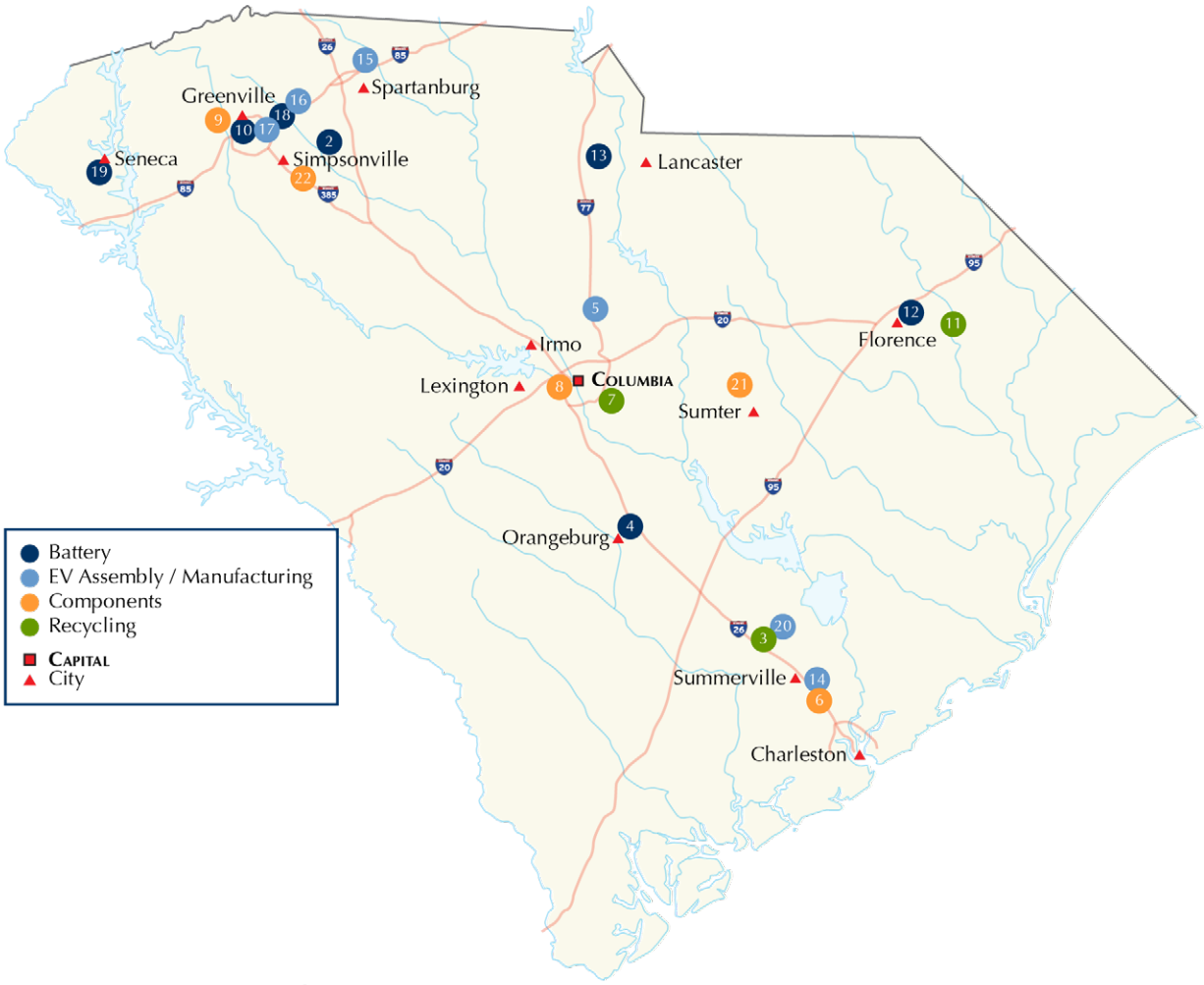
South Carolina is already a national leader in automotive production. Since the mid-1990s, when BMW opened its factory in Upstate South Carolina, Plant Spartanburg, the industry's impact on the state has grown steadily. From 2014 to 2022, South Carolina was the nation's leader in exporting completed passenger vehicles, with more than $10.1 billion in total sales.[1] Legacy automakers are the primary drivers of the state's leading export numbers. BMW's Plant Spartanburg is the company's largest plant in the world, employing 11,000 South Carolinians.[2] In 2006, Mercedes-Benz began producing Sprinter vans in Charleston, now employing 1,700 workers.[3] In 2017, Volvo began production at their factory in the Lowcountry, which currently employs 1,500 workers.[4]

Institutional knowledge among the industry, policy makers, workers, and community members stemming from this legacy serves as a major draw for companies to locate new aspects of the rapidly growing electric mobility supply chain in South Carolina. In 2023, EVs made up 18 percent of the global automotive market, a nine-fold increase from their market share of 2 percent in 2018. [5] To meet growing global demand, manufacturers in the United States have begun ramping up electric vehicle manufacturing, both for U.S. consumption and for export to foreign markets. From January 2015 through November 2024, South Carolina has seen $14.5 billion in announced investments in EVs, EV batteries, battery components, and battery recycling, with an estimated 14,100 announced jobs stemming from these investments.[6]

This rapid growth in investment for the final assembly of battery electric vehicles has catalyzed further investment across the entire battery supply chain, from battery pack assembly and cell manufacturing to the production of battery materials like rare-earth magnets, graphite, and lithium. To meet the growing demand, battery recyclers have planned operations across the state to extract critical minerals from spent lithium-ion batteries and remanufacture them into the critical materials used to produce batteries. The increase of and expertise in battery production and associated materials creates a synergistic opportunity for the state to expand battery manufacturing for other applications, such as stationary energy storage.

Figure 1 shows the state has developed a robust network of manufacturing for the battery and electric vehicle supply chains. To support the long-term economic development of South Carolina, state and federal policymakers will need to take steps to support growth sectors like EVs and the batteries that power them.

FIGURE 1: South Carolina's EV and Battery Supply Chain



Plant Name	Investment Amount	Jobs Created
1 ABTC South Carolina Recycling Plant*	$150,000,000	300
2 BMW Battery Assembly Center	$700,000,000	300
3 Redwood Materials Battery Materials Campus	$3,500,000,000	1500
4 Birla (SKI) Graphite Plant	$1,000,000,000	150
5 Scout Motors Blythewood Facility	$2,000,000,000	4000
6 Bosch Charleston Facility	$260,000,000	350
7 Cirba Columbia Battery Recycling Facility	$323,000,000	300
8 ABB Columbia EV Charging Manufacturing Facility	$4,000,000	100
9 ElringKlinger Pickens Manufacturing Facility	$40,300,000	115
10 EnerSys South Carolina Facility	$500,000,000	500
11 Clarios Florence Battery Recycling Center	$150,000,000	375
12 AESC Florence Gigafactory	$3,120,000,000	2,700
13 Albemarle Mega-Flex Processing Facility	$1,300,000,000	300
14 Mercedes-Benz North Charleston Facility	$58,585,000	0
15 Oshkosh Spartanburg Assembly Plant	$155,000,000	1000
16 BMW Plant Spartanburg	$1,000,000,000	344
17 Phoenix Motorcars Proterra Greenville Assembly Facility	$0	290
18 Volvo Trucks Proterra Powered 1 Facility	$76,000,000	200
19 BorgWarner Seneca Battery Plant	$42,000,000	122
20 Volvo Cars South Carolina Car Factory	$600,000,000	1,000
21 e-VAC Magnetics Sumter County Manufacturing Plant	$506,000,000	300
22 ZF Gray Court	$500,000,000	400

Announced EV and battery projects in South Carolina projects co-located with interstate highways and cities in the state.

* No site announcement at time of publication.

Multiple Sources; map and graph data availale upon request.

THE EV INDUSTRY JUMPSTARTS BATTERY SUPPLY CHAIN DEVELOPMENT

All three legacy automakers located in South Carolina have expanded their operations to position themselves in the electric mobility space. In 2022, BMW invested $1 billion into its Upstate facility with plans to produce seven fully electric models by 2030.[7] Volvo invested $118 million to add a new assembly line for its battery electric affiliate Polestar Cars, commencing production of their fully electric SUV in 2024.[8] Additionally, Mercedes Benz Vans invested $59 million to build its eSprinter van at its North Charleston plant.[9] The development of final assembly for electric vehicles in South Carolina has driven a chain reaction of growth across the entire battery and automotive supply chain.

In addition to the investments made into expanding operations at existing facilities to produce EVs for a growing market, new producers have also chosen the state as their home, aiming to take advantage of South Carolina's competitive advantages in the industry. In 2024, Scout Motors broke ground on its $2 billion production center for fully electric trucks and SUVs.[10] In 2021, Oshkosh Defense invested $155 million for a manufacturing facility in Spartanburg to produce battery electric vehicles for the U.S. Postal Service's delivery fleet.[11]

Companies are also allocating capital to support the buildout of battery cell manufacturing and pack production in South Carlina to supply the growth in final assembly of EVs. BMW invested $700 million for the construction of high-voltage battery assembly facility near its Greer manufacturing plant.[12] Envision AESC announced a multi-year partnership with BMW to provide battery cells for its new electric vehicles, with BMW investing $3.12 billion in Envision's Florence manufacturing facility.[13] In 2023, BorgWarner expanded its Seneca facility with a $42 million investment to develop new manufacturing lines for the production of additional battery modules and packs for its EV customers.[14]

The investments in the state continue further up the supply chain, including more than $500 million for the production of rare-earth magnets, and $1 billion for graphite production.[15] Battery recycling companies have also found a home in South Carolina, due in part to the state's strategic location near major battery producers and along key transportation routes, such as interstate highways that span the Southeast's "battery belt," and deepwater ports in Charleston that allow for international trade.[16] In 2024, Redwood Materials broke ground near Charleston on their second U.S. facility, which produces battery materials from recycled lithium ion batteries.[17] Cirba Solutions is also planning a battery recycling facility outside of Columbia to produce battery-grade metal salts, the precursor to battery materials.[18]

SOUTH CAROLINA AS A HUB FOR BATTERY STORAGE INNOVATION

The state's growing specialization in battery technology, aided by the demand pull from domestic manufacturing of electric vehicles, has generated significant public and private investment in batteries for energy storage. In 2022, Kontrolmatik Technologies announced a $279 million investment to build a manufacturing facility for battery cells and modules for the grid-scale energy storage market.[19] And in 2024, EnerSys announced a $500 million investment in a lithium-ion gigafactory to produce battery cells in Greenville.[20]

In 2023, the U.S. Department of Commerce's Economic Development Administration designated South Carolina Department of Commerce to lead the SC Nexus program, a regional technology hub to commercialize energy storage materials and manufacturing in Midland and Upstate South Carolina and parts of Georgia.[21] This program will serve as a consortium of industry representatives, venture investors, economic development organizations, workforce training and education institutions, and state agencies, which will work to secure clean energy supply chains and develop, test, and commercialize grid resilient energy storage technologies.[22]

The development of a grid resilient tech hub across South Carolina and into Georgia will help create synergies across the entire battery supply chain, with growth opportunities and benefits for the automotive industry and subsectors from battery manufacturing to critical mineral refining.

BOX 1: Outcomes from the Discussion

KEY TAKEAWAYS

Participants generally agreed that government funding for new technological research, development, demonstration, and deployment is critical for the global competitiveness of the state's industries. However, technologies that are researched and developed in the United States, like lithium-ion batteries and EVs, are now being commercialized and manufactured in foreign countries at much higher rates than they are domestically.* ***Government support spanning the entire innovation cycle*, from research through early commercial deployment, is crucial to ensuring the United States captures the economic benefits of technologies developed at home.**

Elections inevitably bring changes to markets, including the battery and EV industries. It is important for policymakers to act measuredly and to consider the economic importance of various existing incentive structures and policies. South Carolina, and other states with an automotive manufacturing legacy, have seen record announced investments to revolutionize and revitalize a quintessentially American industry. Unpredictable swings in policy support create an uncertain business environment that hinders companies' ability to make investments and may even lead to the cancellation or offshoring of announced projects. **A *supportive policy foundation* is an important ingredient to maintaining investment in a still nascent industry.**

Without support to stabilize prices and increase demand for domestically produced materials, foreign actors with strongholds on the critical mineral and material markets will continue to dominate the industry, crowding out new emerging actors and creating risks to battery and EV supply chain. **American companies and policymakers should consider *strategies to stabilize critical mineral and material pricing* and promote domestic demand growth for recycled metals to increase U.S. competitiveness in the battery material market.**

A key pathway to increase the volume of domestically produced battery materials and reduce the environmental impact of sourcing raw materials is through battery recycling. **Increasing the reuse of critical minerals requires *better recycling practices and support*, including standardizing collection mechanisms and consumer education, designing batteries for recyclability, and creating incentive structures for recycled materials.**

The rapid announcement of new manufacturing facilities across the state has raised the importance of improving and formalizing engagement with communities hosting projects. Often, to avoid complications—such as speculators driving up the price of real estate on and surrounding a site—projects are kept under wraps before a formal agreement is met. Unfortunately, this limits the ability of companies to understand and address host community needs for new facilities. **Finding ways to *engage with communities earlier in the process* will help mitigate downstream impacts of new projects, ensure proper benefits flow to host communities, and limit delays in project development.**

As South Carolina continues to develop new energy industries, the availability and skill set of workers will need to evolve so they can design, manufacture, recycle, and maintain electric vehicles and batteries. ***Utilizing and expanding the state's existing training programs* and technical college system will be crucial to increasing the workforce as employment opportunities expand into emerging industries.**

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* *IEA, Global EV Outlook 2024, April 2024, https://www.iea.org/reports/global-ev-outlook-2024/trends-in-electric-cars.*

BOX 1: Outcomes from the Discussion (cont.)

POLICY RECOMMENDATIONS

Driving Private Sector Investment and Domestic Manufacturing

Recommendation: To ensure business confidence in announced investments and the long term stability necessary to grow American manufacturing in the battery and EV industries, Congress should maintain clean energy and clean vehicle tax credits, specifically 45X, 30D, and 45W.

→ See "Federal Policy Driving Private Sector Investment and Domestic Manufacturing" on page 7.

Increasing Investment Certainty in the Critical Mineral and Material Market

Recommendation: To derisk new critical mineral projects, Congress should appropriate funds for the Department of Energy to investigate which mechanisms best support private offtake agreements for new projects. The mechanisms should be determined in consultation with industry stakeholders and include options such as contracts-for-difference, and offtake backstops.

→ See "Increasing Investment Certainty in the Critical Mineral and Material Market" on page 9.

Creating Circularity in the Battery Industry

Recommendation: To increase the ability of dismantlers and recyclers to safely remove, handle, and recycle batteries, Congress should direct and appropriate funds for EPA to convene a coalition of industry stakeholders to develop a roadmap for best practices on battery design for efficient removal from a vehicle by dismantlers and recovery of battery materials by recyclers.

→ See "Creating Circularity in the Battery Industry" on page 13.

Improving Community Engagement in Project Development

Recommendation: To help companies and communities engage earlier and more comprehensively in the leadup to large project development, the South Carolina Department of Commerce's Coordinating Council for Economic Development should provide a statewide fund to establish a community benefits agreement council that can be included in the negotiation process with companies looking to site projects in South Carolina.

→ See "Improving Community Engagement in Project Development" on page 16.

Developing the Workforce for South Carolina's Advanced Energy Future

Recommendation: To increase the enrolment of students into technical college programs in fields of need as identified by supply gap analysis conducted by the state's Department of Employment and Workforce, the South Carolina Legislature should appropriate funds to expand the SC WINS scholarship program to cover the full cost of tuition for positions of high need.

Recommendation: To ensure that recent graduates have immediately applicable and transferable skills in high demand employment contexts, the SC technical college system should foster partnerships between individual local colleges and nearby companies to develop curriculums that will train workers for available jobs and incorporate statewide skill needs analysis into their curriculum.

→ See "Developing the Workforce for South Carolina's Advanced Energy Future" on page 17.

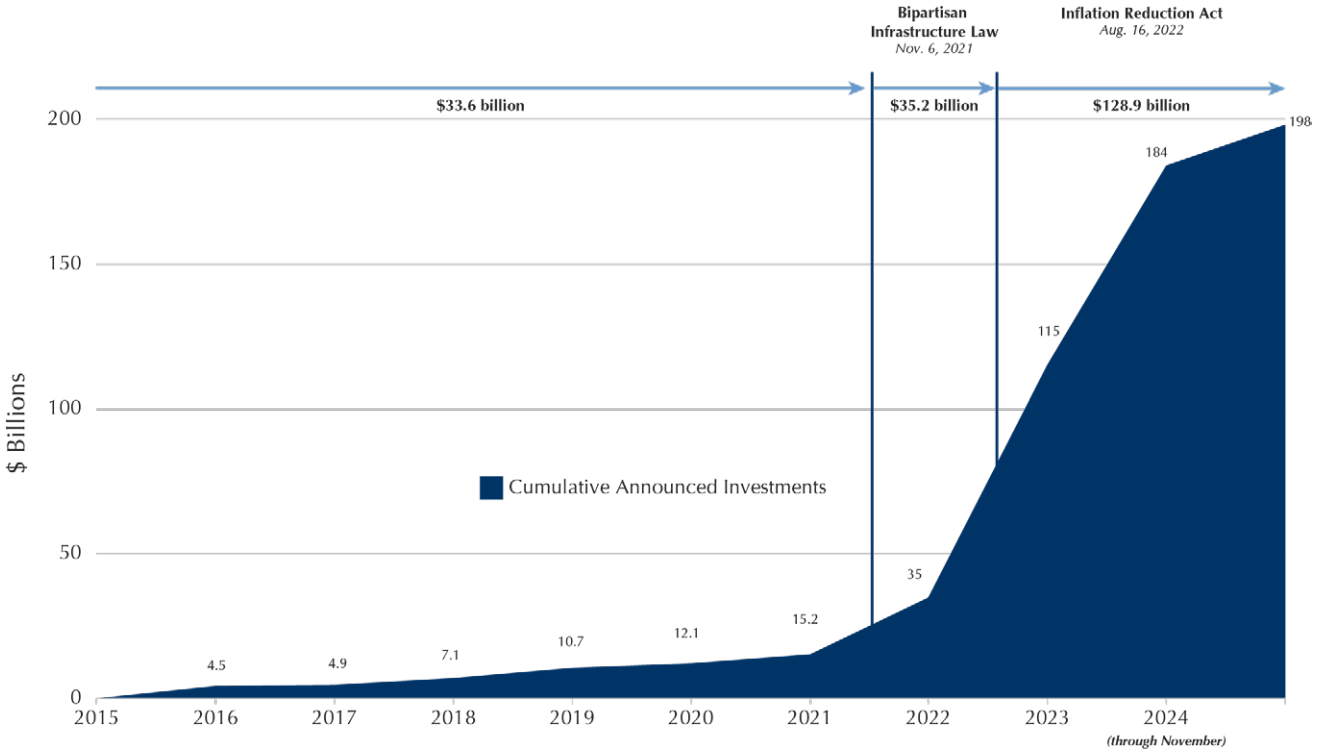
FEDERAL POLICY DRIVING PRIVATE SECTOR INVESTMENT AND DOMESTIC MANUFACTURING

Currently, the automotive sector plays a large role in the U.S. economy, driving $1.2 trillion in annual economic value, equal to 4.8 percent of total gross domestic product.[23] The U.S. electric vehicle and battery industry has seen a burst of growth over the last decade. An unprecedented level of investment has been accelerating across the supply chain since 2021, including final assembly, EV components, batteries, and battery materials manufacturing and recycling. As EVs continue to grow their share of the global vehicle market, it is critical to the long-term health of the U.S. economy to ensure the competitiveness of American based companies in the sector. To do so, policymakers will need to act strategically to help the nascent U.S. industry regain its footing as foreign competitors attempt to monopolize global supply chains crucial to the future of battery and automotive manufacturing.

The record development in this advanced industry that holds critical importance to U.S. energy security and global technological competitiveness coincides with the passage of the Infrastructure Investment and Jobs Act (IIJA, also known as the Bipartisan Infrastructure Law) in November 2021 and the Inflation Reduction Act (IRA) in August 2022. In the past ten years, U.S. automakers have announced $198 billion in EV and battery investments; an overwhelming proportion of these investments were announced after passage of the IIJA and IRA. Sixty-five percent of the investments have occurred since the passage of the IRA in 2022, and 83 percent have occurred since the passage of the IIJA (see Figure 2).[24]

Recent efforts to reverse the policies designed to onshore domestic energy production and manufacturing have generated significant uncertainty in an industry that relies on certainty to make long-term investment decisions. In South Carolina from Q3 2022 through Q4 2024, $19 billion has been announced in investments for new facilities for manufacturing, utility-scale energy, and other industrial processes.[25] However, $12.97 billion (68 percent) remains unspent as facilities wait to move forward with their commitments.

FIGURE 2: Private Sector Investment in EV & Battery Manufacturing Since Landmark Policy Change



Source: Environmental Defense Fund, U.S. Electric Vehicle Manufacturing Investments and Jobs, January 2025, https://library.edf.org/AssetLink/j1n8dp-1041c0g2m68lf0m5qp7p1e2i45.pdf.

The growth following the passage of the IIJA and IRA demonstrates the impact of the specific policy incentives included in these laws. A key provision of the IRA crucial to the the battery material manufacturing space is the advanced manufacturing tax credit (section 45X). This credit offers a tax incentive for the domestic production of battery components and the refining or recycling of critical minerals.[26] Battery cells are eligible for a credit equal to $35 multiplied by the maximum kilowatt-hour (kWh) capacity of the cell. Notably, the credits for critical minerals and electrode active materials do not expire and are equal to 10 percent of their production costs, which include extracting, acquiring, processing, converting, refining, or purifying source materials.[27]

This price support for these domestically refined critical minerals and battery materials is crucial to help build out American manufacturing for battery materials by helping bridge the price premium for producing in the United States relative to more mature markets with lower production costs, like China and Southeast Asia. Currently China has a significant cost advantage over the United States in producing the most common battery cell chemistry (e.g., nickel, cobalt, manganese) at a cost of $95.81 per kWh versus the U.S. production cost of $98.06 per kWh before accounting for tax incentives.[28] If the tax credits remain in place over the coming decade it is forecast that the average cost of cell production in the United States could fall to $76.8 per kWh, helping American producers compete in the global market.[29]

Encouraging demand for domestically produced battery materials and cells is the other crucial component to bolstering cost-competitiveness, necessary to achieve the potential manufacturing build-out needed to ensure the U.S. automotive sector thrives in the decades to come. To boost demand for new clean vehicles, tax incentives included the new clean vehicle credit (30D) and commercial clean vehicle credit (45W), which provides a credit for qualified buyers of up to $7,500 for plug-in EVs and $40,000 for commercial clean vehicles, respectively.[30] There are some criteria vehicle must meet to be eligible for the credit. First, vehicles must undergo final assembly in North America. Additionally, a percentage of the critical minerals that comprise the vehicle's battery—from 60 percent in 2025, to 80 percent from 2027 until the credit expires in 2032—must be sourced from North America or from countries with which the United States has a free trade agreement.[31] These domestic content requirements help support the economic viability of localized supply chains for electric vehicles and batteries. Localized supply chains help protect manufacturers from disruption and can significantly reduce transportation costs. In the United States, stronger environmental standards also provide the basis of competitive advantage for companies looking to ensure responsible sourcing for their products.

In addition to the tax credits, grant funding provided catalytic capital to grow the entire EV and battery industry. For example, nearly $850 million in grants were announced in 2024 alone to retrofit, expand, and build new facilities in South Carolina for critical minerals, battery components, battery assembly, and recycling.[32] These grants, authorized under the IIJA, have a 50 percent cost sharing requirement, requiring a 1:1 funding match from additional private investment or other non-federal sources.[33]

The federal incentives of the IIJA and IRA have sparked the development of an entire ecosystem of battery material and cell manufacturers, component assemblers, and electric vehicle producers across South Carolina as well as the entire southeast. Maintaining the policies these laws created provides the certainty that businesses need to make informed investment decisions that will bring thousands of new jobs to the state and help bolster an industry critical to America's long-term economic interests.

Recommendation

To ensure business confidence in announced investments and the long term stability necessary to grow American manufacturing in the battery and EV industries, Congress should maintain clean energy and clean vehicle tax credits, specifically 45X, 30D, and 45W.

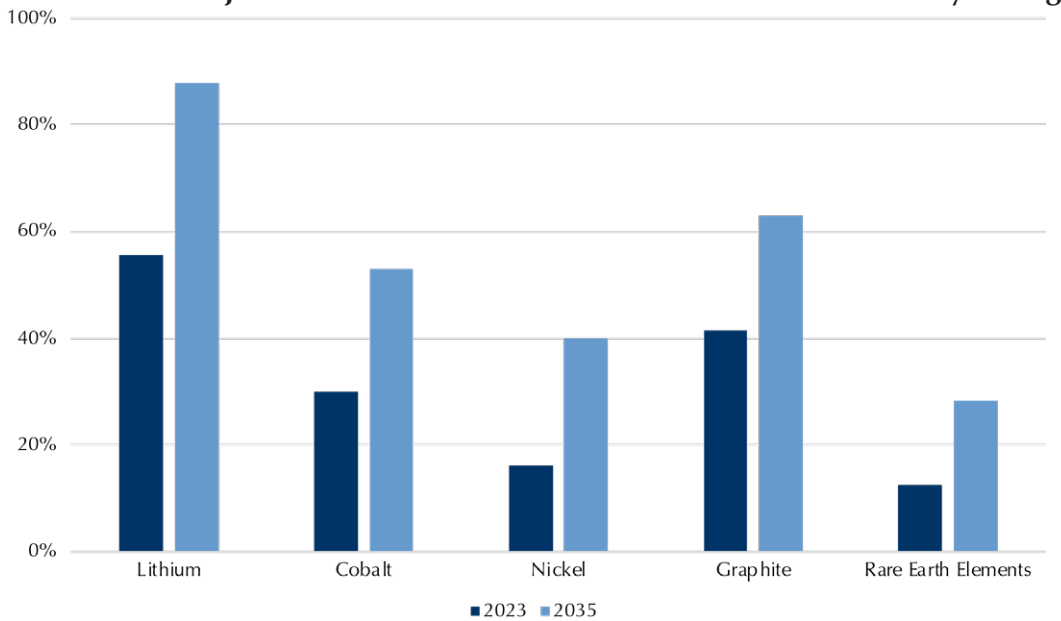
INCREASING INVESTMENT CERTAINTY IN THE CRITICAL MINERAL AND MATERIAL MARKET

DEMAND PULL OF VEHICLE ELECTRIFICATION AND BATTERY STORAGE

The shift toward electrified transportation has created a demand pull for lithium-ion batteries. For thirty years, battery sales have been growing at an average annual rate of 33 percent—doubling every two to three years. As electric vehicle sales have taken off over the last decade, battery demand growth has climbed closer to 40 percent annually.[34] This demand is driving technological improvements in battery technology, which spills over into improvements for other industries like energy storage. The demand for finished batteries from electrified transportation and energy storage has been reflected in rapid growth in the industry over the past decades. This level of growth required the establishment of supply chains interconnecting the raw materials, intermediate inputs, and final assembly that comprise modern lithium-ion batteries. As seen in Figure 3, a significant amount of the demand for the raw materials and intermediate battery components is driven by electric vehicles and grid-battery storage.

With the projected demand growth and global competition for raw, processed, and active battery materials and components, American EV and energy storage battery producers face challenges in sourcing these materials domestically and from friendly nations without concerted efforts to build out new supply chains (See Box 2 and Figure 4 for more information on the battery supply chain). A significant amount of the global mining and refining of these materials is concentrated in a few countries, which impacts the security of supply chains. In particular, China controls 65 percent or more of the global supply of processed lithium, cobalt, and graphite—the key ingredients of lithium-ion batteries. China controls 82 percent of graphite mining and 91 percent of processing, 17 percent of lithium mining and 65 percent of refining, as well as 77 and 28 percent of cobalt and nickel processing, respectively.[35] Figure 5 demonstrates the share of mining and processing of critical mineral in the United States, China, and other countries in 2023.

FIGURE 3: Actual and Projected Critical Mineral Demand from EVs and Battery Storage



The EV and battery storage sectors accounted for 55.7 percent of global lithium demand in 2023 and are projected grow to 87.9 percent in 2035. For cobalt, EVs and battery storage accounted for 29.9 percent of demand in 2023 with a projection of 52.9 percent in 2035; 16.1 percent of nickel demand in 2023 and 39.9 percent in 2035; and 41.5 percent of graphite demand in 2023 and 62.9 percent in 2035.

Source: IEA, Critical Minerals Data Explorer, May 17, 2024, https://www.iea.org/data-and-statistics/data-tools/critical-minerals-data-explorer.

GEOPOLITICAL AND ECONOMIC RISKS OF CONCENTRATED FOREIGN SUPPLY CHAINS

The market concentration of battery materials in regions far from North America creates risks for U.S. battery supply chains that may arise from shifting geopolitics and global crises. Furthermore, the offshoring of much of this supply chain has led the United States to miss out on realizing the total economic value from the industry.

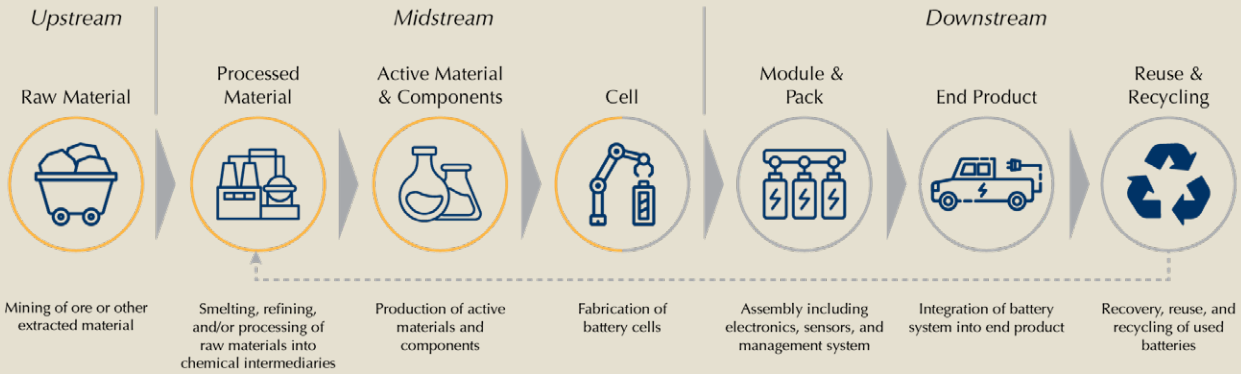
For example, in December 2024, in response to U.S. export controls on semi-conductor manufacturing equipment, China announced restrictions on exports of critical minerals used for applications ranging from batteries to defense technologies, including increased export controls on graphite.[36] A report prepared for the Department of Energy's Li-Bridge Initiative estimates that in 2023 the U.S. economy captured less than 30 percent of the value of each battery cell sold on the U.S. market, which equates to leaving $3 billion in value added and 16,000 jobs unrealized by the industry.[37] This number is estimated to rise to $16 billion in economic value and 60,000 jobs left uncaptured by 2030 given industry growth projections. By comparison, Chinese-based companies captured 90 percent of the economic value for each lithium-ion battery consumed in-country. If more of the battery supply chain can be built in the United States, then more value can be retained domestically.

Most of this unrealized economic potential is lost in the outsourcing of upstream and midstream extraction and manufacturing for battery materials. There are several interrelated challenges to the development of the midstream segment of the battery supply chain (e.g., minerals processing, battery material production, and cell fabrication) in North America. The first is the "opaque" nature of critical mineral markets, which is due to the small number of actors buying and selling in the market and the prevalence of private one-off deals.[38] The opacity of a market refers to the difficulty in determining the accurate market value of critical mineral commodities. This concentrated market structure often exacer-

BOX 2: Battery Material Supply Chain

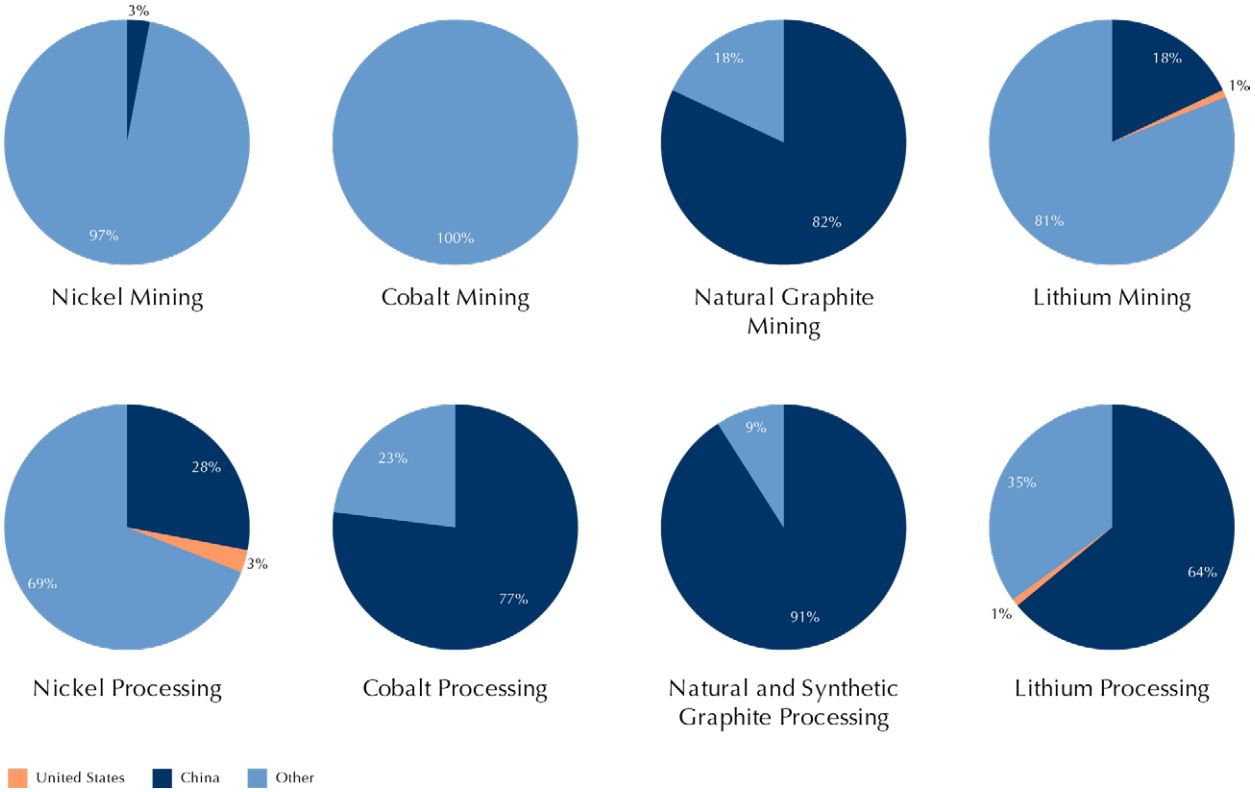
The lithium-ion battery supply chain begins with the extraction of raw materials in the form of ore or brine that contains lithium, graphite, nickel, cobalt, or rare earth elements. The raw material is then refined into chemical intermediates that can be manufactured into active materials that make up the different components of a battery. These intermediate battery materials include the cathode, anode, separator, and electrolyte, which are then used to fabricate battery cells. Battery cells are then assembled into battery packs for their end use as either stationary energy storage or to power electric vehicles. At the end of their useful life, these batteries can be recycled, and the component materials can reenter the midstream supply chain to be reprocessed into active battery materials. The entire supply chain is visualized in Figure 5, which also highlights (in yellow) significant gaps in the U.S. supply chain.

FIGURE 4: The Battery Supply Chain



Source: Aakash Arora, et al., Building a Robust and Resilient U.S. Lithium Battery Supply Chain, (Li-Bridge, 2023), https://netl.doe.gov/sites/default/files/2023-03/Li-Bridge%20-%20Building%20a%20Robust%20and%20Resilient%20U.S.%20Lithium%20Battery%20Supply%20Chain.pdf.

FIGURE 5: Critical Mineral Mining and Processing by Country



Source: Alice Wu, Critical Thinking on Critical Minerals, (Washington, DC: Federation of American Scientists, 2024), https://fas.org/publication/critical-thinking-on-critical-minerals/.

bates price volatility for battery-grade materials, due to the ability of individual transactions to have outsized impact on supply and demand. These challenges—the opaque nature of the market and rapid price swings for critical minerals—create large financial risks for investors in new projects, hampering the development of markets outside of their concentration in Asia. The few producers of battery grade materials in the United States are further disadvantaged by the lack of domestic off-takers. The supply chain concentration in East and Southeast Asia creates significant logistical challenges and further drives up costs.

Opacity in the critical mineral market may be partially attributed to the concentration of producers and refiners among a few industry actors. This concentration makes it difficult to accurately determine prices, which are used to negotiate offtake agreements by new market participants. At the same time, dominant producers and refiners may be able to leverage their market positions to flood the market with materials below fair, domestic market price in a practice known as dumping, allowing them to maintain and grow their market dominance. The U.S. Department of Commerce's recently initiated anti-dumping investigation into imports of active anode material from China illustrates this market challenge for American producers. The preliminarily findings estimate the dumping margin for some Chinese firms exporting active anode material to the United States reached up to 915.74 percent.[39]

These market challenges are reflected in the recent drops in critical mineral prices from their highs in 2022 to their lows in mid 2024. An oversupply of materials at the same time as EV sales slowed compared to forecasts caused a crash in critical mineral markets, with widespread impacts on unestablished producers. Over this time period, lithium carbonate prices fell by 84 percent, cobalt prices fell by 64 percent, and nickel prices fell by 67 percent.[40] This volatility had real consequences for the economic viability of planned projects, including those set to commence construction in South Carolina. Plans by Albemarle, one of the world's largest lithium producers, to build a $1.3 billion lithium refining facility in

Chester County that would have brough 300 jobs to the areas were paused, citing the decline in lithium prices.[41] The company's CEO claimed that prices would need to stabilize for the project to resume. The immediate challenges in nascent markets due to short-term demand fluctuations do not change the long-term trends in EV adoption. New projects like these are crucial to the development of a North American market to provide a stable supply of critical materials for a strategically important growth industry.

The crashing prices in critical mineral markets represent a classic chicken-or-egg scenario prevalent in nascent energy technologies. Stabilizing prices and ensuring more transparent markets requires new producers to come online in more geographically diverse regions, including North America. However, bringing new production capacity online requires stable and transparent prices.

Typically, U.S. government support and loan programs are conditional on a project's ability to secure long-term offtake deals. Securing these deals is a major challenge in a volatile market manipulated by heavily subsidized actors. This challenge calls for solutions that support longer-term price stability and include approaches that have traditionally been outside the realm of U.S. policy support for energy and infrastructure projects.

POLICY INTERVENTIONS TO SUPPORT PRICE STABILITY

Two recent reports developed by the Federation of American Scientists and the Bipartisan Policy Center outline several demand-side financial mechanisms that can be used in both the short and long term to strengthen the U.S. critical mineral market. The Federation of American Scientists recommends the Department of Energy (DOE) implement market-making mechanisms that include offtake backstops, such as pay-for differences and contracts for difference.[42] At the same time, the Bipartisan Policy Center report recommends establishing a wholly owned government entity to use a suite of demand-side tools to flexibly support an adaptive portfolio of strategically important minerals and metals projects for American energy and national security.[43]

An example of a pay-for-difference offtake backstop comes from the U.S. Department of Agriculture's Agricultural Risk Coverage and Price Loss Coverage Program. This program provides income support payments for farms when crop profit level drops below a specified guaranteed price.[44] Similarly, DOE could provide demand-side support for new critical mineral projects by setting a price floor and paying producers the difference between the floor and the spot price. This approach would allow companies to have the financial security necessary to begin production while also more easily engaging in flexible contracts with off-takers while they receive assurance they will meet financial obligations.

Another example comes from the United Kingdom's contracts-for-difference approach that serves as the main mechanism for the government to help the build out of large-scale advanced energy infrastructure.[45] The program helps reduce the risk of fluctuating wholesale power prices and ensures that investors will receive a price for electricity that supports their investment decision. In the context of critical mineral auctions, an entity such as the Department of Energy's Office of Manufacturing and Energy Supply Chains (MESC) could provide offtake backstops for the portion of battery materials a refiner puts up for auction and cover the difference between the purchased price and the set price floor. This means that a refiner can provide battery materials to the open market with the certainty that it will get purchased at an economically viable price, while facilitating the development of new markets for off-takers and creating a transparent North American market price for battery-grade materials.

Finding the right-sized demand support approach is crucial to help get projects built and profitably producing materials. Implementing methods to provide demand side support will help grow the industry and eventually reach the level of trading volume needed to create more transparent pricing. In the long term, a wholly-owned government corporation would be able to house many demand side market making tools to nimbly support growth of the industry. A more direct and immediate home for certain demand side support mechanisms could sit within the Department of Energy that has the precedented ability to support the demonstration and deployment of clean energy projects.

Recommendation

To derisk new critical mineral projects, Congress should appropriate funds for the Department of Energy to investigate which mechanisms best support private offtake agreements for new projects. The mechanisms should be determined in consultation with industry stakeholders and include options such as contracts-for-difference, and offtake backstops.

CREATING CIRCULARITY IN THE BATTERY INDUSTRY

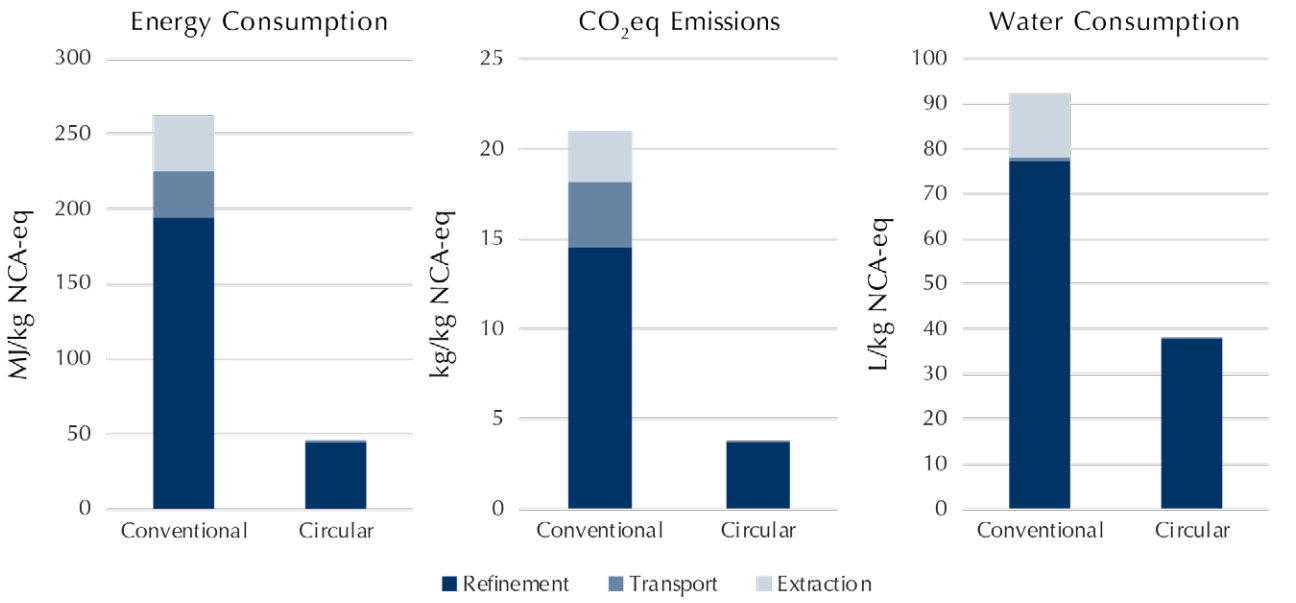
South Carolina is quickly becoming a hub for the recycling and remanufacturing of lithium-ion batteries. With at least five new facilities either announced, beginning construction, or being reconverted to recycle lithium-ion batteries since late 2022, the state is set to benefit from the creation of a circular economy—a model in which resources are repurposed or reprocessed for continued production—for batteries and battery materials. These facilities are the result of investments from Redwood Materials in Ridgeville, Cirba Solutions in Columbia, Clarios Circular Solutions in Florence, Princeton NuEnergy in Chester, and American Battery Technology Company at a site to be announced.[46]

Recycling facilities play a crucial role in the U.S. battery supply chain. These facilities can extract critical materials from spent EV, stationary storage, micromobility, and personal electronics batteries and reintroduce them into the supply chain to be turned into active battery materials once again. Companies break down spent battery packs into several products, each using their own proprietary methods. The primary output is generally known as black mass, which is the conglomeration of critical materials present after a battery has been processed for recycling and shredded. The remaining battery materials are purified and sold to cathode and anode producers, while copper and aluminum are separated and sold as scrap.[47]

Battery recycling helps stabilize supply chains and ensures that the economic value of battery materials remains in this country; it is also crucial to minimizing the environmental impacts of critical mineral extraction. Producing the cathode used in electric vehicles via recycling reduces energy consumption by 82 percent, carbon dioxide emissions by 80.1 percent, and water consumption by 58.7 percent, compared to conventional extraction and production methods of virgin critical mineral materials (see Figure 6).[48]

However, lithium-ion batteries are currently recycled at a much lower rate than other incumbent battery technology. While recycling rates for lithium batteries vary by region and by type of battery, it is generally agreed that they are recycled at lower rates than their embodied value would suggest is economically sensible. For instance, the embodied materials of lithium-ion batteries have an economic value that is 2–10 times higher than lead-acid batteries, depending on the size of the battery. Despite the higher economic value of materials in lithium-ion batteries, between only 2–47 percent of lithium-ion bat-

FIGURE 6: Battery Recycling Reduces Environmental Impact of Supply Chains



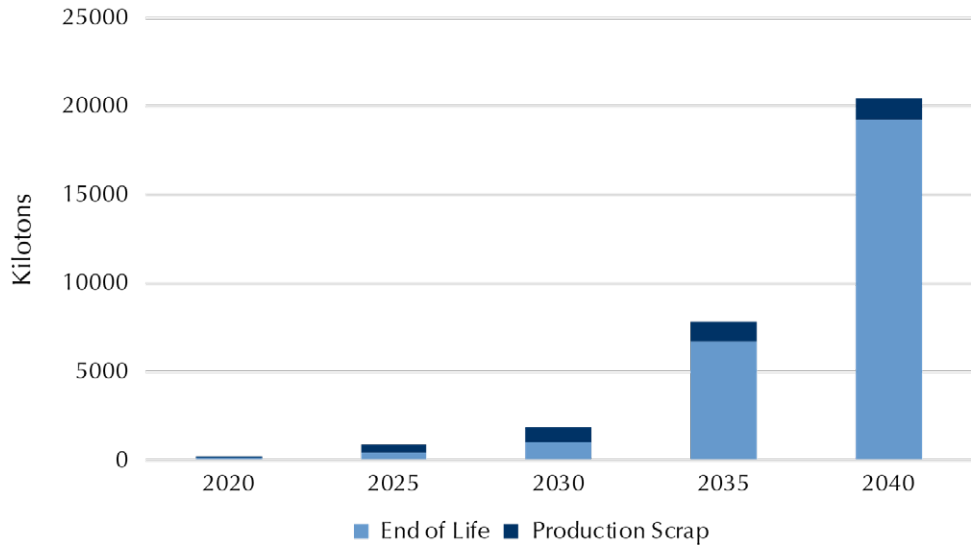
Source: Michael L. Machala, et al., Life cycle comparison of industrial-scale lithium-ion battery recycling and mining supply chains (Stanford, California: Department of Energy Resources Engineering, 2023), https://21672590.fs1.hubspotusercontent-na1.net/hubfs/21672590/Stanford%20University%20Life%20cycle%20comparison%20of%20industrial-scale%20lithium-ion%20battery%20recycling%20and%20mining%20supply%20chains.pdf.

teries are recycled in different markets around the globe, compared to the 99 percent of lead-acid batteries that are recycled in the United States.[49] Lead-acid batteries are more recycled than their lithium-ion counterparts because they are designed for recyclability and their recycling is supported by interconnected infrastructure, including over 14 recycling facilities and 300,000 retail collection sites across the United States.[50] A key question that roundtable participants raised was how to develop a recycling system for lithium-ion batteries to set the industry up for success like what has been achieved in lead-acid battery recycling.*

Given South Carolina's upcoming buildout of battery recycling facilities, the state is planning to convene different members of the battery ecosystem to ensure that batteries find their way to recycling facilities rather than landfills. Participants in the South Carolina roundtable remarked that this task requires collaboration among diverse supply chain stakeholders and innovative solutions to collect, recycle, and reuse materials. Pairing this sector-wide effort to increase the collection and recyclability of batteries with support for the use of recycled materials in new products will help create a circular economy for batteries of all types and the critical minerals within.

Currently, most of the battery content recyclers are processing today comes from consumer electronic batteries and scrap from battery manufacturers. When a new battery manufacturer comes online, scrap can be as high as 30 percent of production volume.[51] In new battery manufacturing markets, as is the case for the United States, it is easier to collect and recycle production scrap than it is to collect and recycle battery materials from end-of-life products. First, the volume of scrap produced by manufacturing batteries is greater than can currently be sourced from EVs at the end of their life, as demonstrated in Figure 7. Additionally, the centralization of this manufacturing scrap creates a single stream to transport a high volume of recoverable materials to the recycler, presumably lowering costs. By contrast, it is estimated that transportation costs account for 41 percent the total cost of recycling end-of-life lithium-ion batteries.[52]A large share of this cost is the price of complying with hazardous waste requirements for shipping lithium-ion batteries. There are only a few collection pathways for spent lithium-ion batteries, and consumers lack the information and education about where to return their batteries. These collection, transportation, and education challenges will limit industry growth if

FIGURE 7: Growth of Recycling Supply From End of Life EV Batteries



Source: Andreas Breiter, et al., "Battery recycling takes the driver's seat," McKinsey & Company, March 13, 2023, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-recycling-takes-the-drivers-seat.

* *For more information on strategies to support the development of a circular economy for critical materials, see: C2ES's past brief on the topic: Stephanie Gagnon, Peter Trousdale, Creating a Circular Economy for Critical Materials in Ohio (Washington, DC: Center for Climate and Energy Solutions, 2024), https://www.c2es.org/document/creating-a-circular-economy-for-critical-materials-in-ohio/.*

they are not addressed before today's EVs reach the end of their useful life.

Many of the EVs currently on the road will continue to remain in use for many years, limiting the amount of end-of-life batteries for recyclers. However, the rapid growth in EV sales at the beginning of this decade indicate an upcoming swell of used electric vehicles and spent batteries that need to be properly accounted for and handled by midcentury. Recycling plays a key role to ensure we maximize the economic value of extracting natural resources for advanced technologies and secure complex supply chains.

STANDARDIZING BATTERY DESIGN FOR END-OF-LIFE DISMANTLING

Once an electric vehicle reaches the end of its useful life and is collected, it needs to be dismantled, which includes the process of removing the batteries that power the vehicle. Battery removal can be a hazardous process due to high voltage and is further exacerbated by the variation of design and integration of batteries into the electric vehicle.[53] Scrap yards and shredders—many of which have not yet handled disposal of an EV—need solutions to these technical and safety challenges.

Typically, EV batteries are deeply integrated into the structure of the vehicle, making them difficult to remove. Furthermore, the designs of battery cells themselves vary among producers. Standardizing battery design could facilitate safe handling of spent EV batteries. However, standardization faces challenges due to two main factors: first, the rapid rise in demand for batteries due to a growing market requires sourcing from a diverse set of producers with varying cell design. Second, producers do not want to share proprietary information about their product design due to competitive concerns. To some degree, cell design is beginning to incidentally standardize across the industry, as cell manufacturers build more standardized factories to reduce the cost of construction and equipment procurement.[54] Still, the removability of batteries from the vehicle remains a challenge due to lack of standardization in removal processes.

The issue of standardization should be addressed by a coalition of battery industry stakeholders who have a material interest in ensuring batteries are easier to remove and recycle. Standardization must be balanced with overly restrictive mandates regulating design standardization, which may stifle innovation in a still nascent and competitive industry. Instead, an industry-led effort with battery manufacturers, auto manufacturers, dismantlers, recyclers, and R&D specialists, among others, should share best practices and work toward design principles that facilitate recycling and recapture of battery materials for remanufacturing.

There is precedent for a stakeholder-led development of best practices for the battery industry supported by the government. As part of the Infrastructure Investment and Jobs Act, Congress allocated money to the Environmental Protection Agency (EPA) to develop battery collection best practices and voluntary battery labeling guidelines.[55] This included a series of virtual feedback sessions, requests for information, and working sessions with industry stakeholders to create industry-led voluntary standards for collection and labeling, A similar program led by EPA to increase the design of EV batteries to increase recyclability would help facilitate best practices to address a critical challenges of ensuring EV batteries are safely and conveniently recycled.

Recommendation

To increase the ability of dismantlers and recyclers to safely remove, handle, and recycle batteries, Congress should direct and appropriate funds for EPA to convene a coalition of industry stakeholders to develop a roadmap for best practices on battery design for efficient removal from a vehicle by dismantlers and recovery of battery materials by recyclers.

IMPROVING COMMUNITY ENGAGEMENT IN PROJECT DEVELOPMENT

Companies and state and local government leaders are working to balance the rapid announcements and siting of new facilities across South Carolina with the responsibility to engage with and maximize the benefit for communities hosting projects. In particular, roundtable participants highlighted the challenge companies face of effectively engaging communities before a project gets started, given the secrecy around negotiating a facility's incentive package, location, and planning process as part of the company's siting decision. These processes are often accompanied by strict non-disclosure agreements that restrict local government officials, economic developers, and corporate representatives from divulging any information about a potential new project.[56] This increasingly commonplace practice restricts the ability of companies and government representatives to engage with communities and incorporate their considerations into the planning and development process.

This process of negotiating, planning, and announcing a project without local input hampers the ability for the leaders of projects to properly incorporate the needs of the host community into their decision making. The downstream challenges that come with new projects can include the energy and water demand from new facilities, increased traffic and infrastructure needs in a host community, providing transportation options for workers, and ensuring adequate housing supply and child-care access to meet the influx of population. There is a clear need for companies and economic developers to include community representatives who are best able to speak to these challenges and potential solutions that will ultimately create more successful projects and reduce delays that could stem from community opposition throughout the project development process.

To secure a robust and growing economy, it is in South Carolina's best economic interest to ensure that projects that have selected the state to establish operations see their project through to completion and provide the promised economic and community benefits that new facilities can provide. To do this, the state should help facilitate the development of municipal-level community benefits advisory councils that are designed to incorporate the needs of a community from the beginning of the planning process.

Community members who are most likely to need advocacy in benefits agreement negotiations often take on this duty without pay in addition to their regular jobs, volunteering time to engage with developers, who by comparison are able to employ their engagement team directly. Having a state-financed committee to integrate community priorities into the planning process helps alleviate this major roadblock to comprehensive and authentic community engagement. By developing a state-financed committee, people who advocate for the community in designing community benefits plans are compensated for their time and work, creating a level playing field and increasing the quality of negotiations between the community and the developers.

There are examples of municipalities outside of South Carolina that have established community benefits advisory councils or committees to help with the implementation of housing, infrastructure, and workforce development improvements alongside new developments. One example comes from the city of Tampa, Florida. Their committee consists of one city staff member and two at-large members, who are selected by the mayor and city council and serve 2-year terms.[57] For a given project, there are also four ad-hoc members that live within a certain proximity of the proposed development who serve until the project is approved or rejected.

In South Carolina's case, the creation of a benefits advisory council that includes statewide at-large members and project- and site-specific ad-hoc members can help to properly address community challenges for new developments earlier in the process. It will also formalize direct representation from the host community, facilitating authentic engagement. To ensure the effectiveness of this community benefits agreement council, members need to be paid for their time and included earlier in project negations. This direct engagement will help lead to better outcomes for communities and increased investment certainty for new facilities.

Recommendation

To help companies and communities engage earlier and more comprehensively in the leadup to large project development, the South Carolina Department of Commerce's Coordinating Council for Economic Development should provide a statewide fund to establish a community benefits agreement council that can be included in the negotiation process with companies looking to site projects in South Carolina.

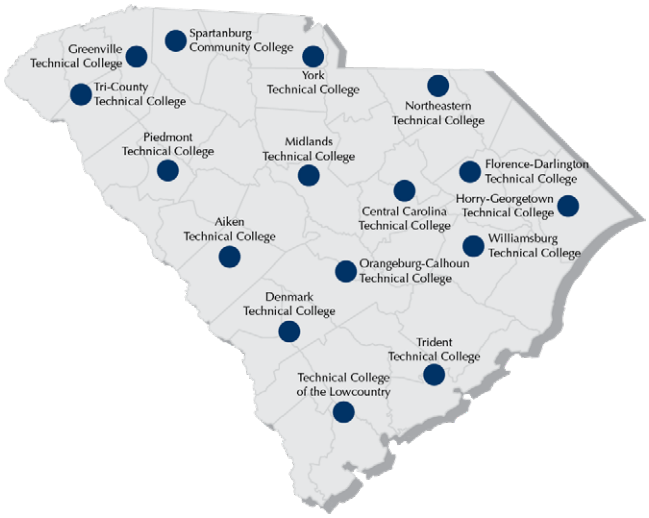
DEVELOPING THE WORKFORCE FOR SOUTH CAROLINA'S ADVANCED ENERGY FUTURE

The rise of new battery and electric vehicle industries in the state is driving demand for workers with skills in high voltage manufacturing and maintenance. These newly emerging skilled jobs required specialized training in addition to traditional trade and technical education. Filling these positions will be difficult in the short term given a lager trend of a national shortage of workers with vocational skills.[58] Many roles for those with traditional trade skills are left unfilled around the country, as many students have been channeled into four-year college pathways.[59] Increasing participation in two-year colleges can help raise the supply of skilled trades-workers to serve new industry growth. Roundtable participants remarked on the ability of South Carolina's two-year technical college system to prepare the future of workers for the state's upcoming growth in battery and EV manufacturing. The system includes technical colleges across the state, as seen in Figure 8, with the ability to draw from many counties and rural areas to train students for the upcoming growth in jobs for the industry.

South Carolina is working to connect its technical college system through a network approach that makes its programs more accessible, affordable, and relevant to the growth of the state's economy and needs of its industries. For example, the readySC program is a division of South Carolina's technical college system that provides a full range of services to qualified companies looking to expand their workforce in the state.[60] By using readySC to develop a training curriculum based on an employer's desired skills, knowledge, and abilities, the technical college system can provide flexible and tailored training pathways for students to prepare to meet the specific needs of the new employment opportunities that are developing across South Carolina.

An example of readySC's work is its partnership with Scout Motors to train the incoming members of its team and ensure a trained workforce is available to fill the expected 4,000 permanent positions at the factory in Blythewood to produce next generation electric trucks and SUVs.[61] This collaborative effort is bringing together a team of workforce development experts from readySC, the local Midlands Technical College, and Scout Motors to adapt and implement the automotive manufacturer's training strategies at an upcoming on-site training facility in Blythewood.

FIGURE 8: South Carolina Technical College System



Source: "Our Colleges," SC Technical College System, accessed March 14, 2025, https://www.sctechsystem.edu/colleges.html.

The state is also demonstrating its leadership in training for the automotive industry by creating collaborative partnerships between its technical colleges and four-year universities. The Revolutionizing Electric Vehicle Education (REVVED) consortium is a partnership between Trident Technical College, Greenville Technical College, Spartanburg Community College, and Clemson University alongside workforce development centers and industry partners.[62] This consortium is working to integrate advanced learning tools, such as virtual and augmented reality, into EV manufacturing training, as well as increase learning pathways and retention for students from rural areas and underrepresented groups.

Meanwhile, South Carolina's Department of Employment and Workforce published an evaluation of the EV workforce in the state, including the skilled roles with the largest shortages of trained workers as well as opportunities to increase labor participation and enhance the state's workforce development mechanisms.[63] The roles with the largest shortages of trained workers in the industry include software developers, industrial engineers, automotive service technicians and mechanics, and logisticians.

Roundtable participants encouraged the state to find ways to increase enrollment in technical colleges to prepare for upcoming job openings. Among the challenges to increase participation in two-year technical programs is the branding of two-year colleges compared to their four-year counterparts. Many students want the traditional four-year college experience and parents associate technical college training with "dirty" jobs that they did not envision their children aspiring to. More clearly demonstrating the value of two-year degrees and highlighting the fulfilling nature of participating in these experiential and challenging programs will be critical to increasing enrolment and meeting the state's future labor needs.

The head of South Carolina's Department of Employment and Workforce highlighted a story about a high school graduate who dual enrolled in a technical college course and an apprenticeship program. Immediately after graduation, the student found a job in mechatronics, a role for engineering technicians that combines skills in mechanics, electronics, and computing, at a conventional and electric transmission manufacturer. Mechatronics jobs in South Carolina pay an average annual salary of $64,000.[64] In 2023, the state's technical college system trained 650 engineering technicians, however the state averaged 250 job openings for those positions monthly, totaling roughly 3,000 openings for the year, highlighting the need to scale the talent pipeline.[65] Because demand for these professions are so high among manufacturers, most program graduates are able to remain in the state and contribute to South Carolina's economy. Across all fields, 93 percent of technical college graduates remain working in state in the field they trained in within a year of graduation. In contrast, while the number of engineering graduates in South Carolina is increasing, by five years after graduation only 30 to 40 percent of them are still working in state, which highlights the need to focus on worker retention in this field.[66]

Finding ways to build a pipeline of talent in areas of need across the state is crucial for South Carolina to capitalize on the economic opportunity presented by advanced energy manufacturing. The state should find additional ways to incentivize enrollment in technical training programs and work to pair those programs with the new projects that are set to commence with skills identified by the state's workforce evaluation.

Roundtable participants suggested that providing tuition assistance to students who enrolled in programs designed to fill currently unmet industry needs could address this challenge. The state's SC Workforce Industry Needs Scholarship (SC WINS) program offers up to $5,000 for qualified students to pursue a professional certificate, industry-recognized credential, or degree from one of the SC technical college system's 16 colleges.[67] The state should also promote increased participation in the workforce for those who want to or are willing to work but may face barriers to doing so. This includes investing in expanded transportation options, housing, and childcare services in the planning and development of new projects. Scout Motors, for instance, plans to provide a childcare stipend to eligible employees and offer an on-site childcare facility.[68]

To ensure the long-term vitality of the battery and EV industry in the state, there is a need to develop creative solutions to increase awareness of new job opportunities, increase access and enrollment in existing training programs, expand partnerships to pair training programs with new projects, and invest in the services needed to grow labor participation.

Recommendations

To increase the enrolment of students into technical college programs in fields of need as identified by supply gap analysis conducted by the state's Department of Employment and Workforce, the South Carolina Legislature should appropriate funds to expand the SC WINS scholarship program to cover the full cost of tuition for positions of high need.

To ensure that recent graduates have immediately applicable and transferable skills in high demand employment contexts, the SC technical college system should foster partnerships between individual local colleges and nearby companies to develop curriculums that will train workers for available jobs and incorporate statewide skill needs analysis into their curriculum.

CONCLUSION

The growing market share of electrified options within the automobile industry offers both a challenge to incumbent manufacturers to diversify their production and an opportunity for South Carolina to position itself to enhance growth and resilience in its economy. C2ES's roundtable in Columbia, South Carolina, provided an opportunity to bring together a wide-ranging group of battery and EV industry stakeholders to discuss how the state can strengthen those aspects of the supply chain that might pose a risk to the long-term resilience of the industry. In-depth discussions among stakeholders on the topics of critical mineral supply chains, battery circularity and recycling, community engagement, and workforce development provided the foundation for a set of policy recommendations aimed at bolstering these aspects of South Carolina's battery and EV industries. In the near term, ensuring announced projects begin production is key to realizing the economic potential of the industry. State and federal policymakers should work to preserve the incentives that are powering the growth of these industries in the state, ensuring that businesses have the policy certainty they need to bring projects, jobs, and economic development to both South Carolina and the nation.

Additional C2ES Resources

C2ES Regional Roundtables
https://www.c2es.org/accelerating-the-us-net-zero-transition/regional-roundtables/

Creating a Circular Economy for Critical Materials in Ohio
https://www.c2es.org/document/creating-a-circular-economy-for-critical-materials-in-ohio/

Deploying Long-Duration Energy Storage in Virginia
https://www.c2es.org/document/deploying-long-duration-energy-storage-in-virginia/

Energizing the Future Mobility Workforce in Michigan
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